Meaning-Making in an Engineering Problem-Based Learning Classroom: An Analysis of Activity and Multimodality

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Dedication

This thesis is dedicated to the memory of my mum, Sa'diyyah, my wife, Moneerah, and my kids: Khawlah, Ali and Isaac.

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Abstract

Problem-based learning (PBL) is a pedagogic approach now widely used across higher education. Its goal is to encourage student-centred learning supported by the provision of information and the active support of a facilitator. PBL can be seen as a process of meaning making, and, in this research, this meaning making occurs in the context of an academic subject in the first year of an engineering degree and a particular PBL module within that degree.

The overarching goal of the research is to contribute to a greater and deeper understanding of the process of students' meaning making in the course of a PBL task. Specifically, the aim of the study is to investigate the role of multimodal representational, communicative resources in enhancing learning and meaning making. The objectives of the research have been to:

1) Understand the role of context in the PBL task;
2) Understand the role of the students in the meaning-making process;
3) Understand the role of the tutor/facilitator in the meaning-making process; and
4) Evaluate the overall performance of the student group in terms of task performance and the students' construction of meaning.

Two conceptual frameworks have been utilised to study learning within PBL engineering: multimodality and activity theory. Activity theory is adopted to review the extended period of meaning making across five PBL classes, capturing the importance of context and, in particular, the rules adopted for a given task. Multimodality looks at how knowledge is created employing different modalities of communication (verbally and through non-verbal semiotic resources ranging from tools, images, online multimedia resources to gestures and other aspects of body language).

A group of five first year engineering students' meaning making in an engineering PBL task was recorded over five separate classroom sessions generating 425 pages of lesson transcripts. The footage was analysed considering the verbal and non-verbal resources used by the students and the facilitator. The data was coded in terms of multimodal concepts and activity theory, following the work of Hmelo-Silver et al. (2007) and Stålbrandt (2007), as well as the researcher's own concepts.

The analysis drawing on activity theory had two aims; the first was to explore context, rules and types of interaction across the entire PBL module, while the second was to identify a number of excerpts that exemplified the varying foci and activities of the students and the facilitator. In addition, the selection aimed to capture the shift of focus between theory and practical work, in this case from the theory of designing a model bridge to the process of actually building this model. The excerpts formed the data that was analysed in detail, using the multimodal coding scheme.

From this dual analysis a number of key findings emerged. First, the context provided by engineering as a subject discipline and the PBL task provided the critical context for the activity of both the students and the facilitator. Three primary contextual dimensions were identified: theoretical, methodological and procedural, and their impact was explored from the perspective of resemiosis and meaning making. Second, as the focus shifted from theory to model building, different semiotic modes were employed. This provides strong evidence that the mode of meaning making shifts according to changes in the object, in part as attention moved from theory to model building and in part as understanding of the task developed. In a number of instances, one mode (verbal or non-verbal) was clearly dominant.

In addition, key differences in how the students acted were observed and four distinct learning approaches were evident: the fully multimodally engaged learner, the engaged peer learner, the facilitator-focused learner, and the passive learner. In addition, the facilitator made use of different semiotic resources compared to the students. In particular, his statements were complex and he made extensive use of scaffolding, as he tried to guide the group's meaning making. On the other hand, his actions were also informed by the nature of the task (timescale, resources and assessment criteria) to the extent that in some stages he tended to dominate discussion with the students and adopted a very directive role.

Overall this thesis makes a substantial contribution by elaborating on Jewitt's (2008) methodology of combining Activity Theory and Multimodality to understand the meaning making process. Both approaches made distinct contributions and, in combination, allowed exploration both of the variations in semiotic mode and the impact of context on the task. The thesis also contributes as an evaluation of PBL in the context of an engineering first year class and highlights the ways in which task and prior knowledge, combined with the role of the facilitator, are all important in determining how much the students can act as independent learners.

Conference Presentation

During the course of the research, the following refereed paper was presented at AILA 2011, 23 – 28 August, 2011, Beijing.

Al Huthali, Mohammed, Borland, Helen and Venkatesan, Srikanth (2011). ‘Investigating the multimodal nature of the PBL engineering discourse and its influence on the interaction process’.

List of Abbreviations

Ack	Acknowledgement of contribution
AF	Agreement with Facilitator
AM	Agreement with PBL Member
Antec	Causal Antecedent
AS	Affective Scaffolding
BA	Brief Answer
CA	Conceptual Agreement
CD	Conceptual Disagreement
CK	Conceptual Knowledge
Clarif	Seeking Clarification
Cons	Causal Consequence
CS	Conceptual Scaffolding
CT	Concept-related Talk
DP	Data-driven Planning
EE	Elaborated Explanation
Enab	Enablement
ET	Elaborated Telling
Expec	Expectation
FE	Facilitator's Explanation
FM	Facilitator's Monitoring
FT	Facilitator Explaining Tool-related Utterances
GD	Group Dynamics
GM	Group Monitoring
GrB	Grounded Belief
IFS	Facilitator-to-Student Internalisation
IH	High-Level Interpretation
IL	Low-Level Interpretation
IM	Individual Monitoring
IPP	Peer-to-Peer Internalisation
ISF	Student-to-Facilitator Internalisation
LA	Local Analogue
LC	Comparison
LD	Definition
LE	Example
LI	Interpretation
LJ	Judgement
MetaQ	Metacognitive Questions
Meta	Metacognition
ModI	Modification of Ideas

MS	Metacognitive Scaffolding
MSDL	Self-Directed Learning
N	New ideas
NC	Need Clarification
PE	Prior Experience
PQ	Plan-related Questions
PresE	Personal Experience
PS	Procedural Scaffolding
PT	Personal Talk
QF	Questioning Facilitator
Quant	Quantification
RA	Regional Analogue
Ref	Reflection
Requ	Request
SC	Conceptual Question
SD	Disjunctive
SDL	Self-Directed Learning
SF	Feature Specification
SI	Summaries of group's Idea
SQ	Self-answered Question
SS	Strategic Scaffolding
SV	Verification
TA	Task-related Agreement
TD	Task-related Disagreement
ThP	Theory-driven Planning
TM	Task-oriented Monitoring
TR	Tool-related Talk
TS	Technical Scaffolding
TT	Task-related Talk
UP	Unjustified Planning

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Chapter One
Introduction

1.1 Introduction

The process of meaning making has been researched from a variety of perspectives including psychology, sociology and linguistics. These academic fields offer a variety of insights into the process and stress the importance of existing knowledge of the participants, the nature of the task and the social setting of the task as having an influence on the meaning making and problem solving process. The relatively new field of social semiotics (O'Halloran, 2008) indicates that meaning making can involve a range of processes (speech, gesture, tools) depending on the circumstances.

In this research, the focus is on the shifting usage of semiotic resources in meaning making and problem solving. The study takes place in a Problem Based Learning (PBL) class focussing on an engineering design problem (to construct a model bridge to given specifications and to meet set requirements). As discussed below, PBL is structured around individual and group learning by students and expects them to take the lead in constructing their understanding of the task, aided by a facilitator, so understanding how meaning making occurs is particularly pertinent. The facilitator is there to guide their meaning making and assist the students as needed, but ideally should not provide the solutions to the problem. Thus in a PBL session, there are two active sets of meaning makers – the students and the tutor – with different levels of subject domain expertise. This creates the scope to explore how differences in position and expertise affect the meaning process and usage of semiotic resources in constructing understanding.

Problem-Based Learning (PBL) initially emerged in a group of US universities that taught medicine in the late 1960s as a reaction against the then dominant mode of tutor-led instruction (Savin-Baden, 2000; Savin-Baden & Major, 2004). In particular, PBL adopted the core philosophy that student learning was enhanced when the student had to take an active role in creating meaning in a lecture rather than remaining a passive recipient of knowledge. To its supporters, PBL is more than just one of a number of techniques designed to encourage student-centred learning and active learning (Dantas & Kemm, 2008; Haggis, 2009) and instead offers a unique chance for students to both gain academic and domain-specific knowledge as well as wider problem-solving and group work skills. Critical to PBL is the concept of scaffolding (Choo, 2012; Greening, 1998; Hmelo-Silver, Duncan, & Chinn, 2007) where a tutor or facilitator, sometimes replaced by an electronic system (Kaliyadan, Amri, Dhufiri, Amin, & Khan, 2012), provides support by helping the students frame the set problem so as to ensure their meaning making remains focussed on the specific task demands.

However, there are two frequently cited problems that affect PBL sessions:

1) The frustration of being presented with a problem before having the knowledge to solve the problem (Hmelo-Silver, 2004; Ribeiro & Mizukami, 2005; Savin-Baden, 2000; Tan, 2004); and
2) Some or all the group disengaging from the task (Woodward-Kron & Remedios, 2007).

Both these issues are explored in more detail in Section 2.2.2, but there are two key areas within PBL, student-led problem solving and group problem solving, where students have been found to most often struggle (Hmelo-Silver, 2004; Ribeiro & Mizukami, 2005; Savin-Baden, 2000; Tan, 2004). For this reason, individual and group problem solving by the students will be a key focus of concern for this study.

Jewitt (2008) argues that PBL can be effectively studied by taking a multimodal approach to understanding the learning process. In this sense, multimodality focuses on the interaction of various semiotic resources (speech, gestures, physical objects) to convey meaning. An analysis of multimodality seeks to elucidate how meaning is constructed and how meaning is modified both by the use of different semiotic resources (intersemiosis) and, at least notionally, the wider environment (resemiosis) (Iedema, 2003; Jewitt, 2008; Norris, 2004b).

However, there are two specific problems with a purely multimodal approach. One is that, unless the coding is purely quantitative (explored in more detail in Chapter Three), then the complexity of any coding structure as it captures the interaction between speech, gesture and tool use, means that it has to focus on relatively short periods of interaction (O'Halloran, 2011a). The second is that although the concept of resemiosis (Iedema, 2003) is seen as important, it is actually rarely effectively applied in an analysis of multimodality (an argument developed further in Chapter Two). To address these issues, this thesis has adapted Jewitt's (2006) combination of activity theory and multimodality (Jewitt, 2006).

Activity theory offers two valuable elaborations of a purely multimodal approach. Firstly, it can be used to analyse much longer blocks of meaning making than can be dealt with using conventional techniques of multimodal analysis (O'Halloran, 2011a). Secondly, activity theory is particularly valuable for situating the students' meaning making in the wider environment of the subject studied, the process of PBL and the requirements for the class.

With this perspective this research directly addresses two questions. First, does the usage of semiotic resources vary according to knowledge, role and social setting of the participants? Second, how can the methodological issues of gathering and interpreting this data be addressed? Since the setting of the research is a PBL class, it is hoped that those with an interest in PBL, or student-centred learning pedagogies, may also find the insights and findings of interest.

1.2 Key concepts from literature

This thesis draws on three fields. The empirical setting for the work was a Problem Based Learning class and the classroom interactions have been analysed using a combination of multimodality and activity theory. This section briefly summarises each of these fields in turn, with all three being explored in more detail in Chapter Two.

In effect, the process of meaning making in a problem based learning context has been analysed using two theoretical domains following Jewitt (2006). Here Activity Theory provides theoretical insights in its own right, in particular about how process of how meaning making adjusts to changes in the overall situation, but fundamentally it is used to gain an overview of activity across the entire PBL session. From this analysis of activity, representative smaller blocks were then able to be selected and analysed in detail using concepts drawn from multimodality.

1.2.1 Problem-Based Learning (PBL)

Problem-Based Learning (PBL) was introduced as a student-centred learning pedagogy based on social constructionist models of adult learning (Hendry, Frommer, & Walker, 1999). Central to the PBL model is that the student should be an active participant in meaning making and that he or she can learn this by researching a topic, integrating new and existing knowledge and constructing an explanation or solution (Savery & Duffy, 1996). Advocates of PBL (Hmelo-Silver et al., 2007) argue that students are much more likely to retain their knowledge with this approach more self-directed and active approach to learning than if it was presented by a conventional mixture of lectures and tutorials (Camp, 1996). However, despite almost 40 years of practice and use across a range of subject areas the evidence is mixed as to whether PBL does lead to either improved knowledge acquisition or to better learning of generic skills, such as problem solving and in-group empathy (Berkson, 1993; Tan, 2004). However, a variety of findings are suggesting that the range of activities described as PBL, are as much what leads to its effectiveness as the overall focus on problem-based learning (Strobel & Barneveld, 2009).

1.2.1.1 Role of the PBL tutor

In the early stages of the adoption of PBL pedagogy the tutor was seen as an expert in facilitating group discussion and group problem solving rather than as an expert in the particular subject field (Dolmans et al., 2002). The tutor's key role was to guide the students, but to allow them to take control of their own learning process (Tan, 2004), with the tutor required to gauge how to respond at different stages (Holmes & Kaufman, 1994). In particular, it was argued that problem solving is never a linear process and that there is a need to leave space for students to make mistakes and backtrack (Simon, 1978; Sternberg & Frensch, 1991).

However, as discussed below, some student dissatisfaction with PBL can be related to having to work out a solution from limited knowledge when they are aware that the tutor could provide the information they lack. Further, as discussed below, many PBL sessions are time-limited and have a clearly defined end goal (and assessment). As a consequence the conventional role of the facilitator, who allows students the space they need for problem solving, is less easy to sustain in practice than in theory as they can be easily drawn into a more directive role in an attempt to ensure that the students meet the timeline for the task (Greening, 1998; Tan, 2004).

1.2.1.2 Students' meaning making

The core element of PBL is that the students become active in the process of meaning making as they solve a task using the information and tools provided within the overall confines of the academic study. A key concept in delivering PBL is that of 'scaffolding' (Choo, 2012; Greening, 1998; Hmelo-Silver et al., 2007). This means providing the students with the information and the environment needed to successfully deal with the task they were set. It also means enabling students to work as individuals and to make use of the group learning aspect of PBL (Ribeiro & Mizukami, 2005). Critically important in this regard is the role of the tutor who needs to provide enough information, in an appropriate form, to help the students, but not do so in a manner that removes their independence as learners.

Although PBL has been adopted across a number of disciplines (see Section 2.2) the effectiveness of PBL has remained problematic. Students often cite frustration with being expected to solve a problem *ab-initio* when their tutors already possess the knowledge to guide them (Tan, 2004). Overall, there is mixed evidence that PBL leads to either enhanced acquisition of subject knowledge (Polanco, Calderon, & Delgado, 2004; Tan, 2004; Zumback, Kumpf, & Koch, 2004) or the related skills of problem solving and group work. However, Prosser and Sze (2014) have suggested that when the focus is on the process of learning, rather than its evaluation, PBL leads to improved retention of knowledge and skills acquisition. Equally, their research suggests that student preparation and attitudes are important in influencing how much they gain from PBL (Prosser and Sze, 2014).

Students' meaning making in a PBL context is a combination of their prior knowledge, the information they access as they progress with the task, the tools available to support them in the task (books, ICT, physical resources) and the constraints imposed on that task by the wider environment. In addition, there is an interaction between the students as active learners and a tutor/facilitator who has the role of guiding that learning. Furthermore, PBL is an instance of what Kress (2001) describes as multiliteracy, in other words, that as they progress through a task, students must draw on a wide range of resources presented in different modalities as they construct and amend their interpretation of the nature of the problem.

A related contextual issue is that PBL is set in the context of an academic programme of study, which, in turn, leads to rules and constraints (for example, tasks need to be completed in a particular time frame, and assessed in a particular way). The tutor/facilitator faces a significant challenge (Dolmans et al., 2002; Holmes & Kaufman, 1994; Spronken-Smith & Harland, 2009) in creating an environment where the students have the scope for independent learning, but at the same time are allowed to meet the academic expectations of their programme of study.

1.2.2 Multimodality

Multimodality is a perspective that can be brought to bear on the study of the process by which knowledge is constructed and transmitted. A major aim of the current study is to evaluate students' meaning making in PBL from a multi-semiotic perspective. As discussed above, PBL is often cited as a valuable tool to encourage student-centred learning. However, there are persistent issues with the use of PBL and questions as to whether or not it really leads to deeper learning, defined as the internalisation of information due to having to take an active role in constructing the meaning, on the part of students. In addition, the relatively recent, widespread addition of a far broader range of multimedia resources to PBL (via the ICT-supported resources, such as the internet) may have changed the nature of the student learning experience (Yeo & Tan, 2011). Since the student problem-solving process is key to the successful applications of PBL, the current study argues that this can be assisted if proper attention is paid to both the semiotic elements of the interaction and the wider social aspects of learning. Understanding meaning making, and the use of the tools available, such as computers, books and other resources, will lead to insights that can improve student learning in PBL environments.

Multimodality as a concept is based on the study of semiotics, a study with a long history (Berger, 1994), that was extended by Halliday (1978) to include the means by which the social environment and the prevalent social norms affected meaning making as much as the actual structure of a text. This concept of *Systemic Functional Linguistics* (SFL) (Halliday, 1978) remained focussed on language (both written and spoken) as the dominant mode of meaning making (Iedema, 2003). SFL was, in turn, extended through the context of interactional analysis (Norris, 2004b), as well as the concept of *Multimodal Discourse Analysis* (MDA) as a means of linking the traditional study of language (discourse analysis) to other modes of social interaction

(O'Halloran, 2008), such as vision, gesture, colour, setting and abstract notation systems. MDA in turn was given a stronger social element in the structure of *Systemic Functional Multimodal Discourse Analysis* (SF-MDA). This insight is important in the current study as a key argument is that the meaning making adopted in the PBL task can only be understood in the terms of the rules set for that task.

As MDA has developed, one question has been to consider, firstly, how different semiotic resources interact and, secondly, how to take account of the wider context. Intersemiosis (O'Halloran, 2008) has become the means by which different semiotic tools are combined. So at a simple level when giving directions, speech and gesture may be used to provide a clear idea of what is meant, although usually in a given situation one mode is dominant (Kress & van Leeuwen, 2006). Resemiosis in turn is the process by which meaning shifts due to the wider context, in theory as changes to both context and social space change the process by which meaning is built up (Iedema, 2003).

In a pedagogic context the analysis of multimodality can focus on one of two key aspects of classroom interaction: understanding students' meaning making or helping students become aware of the importance of non-verbal gestures and of dominant means of thinking in imposing meaning (van Leeuwen, 2006). Regardless, at its core is the study of meaning making. Some authors, for example, Airey and Linder (2009), Maher (2011), Martinec (2000) and Márquez, Izquierdo, and Espinet (2006), stress that science, for example, is inherently multimodal as teaching will involve practical demonstrations, verbal descriptions, visual images (graphs and pictures) as well as the use of specialist scientific notation.

In the current study, the analysis of multimodality is concerned with the first aspect (i.e. understanding the students' meaning-making process). It provides a tool that allows careful consideration of the learning (both individual and group) within the PBL group studied. In turn a focus on multimodality allows exploration of the ways in which the learning approach of the students can be related to both the resources on offer and the manner in which they operated as a group. However, although in principle an analysis of multimodality seeks to take account of the wider context of learning via the concept of resemiosis (where meaning making takes on a particular form due to the wider context), in many studies this actually plays a limited role (this is shown in Table 2-1 and explored in Section 2.3.2.4). As with many other theories that can be broadly situated within a social constructionist paradigm (O'Halloran, 2011b), in practice many studies assume the process of resemiosis happens, but offer no detailed analysis of how it can take place (it is taken for granted).

1.2.3 Activity theory and socio-cultural theory

The antecedents of both activity theory and socio-cultural theory are found in work by scholars in the then Soviet Union. Activity theory is derived from Vygotsky's theories of how meaning making is shaped (Vygotsky, 1962) by the social environment and the cultural tools for understanding (Leontev, 1978). Other researchers more recently, egs Hedegaard (2001) and Mercer and Howe (2012), discuss how existing tools are appropriated in new situations and highlight that one important function in any learning situation is to enable learners to recognise and adopt such existing resources. Kress (2010) argues that this connects with the concepts in multimodal semiotic research as

> learning is the result of a semiotic (…) meaning-making engagement with an aspect of the world, as the result of which the learner's semiotic (…) resources for making meaning and, therefore, for acting in the world, are changed – they are augmented. (p. 174)

Social-cultural theory was initially developed by the Russian psychologist Lev Vygotsky in the late 1920s. He sought to challenge the 'behaviourist' models of psychology then gaining popularity by placing the focus on how the individual uses the tools available to him. Initially Vygotsky focussed on language, but eventually included social norms and physical tools and resources – to make sense of events and to construct meaning (Mercer & Howe, 2012). By the early 1960s his colleagues and students, in particular Aleksai Leontev, started to develop Vygotsky's work (Spencer, 1999). They stressed the importance of reflection for the individuals involved in any action, especially as members of a group, and of the constraints under which they are acting, based on their understanding of the task that is being undertaken by them (Tolman, 1987), as well as the importance of the group context in which they are acting, considering the division of labour that governs their action. Leontev's (1981) framing of this process can be summarised as:

> For a man to take on the function of a beater (in a primitive hunt) it is necessary for his actions to have a relation; that connects their result with the outcome of the collective activity; it is necessary for this relation to be subjectively reflected by him so that it becomes ‘existent for him’; it is necessary in other words for the sense of his action to be revealed to him, to be comprehended by him. Consciousness of the sense of an action…comes about in the form of reflection of its object as a conscious goal. (pp. 212-213)

Engeström (1987) developed concepts taken from activity theory in a framework that can be used to understand a problem-solving process and the means by which knowledge is mediated by the social context. This extended activity theory thus can be used to study the effect of the different tools available for PBL, but also as a means to understand language use, negotiation between students, and the extent to which all members of a group participate in a PBL session (Roth & Lee, 2007). In addition, it provides a tool to analyse and categorise group discussions and group dynamics (Arvaja, Salovaara, Häkkinen, & Järvelä, 2007) and the interaction between personal learning and group learning. In particular, activity theory allows us to differentiate between types of interaction in social contexts such as a PBL session, eg. collective interaction where all the students are interacting and communicating or partial interaction where sub-group of PBL students are interacting, as well as the way in which interactions are framed by the social context (such as being at a university).

In consequence, activity theory can play a useful role in studying learning activity in PBL-based classes. The theoretical model elaborated by Engeström (1987) provides a valuable framework for breaking down observed actions and exploring the various constraints and dynamics within a PBL session. Similarly, the structure allows consideration of how some resources change role as the problem-solving process is undertaken. In this research, following Jewitt (2006), activity theory and multi-modality are seen as comprising complementary theoretical and analytical structures. Both focus on meaning making and how this is mediated by the external environment (Mutton, Burn, & Hagger, 2010).

1.2.4 Defining Key Terms

One issue across this thesis is the usage of certain key terms. Since there is a multidisciplinary aspect to this research, resting on two different theoretical domains and drawing heavily on concepts from PBL as a pedagogic approach clarity in definition of the key terms is important.

The first aspect is to distinguish between the concepts of Multiliteracies and Multimodality (Kress et al., 1998, Liu, 2009). Multiliteracy is a concept developed by the New London Group and has been used to argue that multimedia (ie text, sound, images) can be combined to create new ways of meaning making (Liu, 2009) and associated new ways of being literate. More generally, the original manifesto (Kress, G. et al., 1998) identified six potential metalanguages, all of which have a role in meaning making. These were described by Kalantsis and Cope (2001, p. 12) as "Linguistic Design, Visual Design, Audio Design, Gestural Design, Spatial Design and Multimodal Design".

Multimodality (Jewitt, 2008), as discussed earlier, is best seen as the encompassing generic concept of how meaning making is is realised through the use of different modalities of communication (speech, text, signs, gestures and body language) influenced by the wider social dynamics. In effect, it is an attempt to draw together all the potential modes of meaning making and Kress et al (1998) argue that "a social semiotic theory of multimodality … provides a 'take' on *meaning* … and it provides a view on the characteristics and uses of *modes* in representation (Kress, 2009, p. 19). From this perspective, Kress argues that multimodality shows that meaning making uses much more than just speech or writing.

The second key definitional issue is the difference between social constructivism and social constructionism. In this context, social constructivism is the process of shared meaning making by a group (Vygotsky, 1962) and social constructionism is related to the meaning making in the sense of the production of artefacts. However, this distinction is not always applied consistently in the literature (Cromby. and Nightingale, 1999) with social constructionism often being used as an encompassing concept for any process of meaning making that takes account of the importance of the social setting in which it takes place.

In this thesis, social constructivism is used to indicate the meaning making process and social constructionism refers to artefacts created in this social constructivist process (such as the model bridge built by the student group in the engineering PBL task studied in Chapters four and five).

1.3 Research goals

The goal of the research is to contribute to a greater understanding of the process of students' meaning making in the course of a PBL session. Due to the complexity of meaning making within PBL, two different approaches are used to explore how meaning making occurs. The overall PBL session and its outcome are evaluated using activity theory as that has the concepts useful for constructing such an overview. Within the PBL session, seven specific sub-sessions (spread across the five class sessions that were video-recorded) were evaluated in much more detail, employing the framework of multimodality, to explore the extent to which a focus on the semiotic resources employed will extend our knowledge of the process of meaning making.

The overarching aim of the study is to investigate the role of multimodal representational, communicative resources in enhancing learning and meaning-making processes by undergraduate students taking an engineering design course that adopted PBL as the teaching method. The objectives of the research are to:

1) Understand the role of context in the PBL task, specifically - How far can the actions of both the students and the tutor be understood in terms of external constraints rather than their own preferred problem-solving / meaning-making approach?
2) Understand the role of the students in the meaning-making process, specifically - Do they use different semiotic resources as the task evolves and their understanding shifts?
3) Understand the role of the tutor/facilitator in the meaning-making process, specifically - Does the tutor's use of semiotic resources vary as the task evolves and, if so, how does this affect his/her interaction with the students and use of scaffolding?; and
4) Evaluate the overall performance of the student group in terms of task performance and the students' construction of meaning.

The data collected and analysed to address the research questions compromises the interactions of a group of engineering students who were video-recorded while they completed a PBL task, which was to design a bridge structure that would withstand a fixed weight placed on top, across five PBL class sessions.

1.4 Rationale for conducting current research

The researcher used to work as a teacher of English-for-science at Taif University in Saudi Arabia. His profession as an English-for-science teacher encouraged him to become more qualified to deal with different teaching approaches to deliver his course adopting a more contemporary professional method, instead of merely assuming the position of an information deliverer to science students who are often passive. This desire motivated him to undertake postgraduate studies. He completed his Masters degree at the University of Adelaide, Australia, including both coursework and writing a dissertation. The courses he enrolled in during his Masters enhanced his understanding of how teaching and learning processes are constructed, including exposure to different teaching methods.

Principally as an outcome of these initial postgraduate studies, the researcher was influenced to consider teaching as a socially constructed process (Vygotsky, 1978). This means that learning should always be considered as an interactive process (Le & Le, 2012) between teacher and students. Students should also be active to learn. Students should exchange information and experiences and communicate. It is a matter of searching for a teaching approach in which we can teach the sciences and English-for-science in a better way in order to help students become more actively engaged. Therefore, it became clear to him that new approaches should be employed. One of these approaches is PBL, a teaching pedagogy which mainly depends on group-based collaborative learning techniques, and which has gained quite wide acceptance in the tertiary learning environment. PBL gives the students the opportunity to become actively involved in the learning process, and to work on addressing their learning needs through collective group engagement. Accordingly, the researcher proposed to learn and research further about PBL, and selected a PBL university student team, studying engineering at Victoria University, Melbourne, as a key focus for his research as part of his in-depth investigation of PBL.

Through the research process the researcher aims to be able to return to his professional position as teacher of English-for-science and to be able to draw on insights from his research about PBL as a teaching method to better engage his students, but taking into consideration what this research has taught him about the strengths and challenges in implementing PBL from the perspective of student engagement and learning.

1.5 Structure of thesis

The literature review in Chapter Two first discusses the existing research on the application and use of PBL in higher education and develops the analysis briefly sketched out in the introduction. The chapter then discusses the issue of multimodality and related research issues, and activity theory. Finally, these are integrated, with the chapter setting out the theoretical underpinning for the model of student learning that informs the multimodal coding system used in Chapter Five.

Chapter Three sets out the research methodology adopted. The chapter commences with a discussion of the underlying epistemology of the research and then proceeds to discuss the various applied research approaches used in published studies on PBL, multimodal analysis and activity theory. The chapter then sets out the design of the research and documents how it was carried out.

Chapter Four presents an overview of the PBL sessions and uses activity theory to explore the processes of meaning making within the student group and how this meaning making is influenced by both external and internal information. From this analysis, a number of sections within the PBL sessions are identified that exemplify the development of meaning making and group interaction across the PBL sessions.

Chapter Five looks in detail at seven specific sections drawn from the video recordings of the student PBL classes. Here the focus is on the use of semiotics in the meaning-making process and how students take account of various semiotic resources (intersemiotics) and the wider context (resemiotics) as they deal with the set task.

Chapter Six draws together the two analytic strands represented in the research questions to present an overview of the meaning-making process, and Chapter Seven evaluates the contribution of the entire thesis and suggests themes for further investigation.

Chapter Two
Literature Review

2.1 Introduction

This chapter reviews the three main theoretical concepts at the core of the study. The chapter draws together how the model of student-led meaning making that is central to PBL can be explored using the concepts of multimodality and activity theory. In this research context, meaning making is seen not just as an internal, cognitive, process, but one that is influenced by the nature of the task, the resources available and the overall framework within which it takes place, i.e. problem solving, can be best understood as a process that is social constructivist. This chapter is divided into three main sections: reviews of PBL, multimodality (in particular in an educational setting) and activity theory (again with an emphasis on how this is applied in educational settings).

From the PBL review, it is clear that both the process of student-led meaning making and of the support provided by the tutor in the form of scaffolding are key to success. The analysis of multimodality offers one means of examining how different semiotic resources are used in the meaning-making process and how they might interact. In turn, activity theory explores similar ground, offering a powerful insight into the importance of context in framing a problem-solving task. These three strands are then drawn together in a short section that reviews the model of student learning that is implicit in the PBL method. That model is then used to evaluate the research findings reported in Chapters Four and Five.

2.2 Problem-Based Learning (PBL)

2.2.1 Development and controversies

PBL was originally introduced by a group of medical schools (Bereiter & Scardamalia, 2000; Rideout, 2001; Savin-Baden, 2000) in Europe and North America in the late 1960s (Barrows & Tamblyn, 1980). PBL was not just a pedagogic tool used to supplement other models of learning, it was seen as the basis to organise the entire curriculum. At its core PBL was seen as student-centred and based on philosophies of experiential learning (Savin-Baden & Major, 2004) developed from a social constructivist model of adult learning (Hendry et al., 1999). The choice of PBL was a rejection of the older model of medical education with its emphasis on classroom instruction with the students positioned as passive learners (Hmelo-Silver, 2004).

McMaster University and Mercer University School of Medicine in Georgia were among the first to adopt PBL across their entire curriculum, even though there are claims (Berkson, 1993) that PBL as a pedagogic approach influenced the teaching of medicine as far back as Ancient Greece. All the institutions that initially pioneered PBL in the 1960s were relatively new and, were thus open to the idea of finding a new way to deliver the traditional medicine curriculum (Berkson, 1993). PBL was seen not just as a different way to deliver the curriculum but was "expected to influence the whole student, or, at least, many aspects of the students' learning experience" (Camp, 1996, p. 1).

PBL appeared to offer a means to move beyond the student learning information simply in order to pass examinations to the student valuing ongoing learning as a desirable end in itself. In this respect, PBL aligned itself with those theories of adult learning that stress the importance of the student understanding why information is important, how it fits with existing knowledge and that, if the student is actively engaged in the learning process, they are much more likely to retain the knowledge (Camp, 1996). Generally the view was that learning 'in context' (Berkson, 1993) would improve both the students' practical clinical performance and their grasp of the underlying scientific principles.

Subsequently PBL was adopted in other universities and then slowly spread into other disciplines (Savin-Baden, 2000). The relative isolation of medical education within the tertiary sector may have delayed this transmission (Perrenet, Bouhuijs, & Smits, 2000). However, the expectation that PBL was the means to deliver the entire curriculum, not just specific elements or modules (Pennell & Miles, 2009), also limited its spread outside medicine.

Outside medicine, PBL has tended to be adopted more piecemeal, for particular parts of a course. In doing so, the distinction between PBL and other forms of student-centred learning has been partly lost. For example, many management schools make substantial use of case studies as a core pedagogic device (Ford, Harding, & Learmonth, 2010), in part as a means to make the curriculum more relevant to the world of work. What is not clear is whether or not this is automatically a form of PBL, or would even be described as such within the discipline (Camp, 1996). Some medical programmes even are now starting to argue that simulation-based learning is a superior approach to conventional PBL (Steadman et al., 2006). Most science subjects have adopted PBL also in a relatively isolated manner. For example, a chemistry degree (Belta, Evans, McCreedy, Overton, & Summerfield, 2002) makes use of PBL as a learning tool for situations where there is no single correct answer and where the core learning outcomes are the process of reasoning by the students, not the answer proposed. Here again, there is also a degree of conflation between using a case study model and the ideas of PBL.

Engineering too has adopted PBL in its own way, not least as the engineering curriculum has had a long tradition of being based on problem solving (Perrenet et al., 2000; Ribeiro & Mizukami, 2005) and project work. Engineering shares with medicine the interest in closely linking theoretical underpinnings with practical applications (Mills & Treagust, 2003; Perrenet et al., 2000). Here again the controversy is raised as to the meaningful difference between the traditional project-based model and one structured around PBL (Mills & Treagust, 2003). However, it has been argued that PBL, as a specific approach, promotes the acquisition of a deeper understanding that allows students to apply knowledge gained in one domain to another (Ribeiro & Mizukami, 2005). This is significant as the contemporary engineer is facing numerous demands on a daily basis and is often asked to solve issues and concerns amidst limited resources and data. Such demands highlight the importance of employing problem-based scenarios in engineering education. Polanco et al. (2004) studied the influence of PBL on engineering students' educational performance and concluded that PBL strengthens such performance. It is argued also that adopting PBL in engineering education will enhance students' confidence to work with the PBL engineering task and to be able to learn effectively (Dunlap, 2005). Du's study (2006) also showed that PBL in engineering helped increase the reciprocal construction of engineers' identities.

A recent nationwide survey conducted in India determined that 64% of graduate engineers were unemployable (Blom & Saeki, 2010). This highlights that although engineers may be entering the workforce with the technical resources and understanding to comprehend the work, they may not be trained in how to work in teams and have the communication skills that are vital for job applications.

Overall, even where PBL has been adopted, the approach has been adapted to the demands of the academic subject:

> In engineering some topics are characterised by an hierarchic knowledge structure and complex problem-solving. These topics cannot be approached without risk in a PBL-setting. Therefore, separate direct instruction and supervised practice are needed: direct instruction of outlines, demonstration of expert problem-solving, teacher-guided discussions, problem-solving tutorials with specially structured group work. (Perrenet et al., 2000, p. 356)

In this respect, PBL in engineering has been identified as an important tool to allow students to move beyond manipulation of equations to instead "reason effectively at the qualitative level" (Molyneaux, Setunge, Gravina, & Xie, 2006, p. 2). This argument has seen the curriculum being designed around the basic principles of team project work, model building and testing and practical experiments as well as more conventional lectures and examinations (Molyneaux et al., 2006). Furthermore, PBL as a pedagogy in engineering has been integrated into an otherwise conventional curriculum, in contrast to the early approaches in medical science, but in a manner typical of its application in most other academic fields (Ribeiro & Mizukami, 2005). Engineering students often report satisfaction with their experience of PBL (Ribeiro & Mizukami, 2005) although Ribeiro & Mizukami's (2005) study was again of a mixed programme (PBL and conventional delivery) and it may be that students appreciated the blend of PBL and more structured methods of knowledge acquisition rather than learning in a purely PBL context.

One related issue with PBL in an engineering context, especially in the early years, is the need to ensure that the students have the grounding in the knowledge required (Mills & Treagust, 2003). This means that the selection and framing of the problem is important, too trivial and any learning will be limited, too challenging and the students will lack the knowledge to make progress without substantive help. As discussed in Section 3.2.2.2, an early case study in this research looked at a PBL class in the first semester and, on reflection, the problem was sufficiently simple that there was little use by the students of complex meaning making. This fits with the discussion of Perrenet et al (2000) who argue that while PBL can enhance the early stages of an engineering degree, it cannot replace the entire curriculum (as has been the case in some medical degrees). However, PBL can be a useful addition when the goal is to encourage students to apply and deepen knowledge they have gained elsewhere in their studies.

Students learn in many different ways, and while some students might be able to translate their academic studies in content over to a practical application, this is a rare skill naturally. However, when PBL is employed by engineering academic programs, there is a great potential for reaching students with varying learning styles (Felder & Silverman, 1988). Incorporating multiple modes of teaching reinforces ideas and reaches students with different learning preferences, but it also challenges students to put their skills to the test and encourages teamwork. These two skills are ones that the career workforce of engineering desperately needs (Felder & Silverman, 1988). Another benefit of incorporating a problem-based model that has been proposed is that students are more engaged in their task, and, therefore, will have deeper comprehension of principles (Graaff & Kolmos, 2003).

A new model of problem-based learning (PBL) was implemented at the graduate programme in Aalborg University in 2010. Shinde and Kolmos (2011) conducted research by interviewing students involved in the programme to comprehend their learning process. Students reported feeling that the project they worked on was successful in terms of learning as a team and that working in a collaborative atmosphere contributed to their deeper comprehension of the issues surrounding the project (Shinde and Kolmos, 2011). It is also notable in this study that the majority of groups did encounter conflicts, but continued to work as a group despite these conflicts. The teamwork atmosphere very closely mirrored the working atmosphere of engineers. Other research studies have also supported the ability of problem-based learning to increase both professional and process skills for engineers (Graaff & Kolmos, 2007).

Despite almost 40 years of experience in evaluation as to its impact on student learning, a wider issue is that the value of PBL as a pedagogy remains contentious and debated. Evaluation has covered both the acquisition of knowledge and of softer skills, such as problem solving and empathy (Berkson, 1993). In the main, there is mixed evidence that students from a PBL programme do better than those from more conventional programmes, either academically in terms of problem solving, or in terms of performance on work related placements (Tan, 2004). However a recent review by Strobel and Barneveld (2009) concluded that, on balance, PBL was more effective, particular in terms of:

- Knowledge assessment where there is evidence that PBL favours longer term retention of learning;
- Performance of skill based assessment, where medical students scored higher in terms of “patient simulations, and elaborated assessments such as essay questions and case studies” (2009, p. 54); and,
- Mixed knowledge and skill, in particular ability to cope with oral examinations, where, again, PBL produced stronger outcomes.

These findings are drawn from the usage of PBL for medical degrees. One important finding was that “PBL was superior when it comes to long term retention, skill development and satisfaction of students and teachers, while traditional approaches were more effective for short-term retention as measured by standardized board exams” (Strobel and Barneveld, 2009, p. 44). This matches the earlier argument of Greening (1998) that conventional assessment instruments fail to capture the key differences between PBL and other pedagogic models. If students from a PBL curriculum are tested conventionally then some of the expected advantages will not be picked up by the assessment tools in use (Savin-Baden, 2004).

More generally, the findings of Strobel,and Barneveld (2009) may reflect that PBL is at its most effective when it informs the whole curriculum. Their conclusions relate directly to medicine where PBL is relatively widespread, and covers the whole curriculum. For the most part, undergraduates in this field are selected from the academically most able and have a high level of vocational commitment to their discipline. They will do well in formal assessment, almost regardless of teaching pedagogy (Distlehorst & Robbs, 1998). Finally research has also found that depending on how problem-based learning is implemented, there may be gaps in student knowledge depending on the depth and types of problem explored (Graaff & Kolmos, 2003)

One key goal of a PBL-based curriculum is to improve students’ generic problem-solving skills and thus their readiness to enter work at the end of their academic studies. A relatively limited survey of students who left with a civil engineering degree, which was characterised by the use of both PBL and work-integrated learning (O'Brien, Venkatesan, Fragomeni, & Moore, 2012), suggested that the students believed they were well prepared for the transition to work, in particular in terms of their exposure to teamwork. However, no control group (of students who did not study using PBL) was offered and, as with medicine, civil engineering is an academic subject area where the practical application of theoretical knowledge is a key part of the curriculum, however that is delivered.

2.2.2 Nature of PBL

As discussed above, PBL is based on the concept of the student being responsible for his or her own meaning making (Savery & Duffy, 1996). This means that the idealised learning process is for students to first understand what they already know, identify what they need to know, and finally to identify how they will fill in this gap in their knowledge (Pennell & Miles, 2009). Burch (2000) describes this basic cycle as one of moving from problem identification, through analysis, to researching possible solutions. In essence the underlying maxim is one of: "I hear and I will forget. I see and I may remember. I do and I will understand" (Burch, 2000, p. 31). The underlying argument is that this active construction of meaning will improve overall student learning.

2.2.2.1 Construction of meaning within PBL

Within the literature on PBL, the model of problem solving is linked to those models of learning (Gijbels, Dochy, Van den Bossche, & Segers, 2005) that emphasise knowledge creation by gathering information, then testing it against other assumptions and either moving closer to understanding or having to step back and review the entire problem structure. PBL is designed to work with this paradigm for knowledge construction, and one reason for the frustration voiced by students (as discussed below) may well be that they are not used to such a non-linear learning model. To address this problem, the concept of scaffolding (Greening, 1998) is important to understanding how students learn and construct meaning as PBL uses a structure to guide the students in the creation of their own understanding through tools such as their tutors, the overall curriculum structure and the learning support provided

(Hmelo-Silver et al., 2007). In addition, it draws on Piaget's hypothetico-deductive model (1954) of knowledge, where this is created by setting out a hypothesis (why is this happening?) and then understanding comes from creating conjectures and testing these assumptions. In effect, meaning making is a simplified form of the conventional scientific reasoning process (Lipton, 2004).

Although scaffolding gives the impression of a linear task where the learner only progresses towards a set goal, in reality such a style of learning, as with any realistic model of problem solving (Simon, 1978), is iterative. Options are explored and rejected, progress is sometimes sideways, and sometimes an entire conceptual framework is rejected as it proves unlikely to provide an adequate explanation. In this PBL seeks to emulate real-life problem solving, but such an iterative framework has been found to be frustrating for students undertaking a PBL task. For this reason, constructing an appropriate support mechanism both in the form of a tutor/facilitator and structured resources becomes critical to enable student success (Choo, 2012).

Stålbrandt (2007) relates the concept of scaffolding to Vygotsky's social-cultural theory of learning and works from the premise that, "…every person, has a larger extent of potential for learning than the definite capacity of the individual when learning is facilitated just by someone with larger knowledge" (p. 37). This is Vygotsky's 'zone of proximal development' (Harland, 2003) which is a critical part of his learning theory. In that zone, learning can take place, in other words new knowledge is related to existing knowledge, and the process of scaffolding allows the student to make new links and thus extend his or her learning. Hill and Hannafin (2001) identify four types of such scaffolding as shown in Figure 2.1.

Scaffolding Mechanism		*Function Examples*
Conceptual	Mechanism designed to assist with defining things to consider.	• Creating an outline of a paper before you start to write or examining a map of a location to determine best ways to reach your destination (either in a paper or a physical place).
Metacognitive	Assist with establishing what is known and how to think.	• Providing learners with structured "reflection reminders," which may come in the form of daily journal entries. • Enabling scaffolded inquiry so that as learners are engaging the process, they are assisted in ways that make the most sense for them.
Procedural	Assist with how to use a resource.	• Providing and encouraging the use of help functions in productivity tools to assist the learner with trouble-shooting and problem-solving. • Creating Web site maps so the learner can get a sense of the scope of the site, as well as indicators of how varied elements in the site are linked together.
Strategic	Alternative ways to do a task.	• Arranging for an expert consultant to demonstrate how to perform a task so learners can observe and ask questions while learning a new technique. • Creating "question pools" where learners can pose questions for others to provide responses, enabling multiple perspectives on a problem.

Figure 2-1: Scaffolding mechanisms (Hill & Hannafin, 2001, p. 45)

Conceptual scaffolding is the process by which students' learning is guided so as to assist information processing and build connections as they construct meaning (Stålbrandt, 2007). Metacognitive scaffolding assists a learner in understanding what they know and what they now need to understand and guides the overall process of integrating new and different concepts (Hill & Hannafin, 2001). In turn, procedural scaffolding is the process by which learning is eased. Procedural scaffolding can be enabled through search tools, structured resources or guidance notes, all of which assist the process of both deciding on the next step and the ease by which that step can be taken (Greening, 1998). Finally, strategic scaffolding represents alternative ways in which a task could be undertaken and can be guidance from an expert (or teacher) seeking to provide guidance to a group of students (Hill & Hannafin, 2001).

On the other hand, Choo (2012) suggests a simplification of the range of scaffolding concepts into 'soft' and 'hard'. The concept of a soft scaffold is the manner in which the tutor interacts with the class in guiding the students' learning, in particular in the form of posing questions to enable student learning and exploration. A hard scaffold, on the other hand, represents the structured support that exists to assist student learning in the form of paper or worksheets or based on computer technology. In this respect, Choo (2012) also argues that this should be more than a neutral resource containing information the students may need, and instead:

> One way to ensure that students understand the underlying concepts related to solving the problem would be to have scaffolds that help to activate their prior knowledge so that they are better positioned to make connections to the new or unfamiliar content. We should always place ourselves in the shoes of the students to understand the possible conceptual gaps they have. (p. 178)

There is a need to balance the availability of such resources. Too much directed assistance will undermine the goal of student-led learning, while too much available information may lead to the students (especially early in their programme of studies) becoming lost and unable to evaluate the material effectively (Choo, 2012). Designing effective support structures for PBL is a challenge (Buus, 2012) and to some extent the choice and range of what Choo (2012) calls hard scaffolds depends on the knowledge and overall pedagogic approach of the teachers as well as an understanding of what approach will effectively support student learning. There is a wider debate about the role of authoritative sources of information in a constructivist and PBL learning environment (Yeo & Tan, 2010). In particular, there is a risk that students might defer to the information in provided texts (physical or on-line) rather than engage in individual inquiries.

Overall, scaffolding offers an explanation for an approach to student learning that is based on the construction and exchanges of information (Chernobilsky et al., 2005b), with this process reflected in the verbal utterances of the learners. It thus reflects concepts from activity theory:

> Each activity is composed of a subject, an object, mediating artifacts, community and division of labor and rules. Two basic processes are found in any activity – internalization, a process of shifting the material from the social plane to an individual and, externalization, a process of joint construction of an understanding of an activity, which is characterized by a movement of material from a person to the social environment. (p. 53)

Although scaffolding is an important part of the pedagogic support within PBL it should be seen as supporting students to use a particular model of reasoning. This hypothetico-deductive model (Piaget, 1954) in effect argues that meaning making comes from a sequence of generating a plausible explanation for an event, testing different rationalisations against the data and then forming a conclusion. In learning terms this has links to Vygotsky’s (1962) concept of the zone of proximal development where meaning making proceeds from the known aspects of a problem (ie what the learner can do unaided) and develops to a richer understanding, in part with external help and in part as the learners come to understand key elements of the problem. Thus, within PBL, scaffolding is the method by which the facilitator (primarily) helps the students enhance their own understanding and supplies the means to reason about aspects they do not initially grasp.

An important part of PBL as a learning process is interaction within the student group. Thus there is a need for support to talk students through potential issues such as group dynamics, the dangers of consensus-driven problem solving (Montgomery, 2006) and also of exclusion of members of the group (Remedios, Clarke, & Hawthorne, 2008a). In many cases, students appreciate the independence and group-orientated learning embedded in PBL (Ribeiro & Mizukami, 2005). In a group context, the meaning-making process (Savery & Duffy, 1996) will reflect the range of prior knowledge within the group and the process is partly one of learning to communicate within the group or, as can so easily happen, individual members of the group will find themselves isolated (Remedios et al., 2008a). In this case, the group context offers one means by which students can understand the existence of a diversity of ways of understanding and how these models are influenced by exposure to different ways of thinking and new situations (Hendry et al., 1999).

This construction of a shared meaning, within a group, is not just a process of words alone (Fei, 2004) and instead can come from non-verbal gestures and the tools and resources in use. This raises the importance of understanding the interpretation of such semiotic resources (Fei, 2004; Lemke, 1996, 1998). Jewitt (2008) argues that an increasingly important skill in contemporary societies is "the reconfiguration of the representational and communicational resources of image, action, sound, and so on in new multimodal ensembles" (Jewitt, 2008, p. 241).

2.2.2.2 Role of tutor/facilitator

The role, and indeed the title, of the tutor/facilitator within PBL has changed substantially (Dolmans et al., 2002; Hmelo-Silver et al., 2007; Holmes & Kaufman, 1994; Spronken-Smith & Harland, 2009). In the early model, the role was one of a facilitator and indeed there was no expectation that the individual would possess subject domain-specific knowledge. Instead the key skill was in facilitating group learning and guiding such a discussion. As PBL spread outside medicine, and was adopted for portions of the curriculum rather than its entirety, the expectations changed (Peterson, 2004) and in particular, the individual became more often a member of the academic staff with an interest in, or commitment to, PBL as a learning tool. The result is a confusing mixture of terms in the literature with both 'tutor' and 'facilitator' used almost interchangeably. To some extent the distinction can be held to relate to the difference between facilitating the student meaning-making process and the provision of subject-specific knowledge, but as with the discussion around the scaffolding process, that distinction does not seem to exist in practice. On balance, the description 'tutor' seems to be dominant (Greening, 1998) but this is not universal. One summary of the role in PBL is (and note this quote uses 'teacher' which exemplifies this overall confusion):

> The teacher's main role in PBL is to facilitate the tutorials in which the pedagogical aim is to create a space for reasoned discourse in which they can evaluate student learning, develop problem-solving skills and promote critical thinking. The PBL curriculum progresses with a sequence of independent inquiries and regular tutorials. The teacher seeks to gradually withdraw their support and expertise while encouraging students to accept more responsibility for group facilitation as a key part of their learning experiences. (Spronken-Smith & Harland, 2009, pp. 138-139)

In this respect, a critical part of the tutor's role (Greening, 1998) is to refrain from adopting the role of authoritative source of knowledge, and in some approaches, the possession of subject knowledge by the tutor has been argued to be a hindrance to PBL. In some early approaches to PBL, there was seen to be a clear distinction between tutors who possessed subject matter expertise and those with process-facilitation expertise (Dolmans et al., 2002). In the first instance they were technical experts in their particular field and the second group may lack such detailed academic knowledge but be experts in the type of group facilitation work embedded in PBL. This distinction became blurred (Dolmans et al., 2002) as it was acknowledged the tutor needed to be able to shift role depending on the varying needs of the student group.

Over time the norm has become "that tutor expertise favors greater congruence between learning issues and case objectives, and stimulates greater numbers of learning issues to be explored" (Greening, 1998, p. 6). The tutor has a critical role in ensuring that learning takes place, and whilst this role is often one of facilitating, it is also best done with a high level of subject expertise. In consequence, a real challenge to the tutor is to gauge when to engage directly and when to let the student-led problem-solving process proceed, especially when faced with apparently flawed group dynamics (Savin-Baden & Major, 2004). One view (Choo, 2012) is that the key skill for a tutor in such a situation becomes their ability to formulate questions in such a way as to guide student learning but without removing the student-centred nature of PBL.

Within medical approaches to PBL, a key goal is to develop what is described as ‘clinical reasoning’ (Distlehorst & Robbs, 1998) supported by “developing effective and efficient self directed learning skills, including an internal motivation to learn, question, and understand; developing effective patient interaction skills” (p. 132). This places considerable demands on the tutor who has to interact and guide the students but do so in such a way that allows him or her to remain in control of the learning process (Tan, 2004). Conventionally tutors are first trained specifically to undertake this role and then their performance is reviewed by their own self-evaluation, student feedback and sometimes formal monitoring of tutorial settings (Distlehorst & Robbs, 1998). The consequence is that PBL can be a stressful process for both tutors and students (Berkson, 1993). This implies that a substantial staff development agenda needs to be in place to support the introduction of PBL and to develop tutor skills (Holmes & Kaufman, 1994) as the curriculum changes from a focus on teaching to a focus on learning (Constance, 2000).

2.2.2.3 Implications for students

The shift from a content-led to a problem-led curriculum, and using ill-structured problems that lack a clear answer, can be challenging for students as well as staff (Peterson, 2004). This can be particularly the case for students leaving secondary education with its focus on clear answers and on acquiring definitive knowledge and for students undertaking a PBL-orientated module in an otherwise conventional curriculum. Two particular problems are cited repeatedly by students. One is the time commitment needed as PBL is seen as more time intensive than a conventional curriculum which may pose particular problems for mature students or those with substantial paid work commitments in addition to their studies (Ramsden & Brown, 2008). The second problem is student frustration with being presented with the problem before having the knowledge (Hmelo-Silver, 2004; Ribeiro & Mizukami, 2005; Savin-Baden, 2000; Tan, 2004). Tan reports this as being described in terms such as:

> "There were too many learning issues. We didn't have the foundation knowledge. Because there were just too many things left for us to find out on our own we just couldn't cope. Activating prior knowledge? How could we activate prior knowledge if we didn't even know where to begin. My group lost interest because of PBL. There were times when the tutor could have just pointed out and explained some things instead of sending us on a wild goose chase." (Tan, 2004, p. 176)

The larger risk in this respect is the substantial evidence, both in tertiary and secondary education, that once students no longer feel they understand the purpose of a course, they tend to disengage (McClaughlin, Campbell, Pungello, & Skinner, 2007; Robbins et al., 2004). This can lead to withdrawal from education altogether or to lower performance on a particular course. Thus there is a tension between stepping back and letting students make mistakes and understanding when students may well need some direction or input. Not least, even in a PBL environment, students can still be very task-focussed on exactly what they need to do or read in order to pass the course and this may undermine some aspects of PBL (Berkson, 1993). In general, students who feel excluded or uncomfortable either in their personal knowledge or with their peer group can find PBL difficult (Tan, 2004). This can lead to the problem of what are described as 'silent students' (Remedios, Clarke, & Hawthorne, 2008b).

Silent students can often include students who are studying in a second language and the discussion may become dominated by the native English speakers in the group (Woodward-Kron & Remedios, 2007). This is an important issue for any university with a diverse student base to address. In particular, a lack of confidence that inhibits contribution is not just an issue for non-domestic students as shown here:

> I really received a culture shock … problem-based learning was definitely not my style of learning. I was really frustrated that there was no teacher to deliver the notes to me and … feed me with information in a well-structured and systematic manner. It seemed to lack proper direction and structure and I was lost … in the end no 'model' answers were provided. (Tan, 2004, p. 176)

or in this quotation:

> People probably feared saying something wrong, or just not being right … I didn’t want to kind of put my foot in it, so to speak … make a silly mistake. (Remedios et al., 2008a, p. 210)

A challenge in this respect is how should tutors deal with the situation? If they stand back and let the group dynamics work then there is a real risk of little valuable learning taking place. If they intervene, then this may undermine the goals of PBL pedagogy (Remedios et al., 2008a). In either case, what becomes clear is that for PBL to work both the academics involved and the students need to be clear as to the process, likely problems and the sources of help (as well as how to access these). A key skill is learning how to handle differences of opinion in such a way that members of learning groups do not feel marginalised (Ribeiro & Mizukami, 2005).

PBL has a model of group work that means students do not just have to work collaboratively, but also separately (i.e. agree how to divide up a task and then work individually on their own section). They have to work as a team and to draw out each other’s knowledge and experience. This places the issues of group interaction and communication at the centre of a successful PBL exercise (Ribeiro & Mizukami, 2005). In this respect Pennell & Miles (2009) highlight that key steps for a student group include collaboratively coming to an initial understanding of the task, pooling their existing knowledge to identify gaps, identifying their learning needs and dividing these up amongst the group. The final stage is to “bring back their new knowledge to the group, integrating and negotiating what they’ve learned with what they already knew” (Pennell & Miles, 2009, p. 382). This process has traditionally been seen as needing face-to-face interaction, although increasingly various on-line communication tools are being used (McLinden, McCall, Hinton, & Weston, 2006).

A final issue is the use of appropriate assessment strategies for PBL programmes. Savin-Baden (2004) has argued that one potential reason for the mixed evidence about the performance of students from PBL-based courses as opposed to other forms of delivery, is that most conventional assessment is ill-suited to test the specific skills that PBL develops. Stojcevski and Du (2008) suggest that this is partly due to the linear phasing of assessment and learning (i.e. learning is completed and then assessed) and instead what is needed is a curricular approach that integrates the two (Stojcevski & Du, 2008) as:

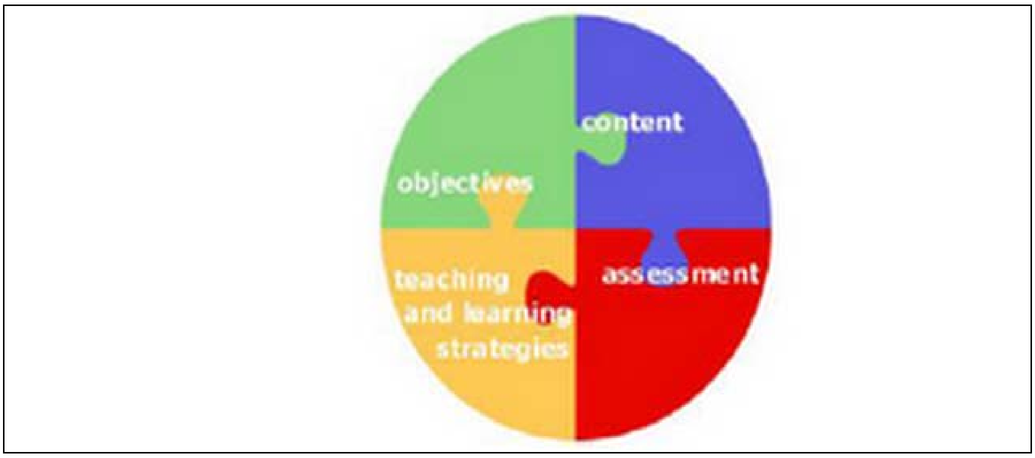


Figure 2-2: Aligning teaching and assessment in a PBL curriculum (adapted from Stojcevski & Du, 2008, p. 2)

2.2.3 Multimedia and PBL

One early development within PBL was to encompass on-line and distance learning (McLinden et al., 2006). Distance learning as a concept became increasingly feasible within tertiary education with the advent of modern digital technology. However, many of the early materials were relatively conventional and as Jacobs et al. (2003) highlighted it is only recently that multimodal resources have become easily available, as well as being more flexible and interactive. It has been argued that PBL is naturally a good fit for on-line delivery as "the emerging pedagogical consensus in relation to online learning is that of constructivism, with an emphasis on collaborative learning, authentic task, reflection, and dialogue, as well as the promotion of identities and learning communities" (McLinden et al., 2006, p. 335).

Broadly speaking, multimedia has been introduced into PBL in two closely related ways. One is as a learning resource that can be searched for information and used to guide learning and discussion. In this, the multimedia resource can be used in addition to the conventional human tutor or to replace that role completely (Kaliyadan et al., 2012). Closely related to this is the use of multimedia resources as the focus of student discussion either to record their ongoing investigation or to become the place where all the group interactions are managed. Overall, students report using a Virtual Learning Environment (VLE) as an enjoyable and immersive learning experience to communicate and engage in collaborative problem solving (Savin-Baden et al., 2011).

According to Luke (2003), a key step to understanding how students use multimedia in learning is to take a multimodal approach to reading the complex semiotics of multimedia, ending with a call for theories that will “play catch-up with the unprecedented textual and social practices that students are already engaging with, often on the sly” (Luke, 2003, p. 402). However, in practice, although the existing research into multimedia and PBL contains evidence for multimodality in meaning making, this is more often implicit rather than explicit.

Other research has supported the argument that adding multimedia to PBL creates a more realistic and holistic learning experience (Persson, Fyrenius, & Bergdahl, 2010), especially as multimedia has the potential to improve the learning materials available for PBL (Barak & Dori, 2005). Unlike Kaliyadam et al. (2012), Barak and Dori (2005) report that student performance in both formal tests and in respect of their overall learning was much improved for the students who had worked in the ICT-rich environment. They looked at formal performance, how students were able to conceptualise their learning, the content of projects and how students made use of ICT to construct models (Barak & Dori, 2005). Similarly Whitehair and O’Reilly (2010) found that PBL “was positively affecting the students’ performance during practicum” (p. 1060).

Other studies query the interaction of multimedia on the student learning process. These concerns include noting that while students prefer the use of multimedia resources in a PBL environment (Basu Roy & McMahon, 2012) there is evidence that this changes the nature of the learning experience, with this becoming more focussed on superficial and surface learning. Strømsø, Grøttum, and Lycke (2007) have noted how the addition of computer-mediated communication to PBL changes the nature of that interaction, with students preparing more responses, but these being less well elaborated. One possible explanation for this observation was that the students were using the resource in a manner akin to ‘chat’ and email in their non-academic interactions (Yeo & Tan, 2011).

2.2.4 Conclusions

PBL originated with a very definite view as to how an entire academic curriculum should be organised, but, given the higher education learning technology of the time, remained grounded in classroom-based paper and text interactions. Subsequently, it has spread to many other subjects, most often being adopted for particular modules within an overall degree course and, increasingly, its implementation has seen the addition of multimedia, on-line distance learning and the wider use of ICT to support the delivery.

Even before this expansion of communication modes, or learning tools, there has been an interest in studying student interaction within PBL in terms of semiotics. A multimodal approach reflects the importance of the sense-making and meaning-making aspect of the learning process for students (Jewitt, 2008). A focus on the use of information by the students, how the wider academic discipline contributes to an understanding of the meaning-making process, and the role of the tutor in structuring this information, allows a deeper study of the learning process within PBL.

2.3 Multimodality and meaning making

Multimodality is one of the perspectives from which meaning making (both by students and teachers) in the classroom can be studied. As a field of inquiry it allows consideration of how speech, gesture and the available resources, such as tools, can be used in the meaning-making process as well as how these different semiotic resources interact. As a field, multimodality was originally developed from the concepts of social semiotics; however, as the focus has shifted beyond speech to encompass non-verbal meaning making, there has been a growing focus on how different resources may be combined in the meaning-making process. This is important, as discussed in terms of PBL above, as meaning making is a process shared between students and the facilitator, influenced by the learning environment (both the resources available and the academic discipline). An initial goal in this section is to review the literature in order to come to an appreciation of how multimodality can contribute to an understanding of these interactions.

This section starts with a review of the early literature on social semiotics and then considers what is meant by multimodality in meaning making. This is followed by a discussion of the importance of intersemiotics (how different resources are used to form, modulate or contradict meaning) and resemiotics (the importance of context for the meaning-making process). Finally the section presents a discussion of the application of the concept of multimodality specifically to education.

2.3.1 Social semiotics

Social semiotics is the basis for current theories of multimodality, having originally been described as *semiotics* or *semiology*. The modern concept of semiotics stretches back to the work of CS Peirce in the nineteenth century (1839-1914), although it has roots in medieval philosophy and semiology associated with the Swiss linguist Ferdinand de Saussure (1857-1913). Both concepts were focussed on how meaning was constructed and understood (Berger, 1994). However, semiotics remained grounded in the study of linguistics and Halliday (1978), through his theory of *Systemic Functional Linguistics* (SFL), added the argument that the social environment and norms informed the process of meaning making as much as the linguistic structure of a text reflecting the social functional meaning (Halliday, 1978).

Halliday argued that semiotic resources are the “system of meanings that constitute the ‘reality’ of the culture” (Halliday, 1978, p. 123). However, initially the focus remained on language as the dominant mode of meaning making (Iedema, 2003). The concept of multimodality expanded this focus to include other modes of communication, such as audio, visual and other sensory signs and the combinations of two or more semiotic modes. So, for example, a web page communicates with both pictures and written language (Kress & Van Leeuwen, 2001). However, multimodality of communication remains, like social semiosis, concerned with signs used to communicate in a social context. Van Leeuwen (2005) argues that is possible to “define semiotic resources as the actions and artefacts we use to communicate whether they are produced physiologically or by means of technologies” (p. 3).

2.3.2 Multimodality

The introduction of the concept of multimodality has been an attempt to capture the wide range of semiotic resources used in meaning making (Williamson, 2005). While social semiotics traditionally focused on language as a semiotic system, multimodality expanded this to signs found in other modes. In other words, multimodality of communication is, like social semiosis, concerned with signs used to communicate in a social context, but multimodality extends the conversation to the use of a combination of two or more semiotic modes (Kress & Van Leeuwen, 2001).

Kress and Van Leeuwen's work led to the development of the concept of *Multimodal Discourse Analysis* (MDA) as a means to link the traditional study of language (discourse analysis) to other modes of social interaction (O'Halloran, 2008), such as vision and touch, as well as to the interpretation of visual images and abstract notation systems. The concept of socially derived meaning making through systemic functional analysis, introduced by Halliday (1978) to semiotics, is replicated in the field of MDA with the development of *Systemic Functional Multimodal Discourse Analysis* (SF-MDA). This development draws on the insight that human discourse is inherently multimodal and as such meaning making cannot be understood just by concentrating on speech or written texts (Scollon & LeVine, 2004).

In particular, using the concept of multimodality as an analytical tool to understand meaning making has become more important with the rapid development of digital media. O'Halloran and Smith (2012) identify this relationship between multimodality and digital technology, arguing that digital technology, including the Internet, has contributed to a significant expansion of the ways in which people communicate. O'Halloran and Smith (2012) argue that this is the latest iteration of a long-standing historical process. An early example was the impact of the printing press as this both created a medium for the wider transmission of information and allowed the combination of images and text (O'Halloran & Smith, 2012).

However, as with many interdisciplinary fields, this breadth has brought complications. There is ongoing debate as to what aspects of human perception should be included (Fei, 2004; O'Halloran, 2011b) and how to develop an appropriate method to analyse communication modes as diverse as speech, gesture and body language (the implications of this in terms of research design are covered in detail in Chapter Three).

2.3.2.1 MDA and SF-MDA

Multimodal discourse analysis (MDA), and the related field of systemic-functional multimodal discourse analysis (SF-MDA) (O'Halloran, 2008), is thus a relatively recent concept being brought into existence by the increasing ease of creating multimodal communication (mostly, but not exclusively, digitally). One consequence is that multimodality and semiotic research still remain grounded in the process of semiosis (meaning making). The multimodal design of a text entails an appropriate structuring of the different semiotic resources to present the intended meaning. Kress (2010) argues that, "the multimodal design refers to the use of the different modes – image, writing, colour, layout – to present, to realize, at times to (re-)contextualize social positions as well as knowledge in specific arrangements for a specific audience" (Kress, 2010, p. 139).

In consequence, the theoretical basis for MDA is complex, as to how to describe the various components, how they are combined and how the wider social setting may shift interpretation. The latter is important as the process of reading such images is not just done by the interpreter (Balcetis & Dunning, 2006) in a vacuum. Social gestures, speech, direction of gaze and other clues of interest or disinterest are also constructed by the interpreter to imply a particular meaning. This links back to early work in the sociology of interpersonal behaviour (Goffman, 1959) and the construction of understanding by observing others (Brown, 1986) has often relied on several clues about the observed and on the different ways in which an individual will seek to construct an image about themselves (Maule & Villejoubert, 2007). There are layers to meaning – how the observer interprets and how the interpreter wishes to be interpreted – all of which places considerable emphasis on the type of behaviour both expect in particular social settings (P. Berger, 2005), something SF-MDA takes into account by emphasising the social and cultural element to meaning making (Norris, 2004b).

In addition, meaning making does not just rely on isolated semiotic resources (O'Halloran, 2008, 2011b) but involves the interaction of semiotic resources (the process of intersemiosis), as we often use speech and gesture at the same time to reinforce or construct meaning. In turn, resemiosis reflects the wider context as meaning shifts due to external circumstances (Iedema, 2003) and, in doing so, changes the process by which meaning is built up. Multimodality can reflect the simple juxtaposition of language and gesture or text and images. In such instances the various modes can be seen as assisting to combine to improve the quality of communication.

A simple example of this is found in explaining the flow of water both verbally and by using hand gestures (Márquez et al., 2006) as one way in which the two modes combine. In other instances body language and gesture may provide information (sometimes unintended) that contradicts or modifies the words actually spoken (Rosenblum, 2008). Thus interpretation of meaning becomes reliant not just on literacy (reading written texts) but multiliteracies, the skill to read several sources of information, combine them and make sense of them in their wider social context. Kress (2000) argues that multiliteracy as a pedagogy emerged in response to the problem that no current language theory could explain all the pluralities of the different modes of communication and representation. Subsequently, studying and articulating multiliteracies entails explicitly or implicitly examining multimodality and semiotic resources and *vice versa*.

However, this expansion of the scope of meaning making is not without theoretical problems. One is that in some fields there is a lack of a ‘grammar’ that can be used to derive information as to what is meant (O’Halloran, 2008, 2011b). This can lead to problems as, without a common grammar, different individuals will read the same symbols in a very different manner. The process of how we read and interpret is itself socially constructed and this issue is returned to in particular in the discussion of activity theory below. Theoretically, some authors have used this gap to argue that there is a need for the construction of ‘grammatical’ rules to link the descriptive elements (shape, colour) to overall meaning (Kress & van Leeuwen, 2001), using sets of parameters to describe subtle changes of degree rather than conventional taxonomies with clear boundaries. This interaction stresses the “interrelationship between language, text and the contexts in which those texts occur, and because it includes a social perspective in the study of language” (Lirola, 2010, p. 80). This also draws on Kress and van Leeuwen’s ideas of a visual grammar (Kress & van Leeuwen, 2006; Lirola, 2010) to both explore how the layout of images can be used to construct meaning and the extent to which our reading of text and images is determined by our cultural experiences, expectations and norms. However, of equal importance is to understand how different semiotic resources are combined in the meaning-making process.

In practice this thesis makes more use of the concepts from the original MDA than SF-MDA. Primarily (and this is discussed in detail in Chapter four onwards), the actual problem solving that was observed made relatively limited use of multimedia resources. Some use of multimedia resources was observed, but mostly students were working from resources such as lecture notes, handouts and text books. As such meaning making can be characterised as relying on speech, gesture and tool use but the problem solving environment made very little use of ICT.

2.3.2.2 Resemiosis and intersemiosis

Multimodality remains fundamentally a study of the process of meaning making (Kress & van Leeuwen, 2001), but one that requires a new set of literacy skills (Jewitt, 2005) as both the range of interpretative frameworks has expanded and the number of modes available to carry information has increased (Kress & van Leeuwen, 2006; O’Halloran, 2011a). From this has come a concern about how different modes interact to reinforce a message, to present different messages or to modulate the message of one mode (O’Halloran, 2008). In turn, this has led to discussion of two related concepts of intersemiosis (the interaction of semiotic choices) and resemioticisation (how meaning shifts as the social context changes) and the various links between these (O’Halloran, 2008). Thus in face-to-face interactions gesture and speech (Xiong & Quek, 2006) may sometimes be used as complementary tools, in others to convey different information and sometimes to mediate the meaning notionally implied in one or the other (i.e. combined in particular ways they mean something different to their separate forms). There has also been an emphasis on the idea that even in a multimodal situation, one mode is the focal communication mode (Kress & van Leeuwen, 2006) and other modes are subsidiary and collaborate with the meaning presented in this key mode. To Iedema (2003) multimodality makes no *a priori* assumption as to which mode is the most important even though one element usually will occupy the ‘foreground’.

Some practical research has offered evidence that different semiotic resources can both combine to support the same meaning or be used to indicate different meanings either by adding new material or by altering the apparent meaning of, say, the words actually used (Benson, 2008; Jaipal, 2009; Márquez et al., 2006). Márquez and colleagues studied situations where either gesture was redundant (i.e. it confirmed the message of speech) or there were discrepancies between gesture and speech, especially when new material is to be introduced, so each communication mode may have a different function (Márquez et al., 2006). To Iedema (2003) multimodality makes no *a priori* assumption as to which mode is the most important even though one element usually will occupy the 'foreground'.

One problem is whether there is really a common grammar that can be applied to all these various semiotic resources. Some of the component fields have a well-developed process for the construction of interpretative grammars such as, for example, the study of the role and meaning of language (Ahmed, 2010; Vygotsky, 1962). Similarly, some alternative descriptive systems of communication, such as mathematical and scientific symbols may rely on clearly articulated and shared interpretative frameworks (Jaipal, 2009; Márquez et al., 2006). In others, such as reading visual images, there is less agreement about the nature of the grammar adopted (Kress & van Leeuwen, 2006).

Resemiosis in turn captures the way in which the wider environment also influences meaning making. This can include the ways in which dominant modes of discourse influence the meaning attributed to events (Peled-Elhanan, 2010) or how a scientific discipline provides a framework for the interpretation of a particular problem (Martinec, 2000). Similarly, social context can change the interpretation of a gesture, word or event (Fei, 2004; Iedema, 2003). At its simplest, a gesture may be a threat (e.g. someone moving very close) or an indication of intimacy, depending on the individuals and the wider situation.

Table 2-1 summarises the varying foci on intersemiotics and resemiotics in recent literature identified deals with multimodality within education. Several overarching themes emerge from this analysis. First, that even when there are several semiotic resources, usually one mode is dominant. Second, that several semiotic resources are usually deployed to support meaning making, sometimes to create a secondary meaning and sometimes to modulate or overturn the notional meaning of the dominant resource. What is clear is that the process of resemiosis is seen as important but quite often left unexplored despite the notional importance of the social context on meaning making.

Table 2-1: Semiosis, intersemiosis and resemiosis in classroom settings

Publication	Focus	Semiotic Resources	Intersemiotic Process	Dominant Mode	Resemiotic Process
Airey & Linder, 2009	Pedagogy - science	Diagram; equation; speech; text; gesture	Used in different combinations, sometimes to support, sometimes to give different meanings	Varies according to purpose	Academic discipline frames the overall discourse
Baildon & Damico, 2009	Pedagogy - interpretation	Image; text; video	How the different modes are used to create a narrative		Construction of a dominant view, essentially that of the author or designer
Benson, 2008	Pedagogy - arts	Text; visual; drama; music	Interaction but also some are easier for some pupils	Text	
Bezemer & Kress, 2008	Pedagogy - meaning creation	Text (design and composition), images, multimedia resources	Interaction between the options		
Hennessy, 2011	Student use of multimedia	Text, image, music, video, voice	How different modes can be combined to present information		
Iedema, 2003	Pedagogy - teaching practice	Image, verbal, text, gestures, metaphors	Used in different combinations, sometimes to support, sometimes to give different meanings		Academic discipline frames the overall discourse
Jaipal, 2009	Student use of semiotic resources	Dress, gesture, speech	Non-speech modes are used to stress self-identity when speaking in a non-native language	Non-verbal	Issue of black South African students using English but asserting their specific identity
Lirola, 2010	Pedagogy - teaching practice	Interactive Whiteboard (IWB), speech, text, visual	Interaction but also how some are used to convey specific meanings	IWB	
Maher, 2011	Pedagogy - science	Gesture, diagram, speech, text, formula	Interaction, some combine to reinforce meaning, others give different meanings	Varies according to situation	Academic discipline frames the overall discourse
Márquez et al., 2006	Pedagogy - science	Gesture, speech, images	Combination to carry meaning	In particular how different resources are used to cover different areas of knowledge	Academic discipline frames the overall discourse
Martinec, 2000	Pedagogy - science	Print, spoken word, illustrations, video and animation	Main focus of the paper, suggests 5 methods of dialoguing, controlling, manipulating, searching and navigating		Academic discipline frames the overall discourse

Publication	Focus	Semiotic Resources	Intersemiotic Process	Dominant Mode	Resemiotic Process
Moreno & Mayer, 2007	Meaning in text construction	Fonts and type spaces	Interaction, how they structure progress through a document		Cultural and social norms evoked when ‘reading’ such resources
Nørgaard, 2009	Textbooks	Words, pictures	Combination, including layout to create meaning		Goal is to create a means by which events are to be interpreted
Peled-Elhanan, 2010	Student use of semiotic resources	Text, image, video, multimedia	Combination as appropriate to carry meaning		
Walsh, 2007	Pedagogic - student learning	Images, speech	How images (pictographs) carry meaning in Chinese script	Images	Wider cultural frame of reference

Although Table 2-1 simplifies the complex research it also starts to indicate some overall trends in the literature. All the papers directly address the issue of inter-semiotics and several studies explicitly look at how or when different semiotic resources are used to emphasise a particular meaning (Iedema, 2003), to modulate a meaning (Maher, 2011) or indeed to import completely different information. However, there is relatively little consistency in the naming of semiotic resources. Some of this is a reflection of focus and scope of the study (e.g. on the type font used in text or on the use of text). However, some differences are less clearly related to the research focus, such as the separation of 'metaphors' (Jaipal, 2009) from the more generic concept of 'speech'. In the main, though, most studies indicate that the main semiotic resources are written text, speech, gesture and multi-media (the latter is, of course, a range of resources in and of itself). The gap is in the coverage of the process of resemiosis and the impact and influence of context is often not discussed, and where it is, this is usually to assert the importance of domain knowledge (in the case of science teaching).

2.3.3 Multimodality and secondary and tertiary education

The concept of multimodality has been applied to education in various ways. In one sense, as discussed in the context of PBL, the advent of multimedia resources has meant there is a need to consider how students use such a range of semiotic modes in their meaning making. As discussed above, there are also issues in terms of differential interpretation of semiotic resources (in particular those not based on text or speech) as well as the consequences of combining several semiotic modes in the meaning-making process.

More fundamentally, there is a long-standing argument that science and engineering are inherently multimodal (Márquez et al., 2006) as teaching draws on a variety of approaches including practical demonstrations, verbal descriptions, visual images (graphs and pictures) as well as the use of specialist scientific notation. Kress and van Leeuwen (2001) argue that the verbal mode is not dominant and the core meaning-making approach within the scientific method is often the presentation of a model. To explore how the various images create meaning, the first step is to understand the various semiotic spaces (such as the topic, classroom, specific teaching approach) available and the teaching processes (discussion of the scientific concepts under review and the process of managing student participation) adopted (Márquez et al., 2006). The study by Márquez et al. (2006) divided these concepts as shown in Figure 2-3:

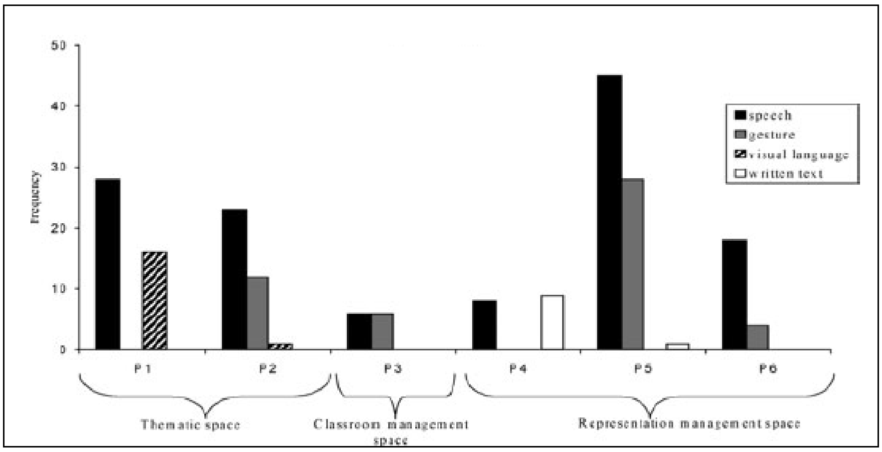


Figure 2-3: Different modes in classroom discourse (adapted from Márquez et al., 2006, p. 213)

Márquez et al.'s (2006) analysis shows an interaction of semiotic modes (speech, gesture, visual language and written text) in different elements of the class, with thematic space concerned with a particular topic under consideration, classroom management space concerned with the layout of the room and representation of management space concerned with an approach to student interaction (Márquez et al., 2006). The teacher of the class under observation had a high reliance on triggering student active engagement. Speech (P1 in Figure 2-3) and gesture (P2 in Figure 2-3) were particularly important in terms of underlying knowledge, with gesture frequently adopted when a physical location was to be indicated (such as whether the movement was up or down). Visual language (i.e. P3 in Figure 2-3), especially the use of arrows to represent flow, were a major means of communication since the specific class was studying water flow and the water management cycle (Márquez et al., 2006).

In mathematics some very similar issues arise. Again it is argued that the field is inherently multimodal, relying on conventional language, graphical and pictorial representation as well as the use of specialist notation to represent knowledge. The growing use of visualisation (Davis, 2006) is not just easing the process of representing complex systems but is leading to new areas of knowledge. Mathematics is changing as the scope for visualisation expands through the use of computer graphical software to capture more chaotic systems, making it easier to change the parameters or output view (O’Halloran, 2011a). O’Halloran (2011a) argues that

> the means for exploring the behaviour of the system remains multi-semiotic (i.e. symbolic, visual and linguistic). However, the meaning potential of those semiotic resources are expanded in the dynamic realm of computer-based visualization (e.g. colour, texture, size, shape, point of view, and so forth). (p. 6)

Outside science, mathematics and engineering the traditional use of multimodal analysis varies. O’Halloran (2011a) argues that it is less well developed within arts and humanities as these fields are not really exploiting the capacity of SF-MDA to move beyond conventional page-based representations. To others, multimodal analysis is well grounded (Kress & van Leeuwen, 2006; Lindström, 2011), given that art, music and related fields have always focussed on the transformation of information across different modes of communication, for example, from visual or aural images into text descriptors.

The application of multimodal research, specifically to PBL and more generally to the process of student learning, is developed in more detail in Sections 2.5 and 2.6 respectively.

2.3.4 Summary

Multimodality as an approach has become increasingly important in understanding student learning as the classroom environment and education in general have become more and more reliant on several communication tools. Interactive Whiteboards (IWB) and multimedia combinations of text, images and videos are becoming the norm and students are expected to be able to read and combine several information sources. If students’ meaning making has become more multimodal, then the concepts of MDA and SF-MDA become more valuable to understand what is going on and to design pedagogic interventions in a way that will assist student learning.

One important element to this meaning-making process is what has been described as ‘resemiosis’, the impact of context on interpretation. Although this is at the core of multimodality, as demonstrated in Table 2-1, it is often overlooked in the literature. In this respect, activity theory (discussed in Section 2.4) provides a useful tool to understand how individuals transform, interpret and act on external information.

2.4 Activity theory and socio-cultural theory

2.4.1 Introduction

Theories of multimodality tend to agree that there are three related processes that inform meaning making. These are usually described as the semiotics (the words, text, gesture, images and so on) that carry the basic meaning, the process of intersemiotics (where all these individual semiotic resources combine and interact to carry meaning) and the wider process of resemiotics (see Table 2-1). The latter is sometimes ignored in the literature, yet it seeks to capture the broad social norms and interpretative systems used to construct meaning. However, where resemiosis is considered, this is usually descriptive, and often rather assumed, so, for example, the concept of the classroom creating a context for certain behaviours and forms of semiosis with the language, discipline norms and overall structure provided by the particular subject (Jaipal, 2009; Jewitt, 2006; Liu, 2009; Márquez et al., 2006). What is often missing is less an acknowledgement of the importance of resemiosis and more the means by which it may operate. Some related psychological theories invoke the concept of metacognition which is "related to problems of awareness, verbalization, penetrability and to the paradoxes of reflectivity" (Yzerbyt, Lories, & Dardenne, 1988, p. 13) in an attempt to reach an understanding of the process by which human cognition constructs meaning and understanding, but there remains a lack of theorising as to how this process actually occurs (Leontev, 1978; Nightingale & Cromby, 1999).

The lack of theorising as to the meaning making process is a problem that stretches across all constructivist models of human behaviour (Bem & Looren de Jong, 2006). Jewitt (2006), for example, argues that while multimodal approaches are useful as a means to understand the range of semiotic resources used in meaning making, multimodality fails to take full account of the "socially situated character of meaning making" (Jewitt, 2006, p. 16). Jewitt suggests instead that activity theory, as developed by Engeström (1987), provides a research and theoretical tool that will improve the extent to which the social constraints and norms influence meaning making (Jewitt, 2005, 2006).

2.4.2 Socio-cultural theory

Vygotsky started out with a critique of the behavioural theories that were becoming prevalent in psychology in the 1920s and later (Mills, 2000; Skinner, 2002), that effectively denied the effect of human cognition in mediating between stimulus and response (Tolman, 1987). Vygotsky's socio-cultural model (John-Steiner & Mahn, 1996; Mercer & Howe, 2012) argued for the importance of both the individual characteristics and the social context in the process of meaning making and gives prominence to the role of culture and variations in language in providing such a framework for both understanding and meaning making. However, he never completed his original research and Leontev and others developed their ideas from an incomplete theoretical basis (Leontev, 1978).

An important element in Vygotsky's model was the concept of semiotic mediation such as through language, symbol systems (including the script forms for writing and mathematical symbols), art, diagrams and maps. Within his model, there is also a stress on the value of interaction as part of the learning process (Mercer & Howe, 2012), whether this interaction is collaborative learning among the students or directed learning led by the teacher. Similarly, the available range of learning strategies, and likely use that will be made of them, is understood as being often heavily influenced by the culture that dominates in a particular instance (Hedegaard, 2001). In an educational setting, for example, different disciplines have differing norms of programme delivery and this in turn will influence how students expect to study in that environment.

At the centre of this process lie the psychological tools by which semiotic resources are used and this concept, in Leontev's (1978) revision, became the concept of appropriation that describes how these psychological tools become the means by which knowledge is processed and understood. This process of mediation between information (semiotic resources) and tools to generate meaning lies at the heart of Vygotsky's model. The distinction between resources and tools was subsequently developed by Engeström (1987) and this is further discussed in Section 2.3.3.

Vygotsky argued that the "psychological systems that unite separate functions into new combinations and complexes arise in the process of development" (John-

Steiner & Mahn, 1996, p. 194). This is important as Vygotsky argues that, for example, the early development of a system to record language did not just create a new semiotic resource (writing), it also changed how speech was understood, as well as fundamentally changing humanity's mode of engagement with the surrounding world (John-Steiner & Mahn, 1996). The contemporary development of multimedia can be seen in the same light – it is not simply a new semiotic resource, it has an impact on other pre-existing semiotic resources and represents a fundamental shift in the ways in which humanity can interact and understand. This, to Vygotsky, gave human development a dialectical aspect (Blinden, 1997), with a sequence of development both for the individual learner and for humanity that sees a constant process of change, adapting to new circumstances and the creation of new processes for meaning making at each stage.

2.4.3 Activity theory

As it developed activity theory split from more cognitive models of psychology (Bem & Looren de Jong, 2006) by shifting the focus from individuals to group actions and activity. Cognitive models tend to stress the information processing aspect of knowledge acquisition (Cook, 2005) by stressing the importance of mental models as a means to categorise and organise new information. At the same time, activity theory moved away from its earlier Marxist roots (Spencer, 1999). Vygotsky (1962) in particular had drawn on Marx to argue that not only do the tools available influence the process of completing a task (so cutting down a tree is different if done with an axe or a mechanical saw) but also change how that act of labour is understood and the degree of interaction (if any) between labourers and as to whether the labour is voluntary and shared, or paid and controlled. In a PBL context, as discussed in Section 2.1, the distinction may be between student behaviour when all the information is presented on paper (or needs to be found by visiting a library) and interaction is face-to-face and when a multimedia resource has been made available that allows both for information search and communication.

The concept of activity as a shifting combination of human actors and tools is an important element in Vygotsky's theory and was developed by Leontev (1978) who argued that by

> introducing the concept of activity into the theory of cognition, Marx gave it a strictly materialistic sense: For Marx, activity in its primary and basic form was sensory, practical activity in which people enter into a practical contact with objects of the surrounding world, test their resistance, and act on them, acknowledging their objective properties. (p. 22)

The three elements of activity, action and operation (Leontev, 1978) have remained at the core of the subsequent development of activity theory but have seen considerable refinement and debate about their functions. Some of the debate about how to interpret Vygotsky and Leontev relates to the issue of translation from Russian to English as well as understanding the constraints placed on scientists in the old Soviet Union (Kaptelinin, 2005). Blunden argues that Vygotsky's approach to psychology cannot be understood except in terms of his use of Marx (and by implication Hegel) in his scientific approach (Blunden, 2011) and, in particular, how to define the concept of activity. To Leontev, the object of activity was both personal (the goal of an individual) and social as, even if carried out in private, the information used to carry out the task was determined by wider social and cultural norms (Kaptelinin, 2005). In combination this creates problems in understanding the meaning and usage of two critical terms in Activity Theory – 'object' and 'context'.

Object is a complex concept as the meaning in Leontev's (1978) original work is that the object of work is to be understood in a dynamic, Hegelian model (Sokolova, 2011). In effect, the subject (actors) work on the object (task) and, in turn, are influenced by that interaction (gaining knowledge, becoming exhausted, creating something new and useful). A further complication lies in the process of translating Leontev's work from Russian. The concept of the 'object' is central in Activity Theory but in Russian two different words "*Predmet*" and "*objekt*" are used for this concept (Kaptelinin, 2013; Leontev, 1978). "*Predmet*", in particular, according to Kaptelinin (2013) tends to refer to an object that was specifically designed to support human activities, while "*objekt*" can refer to any object (ie something that is naturally occurring as well as something specifically constructed by human beings). In consequence, within an Activity Theory framework the meaning of object shifts according to its nature (in particular if it is deliberately man-made) and as the task is performed.

Of perhaps even more relevance to a discussion of the application of

Activity Theory in terms of student learning is the controversy around the idea of ‘context’. Cole (2003) describes this as a ‘slippery concept’ which draws on the interrelationship between the learner and the situation in which the learning takes place. In this sense context can be linked to the other key idea of the ‘Zone of Proximal Development’ as constructing the likely focus of any learning experience. In a later paper he cites Vygotsky directly (Cole & Gajdamaschko, 2010) to link meaning and context as:

> “Meaning is only one of these zones of the sense that the word acquires in the context of speech. In different contexts, a word’s sense changes. In contrast, meaning is a comparatively fixed and stable point, one that remains constant with all the changes of the word’s sense that are associated with its use in various contexts” (Cole and Gajdamaschko, 2010, p. 257)

An important part of this argument is that words shift meaning as context changes and one way in which the context can change is in terms of developing knowledge. In this respect, the learner,, whether the child (Vygotsky’s original focus) or a student in a PBL class, is both influenced by context (what they know, task boundaries, the social norms) and redefines the context as their knowledge develops. Of particular importance for PBL, which links also to the issue of silent students and the difficulties those from different academic traditions might experience, is that if a given mode of learning is outside their context (ie prior experience), then they will struggle. In effect, “if the content of the problem was changed so that it was familiar and meaningful, these same students were overwhelmingly correct” (Cole & Gajdamaschko, 2010, p. 271).

Contemporary activity theory (Engeström, 1987; Leontev, 1978) was developed from Vygotsky’s basic concepts of the way in which a task was understood in terms of language, the tools, its purpose and the surrounding social organisation to capture the range of influences (past, future goals, other actors, knowledge and understanding, tools available for use) that affect the approach chosen to achieve a particular goal. It is a complex theoretical model and is easiest to explain by examples and analogies. For example, the process of information search 200 years ago would have consisted of a face-to-face interaction, an exchange of correspondence with an acknowledged expert or a visit to a major library. Today, for most people, the natural starting point would be the Internet. Thus the same goal is carried out in very different ways and in doing so reflects wider changes in society and our understanding of how to look for information, and indeed just what the concept of information search implies. Again, in a PBL context, this may see the difference between students being presented with a folder of photocopied articles and having access to a multimodal web-based information resource. In each of these situations the basic activity 'information search' takes place in a different way and demands different skills.

Methodologically, activity theory has retained the concepts of an *object* (the purpose of an action), a *subject* (usually the individual(s) carrying out the action) and tools (the means by which an action can be carried out). In the example of information search (Jewitt, 2006), in the terms of activity theory, the *object* is to acquire more information, the *subject* is either the individual or the other contacts available but the *tools* are potentially very different, having shifted from letters or a physical library to a search using the Internet.

Vygotsky (1962) had argued that the individual actions and understanding are influenced by the wider social norms and beliefs of a particular society. He argues that problem-solving behaviour is heavily based on a combination of internal dialogues used to create meaning and test scenarios and the interaction between this internal dialogue and collaboration and/or testing with other people (Jewitt, 2006). In addition, problem-solving behaviour is heavily influenced by the tools available (so knowledge acquisition is a different process with and without the Internet), but those tools are given meaning by the wider social processes. It was this element, in particular that which Leontev (1978) developed, arguing that human activity is most appropriately seen as a series of linked operations, some more or less automatic, but in pursuit of a defined goal, so:

> Initially every operation, such as shifting gears, is formed as an action subordinated specifically to this goal and has its own conscious "orienting basis"…. Subsequently this action is included in another action, such as that of changing the speed of the automobile. At this point, shifting gears becomes one of the methods for carrying out this action-that is, it becomes an operation necessary for performing the action. (p. 64)

However, activity theory should not be seen as a conventional theory with a predictive causal model that relates external variables to outcomes. Instead, it provides a framework that can be used to describe what happens when individuals make use of the wider social norms and rules to understand information and respond to specific situations (Blin, 2004).

2.4.4 Educational applications of activity theory

Of particular use within PBL is Leontev's (1978) linking of goals and motives to activities and actions, so that understanding is eased when a task is meaningful and the context is understood (Blin, 2004). Engeström (1987) argued that Leontev's three concepts of object, subject and tool were not sufficient and instead proposed that the particular task or focus at any one time should be seen as an activity. Within this, the concept of *object*, *subject* and *tool* retain their original meaning as the reason for a task and to describe the human actors carrying out that task. However, Engeström (1987) then adds three further elements to the process of:

- *Rules* – either externally set or constructed to regulate a particular situation (so a classroom, for example, has both wider social rules and the rules that pertain to an educational process);
- *Community* – an elaboration on the core subject concept to stress that this is likely to be more than one person with a degree of shared goals; and
- *Division of labour* – how the tasks are divided among the community and if there are any vertical divisions in terms of power and status.

Jewitt (2006) adopted activity theory to explore classroom interactions. In her model, the *subjects* are the students and teachers in a classroom and the *objects* are the materials under study or the problem space being constructed, while a *tool* is either the means by which such study is mediated, and this can be a physical technical object (a pen, a CD-ROM, a computer), or a mental conceptual mode that is used for understanding. Some aspects fit both criteria so a computer has a physical aspect and "the ability to transform and reorganise how they deal with intellectual and practical learning" (Jewitt, 2006, p. 24). In combination this gives rise to an activity system, in this case built up as shown in Figure 2-4:

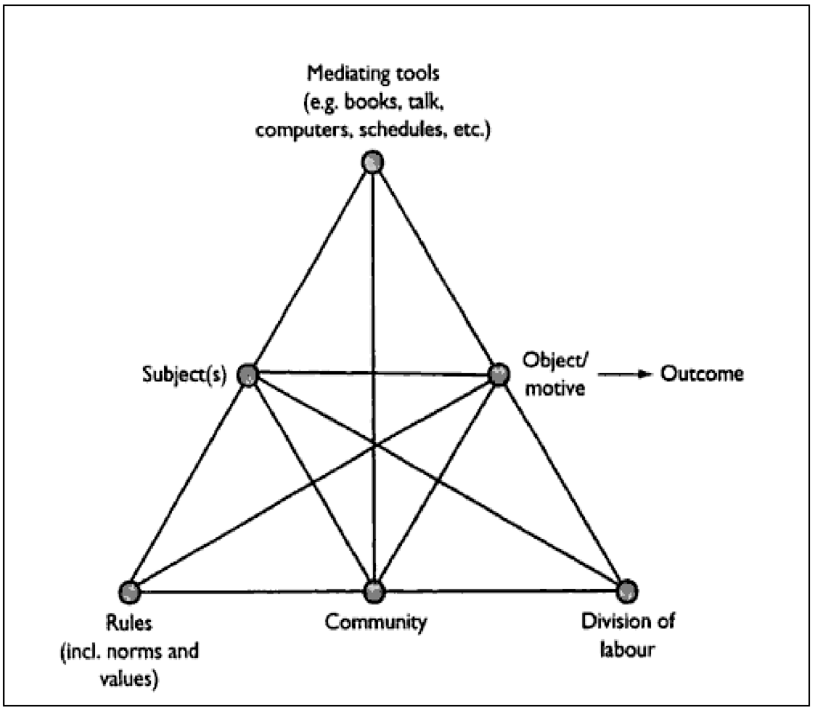


Figure 2-4: Classroom activity systems (Engeström's model's of a human activity system, 1987, p. 78)

In this case, drawing on Engeström (1987), there are also three related social relations at play: the explicit and tacit rules, the roles assigned to both teachers and students as part of their wider peer and professional groups, and the fact that they have distinct roles in learning within the classroom environment (Jewitt, 2006).

This can be related to the PBL student group that is the focus of this research in Chapter Four. The key aspects of the PBL task (see Chapter Three for a full discussion of the coding process) were mapped onto these abstract categories as:

> *Tools* – resources used for building the model, information provided (theoretical and practical), IT resources that were accessed;
>
> *Subjects* – the student group under observation;
>
> *Object* – to build a model bridge that met the requirements of the module;
>
> *Rules* – both the framework set by the wider academic course and the internal rules adopted by the student group;
>
> *Community* – the wider social setting such as other student groups carrying out the same task and the tutor who facilitated the class; and
>
> *Division of labour* – at times reflecting the division of work within the student group and at others the division between the students and the tutor.

2.4.5 Summary

In this context, activity theory – rather than multimodality – provides the methodological framework to bring in the wider elements that influence the expected behaviour and roles in the classroom (Mercer & Howe, 2012). This helps to address one enduring problem in any theoretical model that is based on constructivist concepts which is to explain how the wider social context actually influences individual meaning making. Multimodality uses the concept of resemiosis to explain how meaning making in a particular instance is influenced by the wider social situation but the actual way in which this occurs is often underplayed and, indeed, many studies contain no discussion of resemiosis (as shown in Table 2-1). Vygotsky’s cultural theory (Vygotsky, 1962, 1987) and the activity theory (Engeström, 1987; Jewitt, 2006; Leontev, 1978) that was subsequently developed offer one means to address this gap. As with any theory in this domain activity theory does not seek to offer causal concepts in the sense of setting out what meaning making people will undertake in a particular situation. However, it does offer a tool to explore the wider constraints on meaning making (Tolman, 1987).

2.5 Interaction of PBL, multimodality and activity theory

Traditionally PBL was a class-room based approach mediated by tutors who were physically present and supported by knowledge drawn from textbooks, libraries and supplied bundles of material. In common with the rest of higher education, PBL has become increasingly supported by the use of ICT (Baggott La Velle, McFarlane, & Brawn, 2003; Jacobs et al., 2003), most often in the form of multimedia learning resources (Boireau et al., 2012; Kaliyadan et al., 2012; Persson et al., 2010; Suebnukarn & Haddawy, 2007). However, this has led to a debate on the most effective pedagogic practice that should be adopted to make the best use of these resources (Baggott La Velle et al., 2003; Savin-Baden et al., 2011). So far, with limited exceptions (Hoban, Loughran, & Nielsen, 2011; Yeo & Tan, 2010, 2011), this search for a pedagogic base has not drawn on the literature on multimodality and how various semiotic resources are combined and interpreted (O’Halloran, 2008).

However, one problem is that both the terms multimodal and PBL are used in various ways in the literature. Thus some studies look at the application of multimodal computer-based resources in non-PBL student-centred learning environments (Boireau et al., 2012) or how a variety of practical learning approaches can enhance a student's grasp of real-world applications (Kisely, 2001).

Within the PBL context, students are expected to work with ill-structured problems and to construct their own interpretation of the issues. At its best, working collectively, the students can debate and construct their own reasoning (Spronken-Smith, & Harland, 2009; Tan, 2004). In a group context, this process (Savery & Duffy, 1996) relies on different individuals initially having a different mental model of the problem. Thus the learning process in part is one of learning to communicate within the group or, as can so easily happen, individual members of the group will find themselves isolated (Remedios et al., 2008a). If this works well, it should help students to understand the existence of a diversity of ways of understanding and how these models are influenced by exposure to different ways of thinking and new situations (Hendry et al., 1999).

The introduction of a wider range of learning resources places emphasis on understanding the meaning process, in particular, on how different resources are combined and used. However, the concept of using semiotics to understand student interaction on a PBL module predates the adoption of multimedia resources (Lemke, 1996). Lemke (1996) moved beyond a focus just on the different semiotic resources to consider the role of medicine in framing the overall discourse resemiotically and mediating the differing use of verbal and non-verbal resources. The importance of taking a multimodal approach to understanding PBL is emphasised by the steadily expanding use of ICT, on-line learning environments and multimedia as key learning resources.

In turn, activity theory has been built into PBL in various ways. At its core, PBL seeks to encourage participant construction of academic knowledge, usually in a group context, and being increasingly reliant on some use of ICT, and in particular, on multimedia resources (Kaliyadan et al., 2012; Persson et al., 2010; Savin-Baden et al., 2011). In a PBL context the goal is student-led learning and the claimed value to PBL is that this mode of learning is more effective precisely because the students' need to engage in a problem-solving and knowledge construction process themselves (Arvaja et al., 2007; Chernobilsky et al., 2005a; Kumpulainen et al., 2009; Savin-Baden & Major, 2004).

In turn, and at its simplest (Miao, 2008), activity theory can be seen as a means to understand how individuals or groups work in pursuit of a given goal (Vygotsky, 1962). Vygotsky argued that there was an interaction between how an activity was conducted and the available tools, language constructs and wider social norms and beliefs (Leontev, 1978). On this basis how an individual will engage in PBL is a product of three issues:

- The tools available (so the introduction of multimedia resources will mean that PBL is different to the conventional early model of classroom-based interaction and knowledge search);
- The social norms that will include both the role students expect to play in the classroom and their understanding of the nature of group work; and
- The understanding of what is the purpose of the activity, especially as a common student complaint about PBL is their perception of lack of clarity as to the purpose (Hmelo-Silver, 2004; Pennell & Miles, 2009; Tan, 2004).

More formally, as introduced in the previous section, Engeström (1987) developed Leontev's (1978) original schemata of the constituent parts of activity theory to include:

1) *Object*, i.e. the purpose of an action, so in a PBL classroom this is the construction of knowledge by the students;
2) *Subject*, i.e. those carrying out the action, so in a PBL classroom this will be the students and any tutor offering support;
3) *Tools*, i.e. the resources available, which can be a conventional library, special materials or a full multimedia learning environment;
4) *Rules*, which are either externally set or constructed to regulate a particular situation, so in a PBL classroom these will both regulate the goal agreed and the mode of interaction within the student group and between the students and their tutor;
5) *Community*, i.e. a group on the assumption that usually more than one person forms the *subject*, which in a PBL classroom is of course the group of students and anyone else involved in the learning process; and,
6) *Division of labour*, which captures how the tasks are divided among the community and whether there are any vertical divisions in terms of power and status. Again, in a PBL context, this may reflect how the students break up the task between them, as well as the roles of students and tutors respectively.

Activity theory as a concept is thus useful to understand and break down the various actions that take place within the overall rubric of an PBL (Chernobilsky et al., 2005a). For example, a number of researchers have remarked on how a multimedia environment has changed student behaviour (Savin-Baden et al., 2011; Spronken-Smith & Harland, 2009) as the environment ceases to be like a formal classroom and more like their use of ICT outside formal education. Others have gone so far as to argue that the degree of multimedia adopted can actually disrupt the deep learning process that is the basic goal of PBL (Basu Roy & McMahon, 2012). This indicates the value of looking at PBL in terms of the role and impact of multi-semiotic resources on how students learn and construct knowledge.

One practical exploration of these dynamics is offered by the eSTEP on line problem-based learning environment (Chernobilsky et al., 2005a). This consists of a hypertext-based knowledge resource, a library of videos showing classroom instruction and a module that allows the students to post their observations and findings and access a threaded discussion board. It was noted that the process of group formation and orientation to the task was as expected and that “the apprehension and uncertainty on each student’s mind as they started on their first problem was apparent” (Chernobilsky et al., 2005, p. 59). In particular the shift from a conventional face-to-face ‘warm up’ session to using an on-line environment caused major problems, represented in activity theory terms by an adoption of a new tool, and that “there was little demonstration of any online communication and participation. They tended not to question each other; rather each student posted their research and proposals without much interaction with other group members” (Chernobilsky et al., 2005, p. 59).

The new tool shifted the perceived rules away from a focus on collaborative learning towards a perception that the task was to engage individually with the multimedia resources. However, over time, the students came to a construction of both the new tool and the rules for the task that allowed them to return to a degree of in-group collaboration, although they continued to emphasise the need for personal mastery over the learning environment.

Donnelly (2008) has argued that the use of activity theory provides an invaluable theoretical framework within which an evaluation of a PBL session can be set, arguing that, “it is necessary to make a reflection of technology in relation to activities, learning principles, and a learning theory" (p. 38), with activity theory providing the appropriate learning theory. The social constructivist model that is inherent to activity theory (Engeström, 1987; Leontev, 1978) and to PBL (Savin-Baden & Major, 2004) makes activity theory a useful framework within which to both interpret PBL activities and to guide the design of ICT-based PBL learning environments (Donnelly, 2008). In this respect, the tools concept in activity theory is "increasingly being applied to aspects of technology-supported learning because of its emphasis on the mediation of tools and social factors on human activity" (Donnelly, 2008, p. 43).

However, while activity theory offers a framework within which to understand this process, it is not predictive in that it does not specify what changes in knowledge construction will result from changes in the other possible variables (Engeström, 1987; Jewitt, 2006). In this sense, the concept of rules can be used to explore whether students perceive an on-line environment as changing the process of their interaction with each other, the relative role of students and tutors or has the effect of making them see multimedia and computer assisted PBL environments as being less clearly about formal education (Donnelly, 2008). Such an enquiry could be based on either observation or by questioning the students.

In a different sense, activity theory can be used to explore the collaborative learning process that is key to PBL (Arvaja et al., 2007), especially as "it is not possible to study thinking and cognition independently of the social, interpersonal, cultural, and historical settings" (Arvaja et al., 2007, p. 449). The consequence of this approach is that collaborative learning is a function of the group, a function of the knowledge already acquired and brought by individuals into the group and the rules the group operates with, but nevertheless personal understanding remains an activity of the individual learner. There is a real difference between the concept of interaction and that of collaboration (Arvaja et al., 2007), in particular as "one fundamental issue in these analyses is what kind of social interaction can be called collaborative and how the collaborative opportunities and individual abilities are matched" (Arvaja et al., 2007, p. 458).

2.6 Implications for a model of student learning

In summary, PBL, multimodality and activity theory are underpinned by a broadly similar model of student learning (summarised in Section 2.4). They all share some ground with broader constructivist theories of learning in arguing that learners construct their knowledge through interaction with the wider environment (Brockbank & McGill, 2007; Oldfather, West, White, & Wilmarth, 1999). Gagnon and Collay (2006), in their discussion about constructivist learning design in school classrooms, argue that when learning, students endeavour to build up their knowledge and, if learning is not enhanced by interaction with peers, the process will be constrained. Consequently, learning is both an individual and social process (Gagnon & Collay, 2006). The problem with this apparently solid grounding is the extent to which social constructionist theories diverge amongst themselves, not just in their particular focus but also in terms of just what is being 'constructed' and how this construction takes place (Cromby & Nightingale, 1999).

Social constructivist theory is a very broad domain and, as discussed in 1.2.4, subject to confusing terminology with some seeing social constructionism as the use of tools and others as reflecting the overall academic concept (Cromby & Nightingale, 1999). Some theories are concerned with the (ab)use of power and how social control is maintained, often drawing heavily on theorists such as Foucault (De Angelis, 2007; Lukes, 1974) and Gramsci (1971). On the other hand, there is a focus on how our past knowledge and experience informs how we understand the world around us (Klein, 1998; Payne, Bettman, & Johnson, 1993). Other approaches stress the way that language mediates this understanding (Harland, 2003) and this in turn has become a major theme in both Vygotsky's social-cultural theory and its modern form as activity theory (Engeström, 1987). Overall, there is a wider debate within social constructivism as to the nature of key theoretical elements but there is also broad agreement on certain key aspects (Cromby & Nightingale, 1999), i.e. that:

- Language is rooted in varying historical and cultural frames, with some elements remaining more or less constant across these (Vygotsky, 1962) and other elements changing radically as human social systems change and evolve bringing new approaches, new experiences and new learning tools;
- The language we use is the prime means by which we experience the world and understand those experiences; and

- We actively "seek to explore aspects of our world … and in doing so create knowledge" (Cromby & Nightingale, 1999, p. 5), i.e. act as 'naïve scientists' (Bannister & Fransella, 1986) seeking to impose meaning on information (Kelly, 1955).

Many of these themes have become embedded in multimodal learning models. In particular, the shifting form of meaning depending on the semiotic resources deployed and the extent to which students can be alienated, or engaged, with learning, depending on how comfortable they feel with both the content and the mode of instruction (Kajee, 2011). As discussed above, many academic disciplines, including science, are inherently multimodal (Jaipal, 2009). For students meaning starts from being able to absorb all this information in a structured manner. This in turn has implications for how information is presented between the participants, how the learning is arranged and the relative teaching process. Jaipal (2009) suggests that science teaching relies on four main modes and aspects, as shown in Figure 2-5:

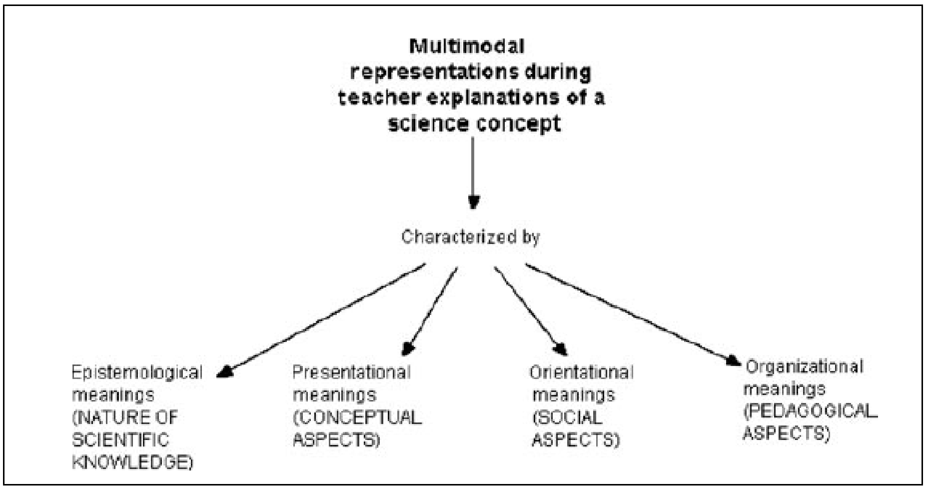


Figure 2-5: Multimodal representations in science teaching (adapted from Jaipal, 2009, p. 54)

Specifically multimodal models of learning seek to explore the relationship between the individual and the social and to understand how students combine the various ways (textbooks, words, gestures, multimedia resources) in which information can be presented (Gillen, Littleton, Twiner, Staarman, & Mercer, 2008; Jewitt, 2005, 2008; Márquez, Izquierdo, & Espinet, 2006; Pikkarainen, 2011; Siry, Ziegler, & Max, 2012; Wei, 2011). A key aspect of a multimodal theory of learning is to accept that each user will make different use of the various resources available. Thus some may concentrate on spoken or written explanations, other may find it easier to understand diagrams or images. Once multiple media (referred to as multimedia) are introduced, the user is able to choose which sign to look at first rather than be compelled to follow the linear structure of a traditionally written book (Kress, 2004). This does not just apply to multimedia as contemporary published materials, whether web pages or books, increasingly use image-rich designs that seek to present the reader with a structure by which they can read the text (Kress, 2004).

A multimodal approach to learning builds on the social constructivist approach. By accepting the variety of learning resources, it accepts that individual learners will navigate through them in different ways. Thus, even in a relatively conventional classroom setting, multimodality implies that a variety of learning strategies will be adopted as students read the various signs and symbols, combine them and develop their own interpretation.

In order to effectively analyse the students' interaction in multimodal terms, it is useful to set out a model of student learning and how this can be described in multimodal terms. Two key concepts are internalisation and scaffolding (Choo, 2012; Hmelo-Silver, 2004; Hmelo-Silver et al., 2008). Hmelo-Silver et al. (2008) suggest that speech in a learning environment can be coded in terms of:

- Content;
- Collaboration;
- Questions;
- Complexity;
- Justifications; and
- Monitoring

These categories can be subdivided, so content and collaboration are broken down further as shown in Figure 2-6:

Category	Example
Content	
Task talk	I recommend that you spend a bit more time on discussing EACH proposal and then vote let's say late afternoon on Tuesday
Tool-related	Frank and I decided instant messenger may be useful for discussing comprised info and ideas
Concept talk	Elaborative rehearsal better equips the student with the information he is rehearsing because it becomes more accessible in his long term memory he has found ways to relate it to other instances and in his own words and he can help his peers understand it on a more simple level
Personal talk	Hey, I just wanted to let everyone know that I will might be a little late logging in on Monday morning. I will be in Connecticut until early Monday morning
Collaboration	
New Ideas	Peer assessment done by each student in each group on their group members
Modifications	I don't think its necessary to peer evaluate within the groups. We might try to give roles out within the group to make sure that each student has a part in the experiment and is working and not slacking off
Agreement	I like Mary's proposal for a hypothesis sheet…
Disagreement	I don't believe peer assessment should be a factor in the student's grade but it could be done as feedback for both students and teachers to use
Summaries	What we have so far: Jack—teacher beliefs, Beth—hands on learning, Ellen—prior knowledge use, Carol—cognitive flexibility theory, Sylvia—collaborative learning
Acknowledgment	Helen did this too so I just want to emphasis a few main concepts and points

Figure 2-6: Content and collaboration coding systems (adapted from Hmelo-Silver et al., 2008, p. 417)

In turn, these categories can be broken down as shown in Figure 2-7:

Category	Example
Complexity	
Telling	Direct instruction: method of instruction for mastery of basic skills, concepts, strategies, facts, and information. This instruction is done piece by piece rather than all together …
Elaborated telling	Games and activities that students are familiar with can help teach specific facts about a country its culture, and its language. … I thought Monopoly would be a good game to use. As long as it was carefully coded as to appropriate linguistic level and maturity level suggested for students
Transforming	This idea supports our objective of "Transfer knowledge of static electricity to everyday examples" And so both motivation and transfer can be achieved through Authentic Instruction, two characteristics of which are Students' work has value beyond the school setting. Lessons become more authentic as the connection to the real world is increased. … Thus, one (authentic) activity would be a field experience (trip) to a lab, power plant, etc., which would should real world use and is social
Justifications	
Personal beliefs	I think a good assessment is to have each student do a mini science project based on static electricity, which I think would encourage students to think more and to not just concentrate on a grade
Grounded beliefs	According to Sociocultural theory, "to capture a student's motivation, the culture of school must find a way to be valuable, relevant, interesting, and challenging in the eyes of a child. This may mean engaging the students in authentic activities of the larger society. It also means challenging them with tasks that are meaningful to the larger culture and are relevant to their lives outside of the school environment" …
Monitoring	
Individual monitoring	I have made a summary about the stuff I got from the knowledge web that i posted as well as my research and printed it out so we can attach it to our sticky paper on Thursday
Group monitoring	Ok, so I think we need to revise or come to a concensus (sic) about how we want to word our final proposals
Self-directed learning	I will research metacognition I still need to look up the concept of "self-directed learning"
Other monitoring	Let's meet on Monday after class to talk about our gallery walk

Figure 2-7: Other coding categories for dialogue (adapted from Hmelo-Silver et al., 2008, pp. 417-8)

Although Hmelo-Silver et al. (2008) use very similar top-level concepts to other studies (eg. Chernobilsky et al., 2005b), the detailed descriptors vary between these studies according to the research design. This modification of tools to fit the research design is a common approach in multimodal research, discussed in more detail in Chapter Three. However, multimodality also needs to encompass the non-verbal element (Iedema, 2003; Jaipal, 2009; Jewitt, 2008) and in particular how the various semiotic modes interact. As discussed in this chapter (and summarised in Table 2-1), the interaction between various semiotic resources can be complementary (i.e. all the resources contribute to the same meaning making), supportive (i.e. different resources produce different aspects of meaning but again the end goal is similar) or contradictory (i.e. different resources are used to modulate and change the notional meaning of the speech).

This kind of interaction leads to the concept of scaffolding as a means by which learning is enabled and supported (Choo, 2012; Hmelo-Silver et al., 2007). At one level, scaffolding represents the way in which the subject itself offers a framework, so, being able to think like a physicist is the key step for students to learn; thus the learning is contextual and the context is supplied by their own appreciation of the wider discipline (Airey & Linder, 2009). Jaipal also looked at the use of context to improve the learning of science (Jaipal, 2009) and the value of ladder learning to understand how wider meaning is constructed by the teacher.

Márquez et al. (2006) also stressed that science is about building understanding and uses a variety of symbolic systems (words, images, graphs, scientific notation), and that teaching is verbal, written and gestural as well as using a variety of teaching aids and information. To explore this they looked at teacher discourse around science teaching and how they used speech, images and gestures to build understanding. The research also looked at whether gesture was redundant (i.e. confirmed the message of speech) or whether there were discrepancies between gesture and speech, especially when new material is to be introduced, so that each communication mode may have a different function (Márquez et al., 2006). Liu (2009), for example, looked at how the symbolic language of chemistry was more than just a transcription or short-hand device and instead was central to allowing a student to build meaning within the subject area.

Liu starts from the concept that meaning is built up by association, so if, for example, an object is described as an ‘animal’ then that in turn gives a particular meaning (culturally derived) and expected set of characteristics. In the case of chemistry, the ability to use symbols both “contributes to the maximal structural condensation while simultaneously allowing semantic extensions for sub-microscopic interpretations not possible with language” (Liu, 2009, p. 134). This brings precision to the teaching, which precludes a range of possible interpretations and wider uses, but in the appropriate domain that precision allows close investigation and description of the phenomena being described. The language of transcription into chemical symbols means that style has both useful mathematical properties, but more importantly, the sequence with the coding carries particular meaning, with the consequences that “chemical symbolism developed specialized grammatical strategies to construe topological meaning and sub-microscopic meaning at abstract levels, which may be transparent for expert chemists to understand, but constitute a serious challenge for novice learners in science education" (Liu, 2009, p. 137). In consequence one key skill in designing a notation system, whether to describe the underlying actions within a semiotic resource or how that resource is used, is to consider clarity to readers.

Overall one consequential danger with multimodal teaching is of information overload (Moreno & Mayer, 2007). This is where scaffolding can make an important contribution as it presents the student with the means to absorb complex information using the context provided by previously acquired knowledge or an existing overall framework. Moreno and Mayer (2007) argue that there are five elements to supporting effective learning as shown in Figure 2-8:

Principle and Description	Theoretical Rationale
Guided activity	
Students learn better when allowed to interact with a pedagogical agent who helps guide their cognitive processing	Guided activity encourages essential and generative processing by prompting students to engage in the selection, organization, and integration of new information
Reflection	
Students learn better when asked to reflect upon correct answers during the process of meaning making	Reflection promotes essential and generative processing by encouraging more active organization and integration of new information
Feedback	
Students learn better with explanatory rather than corrective feedback alone	Explanatory feedback reduces extraneous processing by providing students with proper schemas to repair their misconceptions
Pacing	
Students learn better when allowed to control the pace of presentation of the instructional materials	Pace control reduces representational holding by allowing students to process smaller chunks of information in working memory
Pretraining	
Students learn better when they receive focused pretraining that provides or activates relevant prior knowledge	Pretraining helps guide the learner's generative processing by showing which aspects of prior knowledge to integrate with incoming information

Figure 2-8: Principles behind effective learning (Moreno & Mayer, 2007, p. 316)

Overall the discussion in this section provides a context for a model of student learning and for the descriptive system set out in Chapter Three. The first part is the context provided (Mutton et al., 2010). This can come from specific prior knowledge, from understanding of the learning task and that provided by the wider academic subject (Hmelo-Silver et al., 2007). The second part is the construction of additional knowledge within this framework. Here the key element is scaffolding (Hmelo-Silver et al., 2007) where learners take this prior knowledge and new information and understanding as they learn new concepts. The various figures above are used in Chapter Three to create a coding structure to analyse the video recordings while Chapter Six relates the findings from the empirical research to the concepts developed here.

Chapter Three
Research Methodology

3.1 Introduction

Chapter Two has reviewed the literature in three specific fields that have a bearing on the nature of PBL, multimodality, particularly in a tertiary educational setting, and activity theory. Chapter Two concluded with the development of a model of student learning that stresses the importance of scaffolding (directly by a tutor or indirectly in terms of the context of a given academic discipline) in meaning making by the students. This chapter now discusses both the philosophical and practical issues that arose in terms of constructing a research design that would address the goals set out in Chapter One. For convenience, these are restated here:

1) Understand the role of context in the PBL task, specifically, how far can the actions of both the students and the tutor be understood in terms of external constraints rather than their own preferred problem-solving / meaning-making approach;
2) Understand the role of the students in the meaning-making process, specifically, do they use different semiotic resources as the task evolves and their understanding shifts?;
3) Understand the role of the tutor/facilitator in the meaning-making process, specifically, does their use of semiotic resources vary as the task evolves and, if so, how does this affect their interaction with the students and use of scaffolding?; and
4) Evaluate the overall performance of the student group in terms of task performance and the students' construction of meaning.

There were several fundamental consequences of this focus. The first stage of the data process was the actual data collection which had to been done in the context of a real PBL class and in such a way as to minimise any disruption and intrusion into the classroom setting. On the other hand, the type of data required to sustain a multimodal analysis needed to be collected. This led to the use of video-recording as the primary data collection tool as the resulting videos would provide a data source that can be viewed repeatedly as new research questions were developed. Even once this option was adopted, it became clear that there were secondary issues, especially in terms of the challenge of capturing all the incidents and subtleties of student interaction with only a single camera.

The second stage was to transcribe this data. This was two-fold challenge as there is a need to find a technical solution to adapting the video recording to a format that can be easily viewed and to convert the video recordings to still images for inclusion in this analysis. There was also a need to create a paper-based resource that brought together the images, non-verbal interaction and verbal statements of the students involved in the PBL group and of their tutor. This is discussed in Section 3.3.

The final stage was the analysis of the data. This was done twice, once from the perspective of activity theory (see Section 3.4 and Chapter Four) and once from the perspective of multimodality (see Section 3.4 and Chapter Five). In addition, the activity theory analysis both contributed to the overall analysis of students' problem solving (Jewitt, 2008) and enabled the identification of the shorter blocks used for the detailed multimodal study.

Data coding and analysis becomes very important in consequence and Hmelo-Hmelo-Silver (2003) and Hmelo-Silver et al. (2008) stress the importance of detailed data recording being broken down into very specific categories and the ability to present this both in terms of frequency across a session and of temporal development within a class. Overall, such methods are often mixed together, developed and combined to fit the precise research goal rather than applied as formal theoretical constructs (Mercer, Littleton, & Wegerif, 2009). In particular, Kumpulainen & Wray (2002) argue that there is a need for a range of coding approaches that are combined in the final analysis.

All of these steps are related. The use of video-recording in the classroom environment has become a common tool (see Section 3.2) primarily due to its flexibility, the capacity to capture a lot of information (that in turn can be viewed on several occasions) and its relative lack of intrusion into the classroom setting. It also captures the interaction of speech, gesture and tools that sits at the core of any multimodal research (Chapter Two). The basic transcription was designed to create a similar raw resource that was amenable to multiple analysis and review.

Once the raw data was transcribed, the next step was to impose categories so as to ease analysis. This drew heavily on the material set out in Section 2.6 and is discussed in more detail in Section 3.4. This was done twice; the first time categorising the raw material into the framework of activity theory analysis (see Section 2.3) and the second time using an adaption of Hmelo-Silver's categorisations (Hmelo-Silver et al., 2008; Hmelo-Silver et al., 2007). Both the multimodal and activity theory analyses combine speech, descriptions of gestures and resources and contribute to the exploration of the four research questions.

Silverman (2010) argues that in the methodology chapter the qualitative researcher has to demonstrate the rationale behind selecting the data and the method(s) adopted for analysing this data. In this case, the approach is interpretivist and it is acknowledged that students' meaning making can only be understood in the appropriate context. As discussed in Section 1.1 this has led to the use of two main theoretical concepts, activity theory and multimodal analysis. The logic is that activity theory provides an overview of students' meaning making across the PBL session and multimodal analysis allows a deeper investigation of key stages. More generally, the research tools used to study student interaction and meaning making in collaborative activity are largely derived from the purpose of the particular study (Kumpulainen & Wray, 2002; Mercer et al., 2009) rather than being the application of a widely agreed research approach.

3.1.1 Research epistemology

Although the focus in this chapter is on the practical issues that influenced the research design it is essential to situate this discussion within a broader discussion of research epistemology. Briggs and Coleman (2007) and Silverman (2010) suggest that the methodology chapter should include the theoretical framework of the research so as to articulate the theoretical perspective of any academic study It is also argued that the philosophical assumptions of the research (Briggs & Coleman,2007) and the theory of interpretation adopted (Coghlan & Brannick, 2010) are important as they frame how the researcher will deal with the questions of interpreting the data and generalising (i.e. theory building) from those interpretations (Yin, 2009).

Very broadly, there are two epistemological orientations (Loonam & McDonagh, 2009), split between a positivist and an interpretivist orientation. Loonman and McDonagh (2009) argue that the positivist epistemology is based on the idea that any social realm can be examined separately from those who participate in it. In some empirical research approaches this leads to the idea of an 'approximate truth' (Psillos,

1999) that is slowly revealed by repeated experimentation, and at whose core is the idea that reality is abstract, that it can be captured and measured independently of the beliefs and actions of both those being observed and of the observer (Howe, 2003). In part due to this dissociation of observation and action, it is possible to generalise from a research study as long as the research design meets certain requirements, eg. if there are no unexpected influences on observations in an experimental setting, and thus on the outcomes, the observed results can be generalised to create a theory (Yin, 2009).

In contrast, the interpretivist orientation takes into consideration the role of the participants and observers of any social world in creating that world (Loonam & McDonagh, 2009). Interpretivism is a subjective paradigm that accepts both what is observed and how it is subsequently described, both of which are functions of the social norms that are prevalent at a given time. However, this still leaves open the debate between modernist and post-modernist models of science, both of which fit within the interpretivist tradition (Bem & Looren de Jong, 2006). At its most basic, in a modernist tradition the language used to describe something is subjective and culturally determined but the object being described does, in theory, hold a reality outside the descriptive process. To a post-modernist approach, the key difference is to assert that both the subject (what is being described) and the object (how it is being described) are socially constructed (Bem & Looren de Jong, 2006).

One key consequence of the interpretivist model is the process of generalising (i.e. theory building). Since it is acknowledged that each set of observation is influenced by both the situation and the act of observation then it cannot be readily assumed that it is representative of other situations. To address this problem Yin (2009) suggests adopting the concept of pattern matching. This involves using the existing literature as a framework to which the observed data can be compared. Where the findings match this framework they can be seen as reflecting a general trend. Where there is a difference, the important step is to understand the reasons for the variance. If this is due to the structure of the particular method of observation, then it is not possible to generalise; however, the variance in results may indicate that in a given situation the existing assumptions no longer hold.

One further practical manifestation of this debate is the relative merits of quantitative and qualitative tools. It should be noted that quantitative data can be usefully gathered within an otherwise interpretivist research design (Bem & Looren de Jong, 2006); what matters is not how the data is collected or presented but how it is interpreted (Yin, 2009). Quantitative data become another strand of information used to build an interpretivist analysis of the data.

3.1.2 Quantitative and qualitative approaches to data analysis

Mercer et al. (2009) develop this linkage between quantitative and qualitative approaches, noting that both can be effective in educational settings. One commonly used quantitative tool is *systematic observation*. The goal is to create a typology of categories of interaction, such as speech, gesture, interruption and so on, and then count the number of instances produced by a given member of a group (such as how often they spoke). The categories can be derived either from the researcher's own goals or by using existing categorisation systems (Mercer, 2010). The standard approach is for a transcript to be coded by at least two researchers to ensure a degree of reliability about the allocation of instances to particular categories (Underwood & Underwood, 1999). With the data organised in this way, it is then feasible to use a range of statistical techniques for correlation or regression analysis, in particular when trying to link a type of interactive behaviour to measures of effective learning (Mercer et al., 2009).

The advantages of this approach are relative speed of analysis (especially as there is no need to transcribe the material) and that the relative clarity of a classification scheme allows for comparison across classroom instances (Mercer et al., 2009). The problem, however, also lies in the latter's rigidity. Often comments are ambiguous or serve several roles and the categories themselves can heavily influence the findings, especially if relatively broad categories such as speech, gesture, interruption, etc. are used. Fundamentally this approach runs the risk of failing to "capture the extent to which talk is mobilised towards a particular goal or the creation of shared knowledge. Used in isolation, it would effectively reduce collaborations to a-temporal 'inventories of utterances'" (Mercer et al., 2009, p. 30). Such coding systems may be effective at capturing the level of shared interaction (i.e. is the session dominated by one student or two?) but misses the key question of just how long individuals spoke for or to what purpose.

In consequence the dominant recording and analysis style is based on a variety of qualitative methodologies (Kumpulainen & Wray, 2002), each with particular strengths and weaknesses. It should be noted that for the most part these approaches focus on speech (Kumpulainen & Wray, 2002) and, to a lesser extent, group interaction, but broadly these falls into the following approaches:

- Ethnography;
- Sociolinguistic analysis;
- Linguistic discourse analysis; and
- Conversation analysis/discursive psychology.

These approaches are each briefly reviewed and then attention is given to approaches that combine these different methods, or embed elements of quantitative research into an otherwise qualitative enquiry (Scholz & Tietje, 2002).

Ethnography has been used in educational research since the 1960s (Mercer et al., 2009), with the goal of capturing the entirety of a social interaction. Usually reliant on verbatim recording and transcription, ethnography tends to rely on essentially descriptive writing. The concepts used in ethnography underlie much of more modern research approaches, but for the most part, those have moved beyond the processes and concepts of ethnography as such. *Sociolinguistic analysis* is another field that underpins more contemporary approaches (Kumpulainen & Wray, 2002), adding an explicit focus on language to the wider interest in ethnography on the social processes at play in classroom interaction. The research can be carried out using either quantitative approaches (such as counting instances of speech by gender) or qualitative approaches (with a focus on the use of words and grammatical constructs in the collaborative process). However, though useful, both approaches in their own right have rather fallen out of use (Mercer et al., 2009), having mostly been replaced by approaches grouped broadly under the concept of linguistic discourse analysis (Kumpulainen & Wray, 2002).

However, *discourse analysis* has no clearly defined meaning (Mercer, 2010; Mercer et al., 2009) and in an educational setting has become “focused on the structural organization of classroom talk” (Mercer et al., 2009, p. 32). In this approach, a major categorisation system was developed whose focus was on who was doing the communicating (usually stressing the verbal element) and the interaction between teacher-pupil or among pupils. This focus on speech within discourse analysis has, in turn, led to the increased adoption of *socio-cultural discourse analysis* (Kumpulainen & Wray, 2002), drawing heavily on the theoretical concepts of Vygotsky's model of developmental psychology (Mercer et al., 2009). This shows much less interest in the organisation of discourse and returns to the original focus of ethnography in looking at the social processes at play, both in setting the bounds of meaning making and in the meaning-making interaction itself. Kumpulainen and Wray (2002b) suggest that a suitable framework for recording the interaction in the classroom is then provided by three aspects: cognitive processing, social processing and language use (with the latter encompassing non-verbal communication if appropriate). This has led to an emphasis on research designs that take multimodality into account.

In practice, almost all these approaches can be used to devise a research focus and it is relatively common to find both quantitative and qualitative approaches mixed together (Mercer et al., 2009). Thus a tabular format may be devised that shows the number of instances of forms of interaction and how this varies between individuals and according to the purpose of the interaction. This contextual information may then be supplemented by more qualitative analysis of blocks of speech (or non-verbal communication) to exemplify the process and to place it in context.

A practical example of this mixing of research concepts is the common view that learning in the science classroom relies on the process of 'thematic contextualisation' (Mäkitalo, Jakobsson, & Säljö, 2009). What this stresses is the need to capture information both in context and in sequence as it is these two elements that offer a real insight into the nature of collaborative discourse. The gaps in interactions are also important and need to be recorded as, "observing gaps in interaction is a productive way to pinpoint the demands on students and the difficulties they run into as they learn how to reason and argue in a complex school setting" (Mäkitalo et al., 2009, p. 22). Other practical examples such as that by Arvaja et al. (2007) stress the need to see interaction as both a group process and one of personal learning. To do this meant first using qualitative content analysis to explore what each message was designed to convey in terms of knowledge or information. Then these messages were analysed for their communicative functions which were "were shaped by the socio-cultural context of the activity" (Arvaja et al., 2007, p. 450). Finally the contextual resources that were used in the meaning making were analysed and compared to both the nature of the messages and their function.

Kumpulainen and Wray (2002) argue for a three-dimensional approach that addresses many of the issues raised above:

- Functional analysis – focus on speech and social interaction;
- Cognitive processing – focus on the learning strategies adopted and the problem-solving processes used; and
- Social processing – focus on the social relationships within the group.

Functional analysis looks at how verbal language is used both to transmit meaning and to impose a structure within a group (such as by interruption or by supporting another speaker). This approach can capture the difference between the notional meaning of words or a phrase and "what the speaker can imply, suggest or mean" (Kumpulainen & Wray, 2002, p. 36). In this sense, speech is the core part of the analysis, but is not sufficient by itself to capture the range of social interaction that can be allocated to categories such as reasoning, discussion, argument and so on (Kumpulainen & Wray, 2002).

Cognitive processing brings in the dimension of information processing and knowledge construction and can be allocated to one of three analytic modes (Kumpulainen & Wray, 2002): procedural processing rules, interpretation or exploratory processing and task activity. The final element of their proposed three-dimensional approach, *social processing*, seeks to capture the social relationships within the group, with attention paid to instances of collaboration, domination and confusion. The latter in particular may reflect instances where some or all of the group are unclear about the task at hand or the meaning of a particular result.

This tripartite approach was used in this thesis as it allows a balance to be struck across all the features of multimodal meaning making. Functional analysis is embodied mainly in the multimodal analysis (Chapter 5) which allows a close study of verbal and non-verbal meaning making. Cognitive processing is also studied mainly via the multimodal analysis, but the wider issues of how the task is understood and the social constraints on meaning making and activity are themes developed using activity theory (Chapter 4). In turn, group information processing is studied using both activity theory and multimodality as analytic techniques as both allow different methods to be adopted to understand how the student group co-operated.

3.1.3 Research design of current study

The research design adopted in the current study has been strongly influenced by and is largely based on Jewitt's approach (Jewitt, 2006). In the first,exposition of her approach "Technology, Literacy and learning: a multimodal approach" Jewitt, (2006) addresses the issue discussed in Chapter Two that the concept of resemiotics is present in multimodal theory, but underdeveloped. Here the suggested solution is to use activity theory as:

> Multimodality allows me to focus on all the different resources that are displayed … as part of classroom interaction. Activity Theory offers a useful framework for situating people's semiotic choices and use of technologies with the context of a curriculum subject and the classroom. I bring these two ways of thinking together to help 'locate' people's use of representational and communicative modes in the complex social interaction of the classroom. (Jewitt, 2006, p. 4)

Of importance is her conclusion that, "social semiotics and multimodality offer conceptual tools for the analysis of meaning making. This leaves out the socially situated character of meaning making" (Jewitt, 2006, p. 16). Not all multimodal researchers would agree with this characterisation (O'Halloran & Smith, 2011), but it does match the conclusion of the review of research studies, set out in Table 2-1, that resemiotics are rarely effectively handled in a multimodal study. Jewitt's basic approach has been applied in this research.

In the current study, activity theory is used (Chapter Four) to situate the overall process of student learning across the PBL session, and in turn to place this PBL class in context. In contrast, a multimodality perspective is used for an in-depth exploration of students' meaning making and use of the various resources available. It also allows for an exploration of how the process of meaning making varies as the focus shifts across the entire learning experience. However, as is discussed below, there is a specific problem with rendering multimodal research into a conventional paper form (O'Halloran, 2011a, 2011b). It is complex, and the analysis, almost by definition, is time-consuming. Thus, there is a constraint of only being able to handle relatively short blocks of time, unless the analysis is concentrated essentially on the quantitative level. In the current study, the solution is to use activity theory to both overview the entirety of the class and to identify a number of short sections that are then discussed in detail in multimodal terms. The process of selection is returned to in detail at the start of Chapter Five.

3.2 Data collection

3.2.1 Data collection methods in other studies

For various reasons either participant observation or action research have become the primary methods for data collection in the classroom (Edwards-Groves, 2011). The two main data collection tools are classroom observation (usually combined with video or aural recording) and post-event interviewing of teachers and students. For example, a study of the teacher's use of technology in science classes (Gillen, Littleton, Twiner, Staarman, & Mercer, 2008) used both observation and post-event interview of the teachers and students. Similarly Maher (2011) looked at the use of interactive whiteboards using a combination of semi-structured interviews with teachers and questionnaires administered to students, with some teaching sessions video-recorded. A similar design by Jaipal (2009) saw the research conducted using classroom observation, semi-structured interviews and informal interviews. The classroom sessions were audio-recorded and some lessons video-recorded (Jaipal, 2009).

Airey and Linder in a study of the teaching of physics in Swedish schools (Airey & Linder, 2009) first filmed the lectures and then interviewed students a few days after the lecture, using a semi-structured interview protocol. Students were shown extracts from the lectures at the interview, with the goal "to re-create as closely as possible the original learning situation, thus allowing students to better describe and reflect on their learning experiences in the specific situations that they were shown" (Airey & Linder, 2009, p. 35). For analysis purposes, the interviews were broken up into sections where the students discussed similar themes and these themes were grouped together for analysis. They argue that the key advantages of this combination are as follows:

> At the same time we would argue that this approach had the benefit of better capturing the situatedness of the interview when we were working with the transcriptions. Maintaining this situatedness was considered important since in the interviews we were attempting, through stimulated recall, to vividly recapture for the students the essentials of their experience of being in a specific lecture. Student

> files could also be easily re-related to the whole of the interview due to the timestamp identification code we used which led us directly to the correct position in each master recording. (p. 35)

When the research is more focussed on multimodality there is a greater reliance on video-recording. Thus Márquez et al. (2006) focussed on the communication modes of the teacher and how this may be related to presenting different information. The sessions were video-recorded and transcribed to capture the interactions and the use of four distinctive communication modes, "speech, meaningful gestures, drawings or symbols, and written text on the blackboard" (Márquez et al., 2006, p. 207). The reliance on video-recording was repeated in a study of how teachers combined images and text in their teaching (Poyas & Eilam, 2011).

Overall, video-recording has become the dominant tool to capture the raw material needed for multimodal data analysis (O'Halloran, 2011a, 2011b). The video camera (camcorder), is a valuable data collection tool for multimodal research on learning because of its ability to capture all the communicative and interactional modes co-occurring in learning contexts such as postural, gestural, spoken modes and so forth (Jewitt, 2006). Norris (2004a) emphasises that the video camera is at present the best instrument for collecting data to research the multimodal nature of communication. Furthermore, video cameras provide researchers with the ability to view the data many times (Jewitt, 2006).

However, the use of video recording is not without problems. One is the risk of becoming part of the discussion or interfering with the normal interaction in the student group. The wider issue is that of the o*bserver's paradox* (Labov, 1972). This concept refers to the notion that the researcher should take into account how his/her presence and/or the artefacts he/she is using as data collection tools (such as a video camera, audio recorder and so on) in the social context being studied could affect the phenomenon under investigation and the people engaging in that phenomenon. In consequence students might either withdraw (shyness, a fear of being seen to be less competent) or engage more actively (a desire to be seen as an important part of the group processes) and the researcher needs to account for both (Gordon, 2012).

A related issue is that of student (and tutor) control of the recording process. This involves issues of ethics and participant consent (Miller & Wertheimer, 2009). In this case what matters is reassurance of the participants that the recorded material will only be used for research purposes and that they can withdraw (partially or fully) at any stage (Koshy, 2005).

One particular problem with the use of video-recording is the issue of framing the shot (Dufon, 2002). The advantage of video-recording lies in the richness of the potential data and the capacity to capture a substantial range of evidence (speech, gesture, tool use, social and environmental context) in a single resource. However, this still has its limits. Even in a controlled interview situation there will be events that occur outside the frame of the camera and this is a much larger problem when a group is being filmed in a relatively natural setting (Dufon, 2002). One solution in this respect is to use several cameras, but in turn that either implies those cameras are fixed or that several observers can be used.

The ethnographic community shares the view that to be of value a video recording should be complete and continuous. This has the advantage of enabling a later examination of the entire interaction and preventing self-selection in the gathering of evidence (Asch, 1992). To ensure completeness, researchers are advised to try to use as a wide a view as possible so that events on the edge of the focus can be captured. In a classroom this framing of the shot is often supplied by the physical environment, but this still leaves a problem of focus. These questions involve when to concentrate on the actions of, say, the students and when to provide a detailed focus on the actions of the teacher. There is also a challenge if the goal, as in the case of this research, is to capture the meaning-making actions of the students (which may require a close-up focus) and on the information providing and meaning-making actions of the tutor at the same time. In general, video-recording is an invaluable aid, especially for multimodal research, but it does need some care in its deployment, in particular to ensure that the required information at the appropriate level of detail is captured (Wilkinson & Brady, 1982).

3.2.2 Data collection method in current study

The conceptual issues identified above were dealt with by adopting an overall research stance of participant observation. The technique of participant observation (Dewalt & Dewalt, 2002) is a three-fold method comprising: 1) people agreeing to be observed in their social activity, 2) observing the phenomenon, and 3) recording the situation and its elements (Turner, 2009). Data recording occurred when the researcher was present and used a single video camera as the main tool for collecting data (see Section 3.2.2.1).

3.2.2.1 Using a video camera as data collection tool for researching multimodal learning contexts

The video camera used for this research was not fixed and not set up in one position. It was carried by the researcher who was roaming between the PBL team students as they conducted their task, initially in the sports field. Indeed, there are many different positions the camera can utilize when videotaping research participants, and these positions have been adopted by social science researchers depending on their purposes. For example, the camera or multiple cameras can be fixed and directed to one or, if multiple, more angle/s; the camera can be stationary, the camera can be put on a tripod and controlled by the researcher or somebody else, and the camera can also be carried and the cameraman can walk around the research participants. However, the researcher in this current research was carrying and operating the camera and roaming between the PBL students where they conducted their task trying to focus in on what seemed to be the most important elements of the interactions with sufficient detail to support later transcription and analysis. Shrum, Duque, and Brown (2005) characterise this method of roaming around the research participants with the camera as “guerrilla-style filming” (p. 12). Unless multiple cameras and operators are available, which was not the case for this study, the roaming camera approach is best suited to maximising the quality and value of the data collected by a single operator.

There are two main reasons for adopting a roaming video camera carried by the researcher. Firstly, as stated by Heath, Hindmarsh and Luff (2010), this method of recording is viewed as a synergistic construction between the researcher and the participants being videotaped which gives a deep understanding of how participants talk in their authentic environment and is considered to best capture the distinctive repertoire of the methods the participants follow to conduct their task. The second reason is that the research adopts the multimodal method of transcribing the collected data which itself necessitates the use of a video camera, particularly for the multimodal transcription undertaken for this study using video/photo editing software

(Final Cut Pro operated on Apple computers). Therefore, it is highly required to use a video camera for recording the observed context and the phenomenon under study.

Furthermore, the camera needs to be freely carried by the researcher to capture all the actions and the communicative (meaning-making) resources created by the PBL teams. According to Heath, Hindmarsh, and Luff (2010), using a roaming camera is needed to observe unsettling activities (i.e. activities in which the people are moving a lot and performing a lot of actions). This is exactly what the observed PBL teams were doing. The fixed camera is not able to capture all the actions performed by the PBL students, only focusing on a perspective of one or more static locations of the scenario.

Having provided the rationale above for the approach to single camera filming that was adopted, it is important to acknowledge that effectively there is a real-time selection process being undertaken by the researcher himself about the important aspects of the meaning-making activities to capture on the video record at a specific time. This necessarily means that not all interactions were able to be fully captured from a multimodal perspective, as there was no tangible visual record to accompany some of the recorded spoken text. Given the vast amount of data generated across modes, it could be argued that in the multimodal analytical process, selection of material for detailed analysis is unavoidable. The key discerning feature of the roaming single camera approach is that such selection is taking place in real-time and is directly influenced by the intuition and observation of the researcher about what is most pertinent in making sense of the meaning making process.

3.2.2.2 Early approaches to data collection

In this study, the research participants were undergraduate engineering students at Victoria University in Melbourne, Australia, taking a syllabus that made regular use of PBL. The goal was to adopt a neutral participant observation where the researcher's role is solely to observe and record the different ways in which the PBL students interact with each other using the various meaning-making resources available to them or created by them in the context of a PBL task. Although the students had given their consent to be video-recorded, the researcher needs to be prudent in keeping the identity of the participants anonymous and to give the participants non-identifying names when conducting multimodal transcriptions or use numbers to indicate them and not share their identity with others. In addition, student participants were reminded that they could withdraw at any time, leave at any time and that any data involving the individual who did not wish to participate further will be discarded from the study. Student participants were also informed and reminded that the researcher was not a teacher, and would not direct, instruct or help them with their work.

However, the research reported in Chapters Four and Five was not the first set of observations by the researcher. Two earlier PBL sessions were video-recorded and then discarded as not providing a suitable basis for this type of study.

The initial phase of data collection took place in 2009 in the first semester of the first year of an undergraduate PBL class. Initially it was hoped that this round of data collection would be used in the main study, but in reality this preliminary stage of data collection became an opportunity to test the planned approach to data capture and transcription and to lay a basis for future recording and analysis. The aims of the pilot were:

1) To apply and assess the planned approach to video-recording and observing PBL learning in action;
2) To transcribe the data into a format suitable for multimodal analysis, including the use of image capture and video editing software; and
3) To undertake a preliminary analysis of the data to determine its capacity to enable the planned research questions to be answered.

Following ethical approval, it was agreed that recording would focus on two teams of PBL students enrolled in a unit titled “Problem Solving for Engineers”. This was the students’ first experience of PBL and each task was short-term and relatively well defined with the aim of introducing the learning methodology and assisting the students to become familiar with it. The first PBL team consisted of five students, four male and one female. The second PBL team consisted of four students, all being male.

Figure 3-1: First student group

Figure 3-2: Second student group

The PBL teams were from two different classes, but with the same facilitator tutoring them. The choice to capture different groups with the same facilitator was made because it would enable a potentially valuable comparison of differences in group approach to problem-solving, whilst also having continuity in the facilitator's pedagogical and communicative strategies.

The PBL problem the students were set was to work out how to determine the height of a sports oval light tower using a theodolite and trigonometry and to introduce them to the concepts of engineering surveying. Furthermore, engineering students will learn through conducting this problem-based activity some geometric and trigonometric laws and rules which facilitate the calculations to be conducted. The facilitator's role was to instruct the students in how to use the theodolite in a technically competent way, and then apply the measurements that they derived to calculate the height of a sports field oval light tower. This is why the students conducted their PBL task outside of the classroom in a park adjacent to the campus. The engineering PBL student teams used different resources to conduct their task. Some of these resources were defined by the task such as surveying tools including digital theodolite, tripod, box tape, hammer, pegs and nails. Some resources were used by the students to record their measurements and therefore to achieve their task such as notebooks, calculators and pens.

The purpose of this stage of data collection was to develop a method for multimodal data transcription. Of particular value was the need to consider how to code and interpret the use of resources and how the PBL team interacted with the different surveying instruments (such as the theodolite) to make meaning and hence solve the problem, which is finding the correct answer of a sports oval light tower's height. However, the data obtained was not sufficient to be the main source of the research data. This is because the problem was relatively easy and, in consequence, there was very limited development of meaning making by the students as the nature of the task meant this was mainly the application of technical skills.

The second phase of data collection also took place in 2009 in the second semester of the first year of an undergraduate PBL class. This iteration in the research design was specifically designed to address some problems in the initial phase. In particular the focus was on a PBL class dealing with a deeper and more complex problem. Specifically, the goals were:

1) To obtain sufficient data to be used as main data source for the research; and
2) To avoid the technical difficulties faced by the researcher in the initial phase, such as voice quality, how to follow the students and to focus the camera.

One team consisted of five students (two were female), selected with the help of the researcher's then associate supervisor who arranged the students' consent to being video-recorded for the research purpose. This group was expected to yield richer data as:

1) The students were more active and more engaged in the previous PBL problem/task compared to other PBL team in the class; and
2) They also were more independent in learning than other PBL teams.

In this case the recording was easier as the PBL team met in the classroom and laboratory to work on the problem. For this module, the students were presented with the more substantive task of designing a building to grow crops, taking account of heating, water supply and temperature regulation.

Figure 3-3: Second phase: Student group in laboratory

However, although this phase was designed to compensate for the initial difficulties it was not completed because some new problems and difficulties arose:

1) The facilitator was not helpful in allowing access to the necessary teaching materials about the requirements of the PBL task. This removed valuable contextual knowledge that lessened understanding of the PBL team's interaction and interpretation of the main semiotic resources utilised by the students;
2) In the laboratory, the PBL team tended not to work as a close group and instead the students spread themselves out. Therefore, it was difficult to record them all at the same time, using one camera. The students themselves indicated they were uncomfortable with being recorded despite having given their consent. As a consequence recording was sequential, with the video recording showing one sub-group and then another which meant valuable information was missing and there was less evidence of all-group problem solving; and

3) In addition students from other PBL teams interacted with the main group and since they had not given their consent to being recorded, it was not possible to use these excerpts.

Because of these difficulties, the stage of data collection was cancelled after one month of observation. However, this stage was valuable in refining the data collection approach and these lessons were applied to the final stage (which is the material reported in Chapters Three and Four).

3.2.2.3 Data Collection in the full study

Having completed two experimental phases, the actual data collection method drew on the lessons learnt. Full agreement was sought from the students and, in particular, it was ensured that the students were fully content to be recorded. Their interaction was limited to a single room and the other student PBL teams had little interaction, removing the problem of having to concentrate on only part of the group or to deal with the intervention of other students. Initially two PBL teams were recorded working on the same long PBL problem/task from different classes and with two different facilitators. One team was recorded for three weeks but then their attendance dropped and the group fragmented. After this, the data collection concentrated on just one group (Kevin's team) and they were observed and recorded and used as the main data source for this study.

For the students this was their second semester at university and their second experience of PBL as a learning environment. Their task was to build a model bridge using supplied materials (paddle-pop sticks and glue) that would meet a preset stress test. The group consisted of five students, plus the inputs (structured and ad-hoc) of a tutor. Five sessions were video-recorded, subsequently referred to as Kevin Team 1, 2, 3, 4 and 5, of varying lengths. In theory each class should have been of the same length (i.e. an hour) but after the first class the facilitator left the room after a varying period of time. The students should then have carried on with self-directed learning but in practice they tended to leave the classroom shortly after the facilitator left.

This class was chosen for various reasons. Among these were the pragmatic reason that both the facilitator and the student group were willing to be video-taped.

However, unlike the first instance reported in 3.2.2.2, this particular class involved a substantive problem (build a model bridge) and thus offered the scope for more complex problem solving than had been the case with the theodolite PBL. The design task involved a combination of theoretical knowledge with a practical objective so allowed consideration of how meaning making might alter as the task progressed. Equally, the learning was substantive enough to mean that the facilitator would have to take an active role, either using scaffolding or with the direct input of key information. In addition, as discussed in the introduction, engineering design fits with the researcher's interests in problem solving in science and engineering as it is based directly on resolving an ill-structured, but bounded, problem. Finally, the students had already had experience of one PBL class (in their first semester), so it was expected that they understood the implications and would know they were expected to adopt an active learning style.

Table 3-1: Outline of PBL sessions*

Date	Duration (mins)	Focus	Participants (No.)	Reference	Appendix
16/09/2010	64	Student work on theoretical basis	5	Kevin Team 1	1
23/09/2010	45	Student work on background information for task	5	Kevin Team 2	2
07/10/2010	33	Preparation work, presentation of information on past designs by tutor	5	Kevin Team 3	3
11/10/2010	42	Discussion of how to build model bridge	2	Kevin Team 4	4
21/10/2010	35	Presentation of initial design	5	Kevin Team 5	5

*All sessions were recorded in the same classroom.

The class studied was designed to introduce concepts from mathematics and physics in a practical context using low cost materials that are easy to use. Specifically, the students were studying solid mechanics and the lecturer's philosophy for the approach is that students 'experience and practice' the approach of designing practical solutions for real problems. The design philosophy is summarised by the lecturer as:

"experiences can motivate an individual to go on and succeed when things get difficult. It is the author's aim through model making (and breaking) to create experiences that will deliver this sort of benefit to students as early as possible, and motivate them to finally succeed in their chosen Engineering degree"

To achieve this, the students were provided with 'paddle pop' sticks each of which was 100mm by 10mm by 2mm, originally designed as part of an iced confection. The students were given the criteria as (all information extracted from the class handbook):

"Objective:
To design, draw, construct and test a model truss bridge to achieve a maximum structural 'efficiency' over a 500mm span supporting a single central load within the specifications, rules and regulations as provided. A 'professional' report must accompany the model. ….
Specifications and testing:
1. Model bridges are to be of the under-slung truss type. Any shape/member configuration may be used provided the resultant model fits within the stated dimensional parameters.
2. Testing of models under a central load is in two parts whereby models that pass a
simple load test of supporting a freely suspended 30kgm mass at mid-span go into the
pool of 'proofed models' for final.
3. Final testing utilizes a calibrated Instron TM testing machine via a loading 'head'
which is capable of limited rotation in the plane perpendicular to the model.
4. The load carried by each model at 'collapse' will be recorded and divided by the mass of the model to achieve a strength to weight efficiency ratio.
5. Collapse is defined when either the model cannot support any further increase in load or the deflection at the load point exceeds 30mm.

Material limitations:

- 275 standard, untreated, pine 'paddle pop' sticks as provided and a 250ml bottle of PVA adhesive as provided. No other materials may be used.
- No treatment may be applied to the sticks (Sanding may improve adhesive bond.)
- Sticks may be cut/glued in any shape/way to form the truss members and connections.
- The models must span a clear distance of 500mm with approximately 20 to 25mm end support length. This means the total length of a model must be between 540 to 550mm exactly with a clear span portion of 500mm.

- No part of a model may project up above the level of the support frame by 20mm nor down below the level of the testing frame top by more than 110mm.
- The width of a model must not exceed 110mm at any point.
- Contact between the model and the testing frame to be only at the support tops.”

The final assessment was to test the resulting model to the point where the bridge buckled or broke with this being seen as an important way in which the students could learn about the strengths and weaknesses of a variety of model configurations and design strategies.

3.3 Data transcription

3.3.1 Transcription processes in previous studies

3.3.1.1 General issues

The process of recording and transcribing multimodal research is complex, not least as there is a need to both find a means to represent the various semiotic modes being studied and the process of intersemiosis (their interaction) and of resemiosis (the wider context). In the main the first problem is often addressed by using transcripts of speech, perhaps with notes as to the pauses (Edwards-Groves, 2011). However, the process of intersemiosis (and resemiosis where it is being studied) is usually represented in a tabular form that shows how the different semiotic aspects combine over time (Jaipal, 2009; Márquez et al., 2006). However, this is a complex process, especially as the richness of a range of semiotic interactions needs to be captured on paper rather than in a more dynamic form (O’Halloran, 2011a). Due to the problems of transcription and the limitations of representation on paper, there are concerns that existing methods fail to give a full account of the richness of multimodality (O’Halloran, 2011a).

The approach to representing the individual modes varies largely according to the focus of the research. The most common approach is the reporting in terms of text, but some studies (Lirola, 2006; Xiong & Quek, 2006) rely heavily on pictorial representations (either stills from visual recordings or fixed images) to capture the semiotic resources in use. The standard tool to report multimodality and intersemiosis is a summary table that shows how, in a given time period, different modes are used to build up and create meaning (Jaipal, 2009; Márquez et al., 2006).

3.3.1.2 Recording individual semiotic modes

The simplest part of any multimodal analysis is the representation of individual modes. This can encompass speech, non-verbal communication and an indication of the resources being accessed. In this sense, representing speech is probably the easiest as all that is really needed is to transcribe the spoken words as shown in Figure 3-4.

Mikey:	And so because Mr C changed this way of doing research and writing and stuff it is better for us, I reckon I learnt more, I loved doing it, it was so interesting, we have more say in some of the stuff.
Researcher:	What do you mean by that?
Mikey:	Well, you know, it was different than most other times, um we got to choose what bit we would like to do for the project and then from the beginning got to plan out how we would write the video with other kids in our group. We all got to have a say in the first bit of the plan and even how the video would be made.
Lucas:	I liked that we, I felt important when the others liked my ideas for putting the things together on the show . . . think about the end at the beginning was like using our imagination and that.

Figure 3-4: Example of transcription (Edwards-Groves, 2011, p. 58)

However, the process of capturing non-verbal modes and gestures is more complex and a number of approaches have been developed. These range from a focus on transcription techniques (Kumpulainen & Wray, 2002; Norris, 2004a) to consideration of how to group and report a range of semiotic interactions (Jaipal, 2009; Kress & van Leeuwen, 2001; Márquez et al., 2006). This implies that there may be two distinct stages (coding of individual items and coding their interaction) but in practice the two often interact as the second stage is both derived from the basic transcription but will also influence what is seen as important to be captured in the basic transcription process (Norris, 2004a).

A common approach is to transcribe the different semiotic resources, broken down into small elements such as gesture, posture, materials (artefacts), visual and audio (Lemke, 2002). Following Lemke (2002), Jaipal argues that "constructing and communicating meanings in science requires close and constant integration and cross-textualization among semiotic modalities" (Jaipal, 2009, p. 51). Jaipal (2009) addressed this by transcribing each non-verbal gesture both in terms of its use as well as providing a verbal description of its structure. Other studies adopt a much more visual approach to transcribing and describing non-verbal gestures, for example in showing the height of hand movement as well as the range of motion (Xiong & Quek, 2006).

Norris (2004a) suggests that the key element to coding non-verbal semiotic resources is to transcribe them as text using a structured notation to indicate both the type of semiotic resource in use and their interaction. Figure 3-5 is from a German language class and the spoken German (shown in *italics*) has been translated into English for convenience (in [square brackets], with a description of what was seen in the video recording (in (parentheses)) and blocks where actions and word overlap indicated by the notation '['.

(4)	*Jim:*	mountain. (looking at T's pointing finger)	
(5)	*Joe:*	ground. (looking at T's pointing finger)	
(6)	*T:*	*nein passt mal auf,*	[no look here,]
(7)		*hier das ist die Mauer ja,*	[here that's the wall right,] (pointing at the wall in the picture)
(8)	*Bob:*	a guy (almost inaudible)	
(9)	*Jim:*	[(postural shift)	
(10)	*Joe:*	[(gaze shift to Bob, then to Bob's handout)	
(11)	*T:*	[*hört mal zu,*	[listen,]
(12)	*Jon:*	[(postural shift and gaze shift to Bob)	
(13)	*T:*	*das ist die Mauer* [that's the wall]	
(14)	*Jim:*	(gaze shift to Bob, then to Bob's handout)	

Figure 3-5: Transcription conventions for semiotic resources (adapted from Norris, 2004, p. 59)

The first stage is often to transcribe the complexity of a video recording and Norris argues that it is easiest to commence by transcribing the spoken elements first (using an agreed coding scheme), in part to derive a structure and in part due to the likely importance of the spoken element in creating meaning. However, some studies mix showing the outcomes as a collection of text (to report spoken elements) and visual images (to display non-verbal elements), if needed supported by further text-based explanations (O'Halloran, 2011b) or by showing stills from a video recording that captures changing gestures, body postures and facial expressions (O'Halloran, 2011b).

Finally the process of representing the resources being accessed or created needs to be addressed. A number of studies opt for the use of visual images to show a given resource such as shown in Figure 3-6.

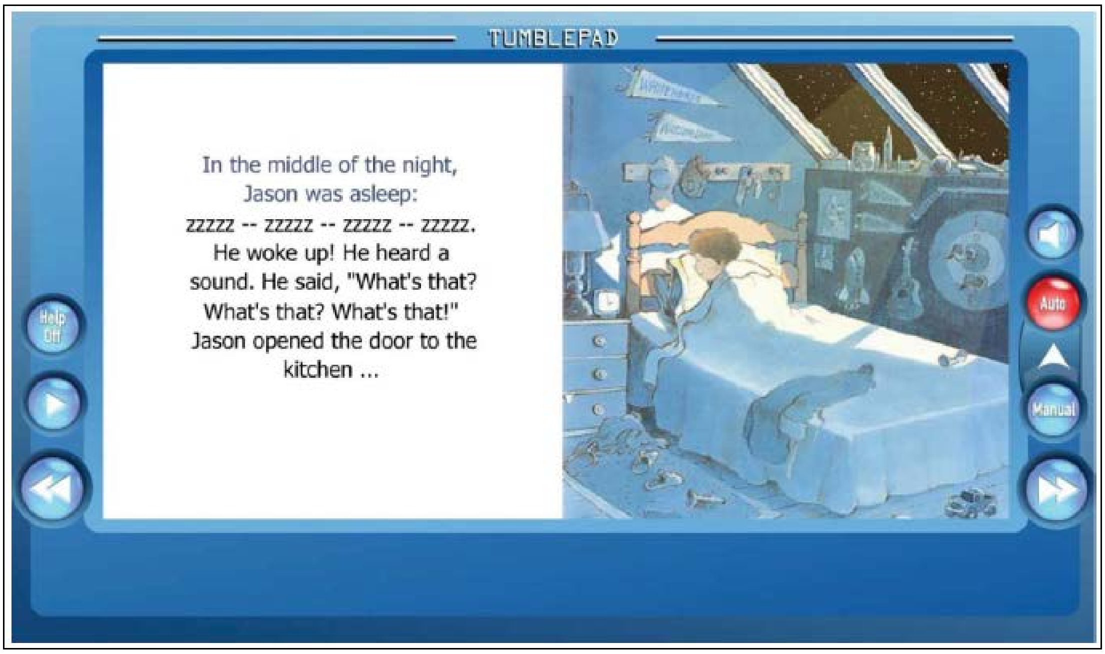


Figure 3-6: Screen shot of image from "50 Below Zero" (Maher, 2011, p. 241)

In this case, the study then showed the dialogue of the students as they engaged with this image, as shown in Figure 3-7.

Teacher:	It was quite funny wasn't it? And it's interesting listening to an E book as well because not only have you got the story that you're listening to, but I guess you've also got the …
Peter:	Pictures
Teacher:	That's right, they were simple, they weren't very elaborate, but they were funny.

Figure 3-7: Teacher-student discussion after showing image (Maher, 2011, p. 241)

However, the written transcription of key parts of interpersonal interactions remains the dominant recording technique. In some cases (Edwards-Groves, 2011), apart from the discussion being grounded in multimodal research, they could be a transcription of an interview in almost any relevant field of study. Overall, although O'Halloran (2011b) has expressed concerns that reporting multimodality in terms of representations on paper means that key aspects are lost, the bulk of transcription approaches consists of taking visual images and rendering them as either still images or as descriptions of the action taking place.

3.3.1.3 Transcribing multimodality

The main challenge to transcribing multimodal research is to show the interaction between the various semiotic modes. This is most commonly done in a tabular form (Lirola, 2010; Xiong & Quek, 2006), even if only two semiotic modes are being studied. However, such tabular combinations can take a number of forms, some, for example, relating the modalities deployed as a classroom teaching sequence unfolds (Jaipal, 2009) along the lines shown in Figure 3-8.

Teaching Sequence	Sequence of Modalities
1. Mr. Grant: Okay, Chemoautotroph, the ones that do chemosynthesis. Take a look at 18.11. (He opens book.)	1. Gesture to open textbook and points to visual diagram
2. Many bacteria oxidize energetic inorganic molecules.	2. Verbal narration and written declarative statement on chalkboard
3. What does it mean to oxidize something? How many of you are taking chemistry? What does oxidize mean?	3. Verbal interrogative questions to reorient students thinking and elicit meaning of oxidation
4. Student 1: From metal to rust.	
5. Mr. Grant: Does that release energy or use energy? [pause]	
6. Student 2: Release.	
7. Student 3: Both.	
8. Teacher: It releases quite a bit of energy. (moves both hands outward in a wide circle). You know the perfect example of that.	Verbal comment and gesture to reinforce meaning of oxidation
9. Think of a sparkler. You know those long sticks at Halloween—sparklers—they burn incredibly hot with sparks coming off (moves hand in circles). That's iron burning! Releases a lot of energy and what does it turn to when the stuff falls onto the ground—little particles of rust (makes small circles with fingers).	4. Visual recall imagery of action evoked by gestures, descriptive phrases, and narrative

Figure 3-8: Integration of speech with other semiotic resources (Jaipal, 2009, p. 57)

Typically, once the data has been built up and recorded in this way, a structured table is then produced to show how these various elements are combined and how they interact (Márquez et al., 2006), as shown in Figure 3-9.

Semiotic Space	Kind of Process	Gesture and Assigned Verbs	Frequency	Total	Processes	Semiotic Space
Thematic space: water in nature (TS)	P1. Processes related to properties and characteristics of water in nature	She joins her hands by the fingertips, forming a sphere (spring out)	1	1	2%	24%
	P2. Processes related to water changes and causes of water circulation	She moves downwards her open right hand (infiltrate)	7	11	22%	
		She follows with her finger the course of the river to the sea (circulate)	2			
		She gestures downwards from the clouds to the surface (rain)	2			
Classroom management space (CMS)	P3. Processes related to the control of students' participation	She stretches her forefinger towards a student (say)	4	6	12%	12%
		She puts her forefinger, pointing up, to her mouth (be quiet)	1			
		She slowly moves her open hands, with the palms to the front (wait)	1			
Representation management space (RMS)	P4. Processes of naming water cycle entities					64%
	P5. Processes related to the management of water cycle diagram	She points to a concrete place in the diagram (put)	19	28	56%	
		She points to the diagram (locate)	9			
	P6. Mental processes	She nods (agree)	3	4	8%	
		She moves her shoulders (it is easy)	1			
	Total			50	100%	100%

Figure 3-9: Example of multimodal coding system (Márquez et al., 2006, p. 211)

The basic goal in this research was to show how the various semiotic resources combine to give meaning, and in particular to explore if particular elements of speech, gesture and text are used in particular instances. In this case the development of a means to capture this interaction has become the key element in transcribing the multimodal process.

The type of summary table presented varies between studies and in the level of complexity. At its most complex, the representation is done so that different frames of a video are analysed in terms of technical issues (such as camera angle and focus) as well as the speech and gestures being deployed (O'Halloran, 2011b), as shown in Figure 3-10.

Stage	'Petrol Prices'									
Phase	Leaked Cabinet Documents									
Sub-Phase	Leaking Documents as Legal Issue		Leaking Documents as Political Issue							
	SHOT 1	SHOT 2	SHOT 3						SHOT 4	SHOT 5
Salient Visual Frame										
	Frame 1	Frame 2	Frame 2	Frame 4	Frame 5	Frame 6	Frame 7	Frame 8	Frame 9	Frame 10
SEMIOTIC RESOURCE:										
Speech:										
Speaker 1 - Tony Jones (interviewer):	*Alright. Tony Abbott*	*you've been in the trenches. That's fair enough isn't it?*			** yes a little – a little bit like the coalition.*	*Leaking going on all round*				
Speaker 2 - Tony Abbott:		*Ah, yes it is*	*but the interesting thing is that the new government is already*	*leaking, Tony. I mean normally it takes many years*	**before a – before – before a government*	*... well I – Tired old governments*	*leak. New, smart, clever,*	*intelligent governments aren't supposed to*	*leak, and the fact that this government is leaking so badly*	*so early is a pretty worrying sign.*
Kinetic Features:										
Gaze:	off-screen; engaged; directed at interviewer	off-screen; engaged; directed at Tony Abbott	off-screen; disengaged; directed at self	off-screen; engaged; directed at studio audience//inter-viewer/Tanya Plibersek	off-screen; engaged; directed at studio audience//inter-viewer/Tanya Plibersek	off-screen; engaged; directed at camera/viewer	off-screen; engaged; directed at studio audience//inter-viewer/Tanya Plibersek	off-screen; engaged; directed at studio audience//inter-viewer/Tanya Plibersek	off-screen; engaged; directed at Tony Abbott	off-screen; engaged; directed at studio audience//inter-viewer/Tanya Plibersek
Body Posture:	angled	angled; leans forward toward Tony Abbott	angled; leans back	angled	angled	straight	angled	angled	angled	angled
Gesture:			raises hand; palm facing outward	raises hand; palm facing outward	hand raised; palm facing outward	both hands raised; palms facing outward/each other	both hands raised; palms facing outward/each other; gap narrowing	both hands raised; palms facing outward/each other; gap narrowing		both hands raised; palms facing outward/each other at reduced distance; downward movement
Cinematography:										
Camera Angle (horizontal perspective)	oblique/ detached	oblique/ detached	oblique/ detached	oblique/ detached	oblique/ detached	frontal/ involved	oblique/ detached	oblique/ detached	oblique/ detached	oblique/ detached
Size of Frame	medium close-up	medium close-up	medium close-up	medium close-up	medium close-up	medium close-up	medium close-up	medium close-up	medium close-up	medium close-up

Figure 3-10: Multimodal analysis including images (O'Halloran, 2011b, p. 17)

3.3.1.4 Software for data transcription

The process of data transcription from video recordings is complicated by the range of potential tools (Bigbee, Loehr, & Harper, 2001). This is partly related to the desired goal, since more complex tools are needed when the intention is to annotate the videos themselves and to ensure they are saved in a format that can be viewed by the potential audience. If the goal is instead to extract a series of visual stills, then the technical requirements are much reduced. In particular, a key element is whether the intention is to study the images on screen or to finally report the results using other media such as paper. Within the multimodal research community, O'Halloran (2011a) in particular has suggested that there is a need to abandon the current stance of reporting multimodal research on paper and adopt the form of computer-based reporting that would allow reporting of the full nature of any meaning making (O'Halloran, 2011a). However, more generally it is acknowledged that the challenge of moving from video to paper will remain a central part of any research reporting (Derry, 2007).

Against this background there is a need for software tools that will support this process. Pea and Hay (2003) suggest that there are up to 10 goals in terms of transcription including: (a) acquisition, (b) chunking, (c) transcription, (d) way-finding, (e) organisation and asset management, (f) commentary, (g) coding and annotation, (h) reflection, (i) sharing and publication, and (j) presentation (Pea & Hay, 2003 cited in Derry, 2007, p. 36). In a review of this and other papers (Derry, 2007), notes that different tools on this list may be more appropriate than others, depending on what is deemed important by the researcher. So, for example, some tools are more useful for transcription, coding and annotation, and other tools are invaluable when the goal is to store the video clips and categorise them so they can be searched on-line. Derry (2007) also notes that "standard tools for qualitative social science research, such as NUD*IST, NVivo, and ATLAS.ti., also possess some basic capabilities for supporting video analyses" (Derry, 2007, p. 38).

The choice of software depends substantially on the goals. If the intention is to analyse and categorise a video so that it can be viewed by the final user then there is a need for one of a number of quite complex tools. If, on the other hand, the goal is to extract images and speech from the video rendered as text then relatively simple tools such as *Final Cut Pro* (i.e. video-editing software for Macintosh computers) will suffice.

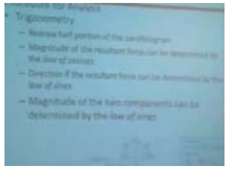
3.3.2 Transcription approach adopted in current study

Once the video recordings were made they were stored on a computer, as recommended by researchers, such as Norris (2004a). The video recording themselves were kept in a secret, safe place at Victoria University, to which only the researcher had access, in a lockable drawer in a special room equipped for the purpose. *Final Cut Pro* was used to convert the videos into a number of stills which were organised in tables. The reason for using *Final Cut Pro*, and not any other video-editing software, is because the researcher found this software easy to learn and apply and it was adequate for the purposes.

However, the stills to be produced need to be selected and suitable criteria developed. The data obtained through the video-recording was transcribed by the conversion of the visual and aural facets to readable sheets (Norris, 2004a). The video data (multimodal data) obtained was converted into still images which can be printed (so the transmission was from video clips to written and printed styles). Two different coding schemes were developed (discussed in Chapters Four and Five) to underpin this process (one used the categorisations of activity theory, the other a multimodal coding system) and using this, the entire sequence of video recordings was converted to text format that indicated verbal and non-verbal interactions and related these to the stills selected from the video recordings.

The primary transcription process was to create a representation on paper. This combined stills (where relevant), written descriptions of any non-verbal actions as well as transcriptions of speech. The key goal at this stage was to capture the full range of multimodality from the videos and not to impose any structure on the data (other than identifying who or what was the focus). A short excerpt from very early in the first video-recorded session is reproduced in Table 3-2 (all these transcripts are in the various annexes) as an example.

Table 3-2: Typical transcription of video recordings

		Facilitator		Student A		Student B		Student C		Student D		Student E		General
Still Images	Minute	Speech	Gestures, Postures, and Materials	speech	Gestures, Postures, and Materials	speech	Gestures, Postures, and Materials	speech	Gestures, Postures, and Materials	speech	Gestures, Postures, and Materials	speech	Gestures, Postures, and Materials	
1.08 	1-1									Yeah, I think I know where I'm going with this now. Then I'll have to figure out the extraction	Student D is talking to Student C while he is pointing at his notebooks.			
1.25  1.59  2.13  2.14  2.26 		Listen guys, if I just uh, have your attention please, I've just got the computer working. The cosine law and the sine law are those two laws which are in the little box there. Write them down in terms of your solution.	The facilitator is explaining to the students these mathematical laws while he is presenting a number of slides on the board next to the whiteboard. The slides show triangles and some diagram explaining these laws.		Student A is solving the problem and using the calculator.		Student B is solving the problem on the sheet and also he is using the calculator. He is rummaging in his pencil case to have his pencil.		Student C is solving the problem on his notebook using the calculator and the pen. He is also drawing a diagram for the forces and angles he is going to measure.				Student E is browsing the pages of the textbook	All the students except Student E are working on their problems on their sheets and their notebooks. One of the students. Student B is solving the problem on his sheet. Therefore, the Students A, C, D are drawing the diagrams again on their notebook.

This excerpt is from the start of the first PBL class when the facilitator first starts to speak. The intention was to transcribe the video recordings so that the speech was recorded verbatim and any gestures (and resources in use) were described but not classified. To ease later analysis and to provide further contextual information, stills (time stamped) from the video were included as appropriate.

This approach to combining verbatim speech record, description of gestures (and resources used) together with indicative stills from the video follows the approach suggested by O'Halloran (2011b) as allowing the reader to view the interaction of all the multimodal elements and their development over time. The inclusion of the actual images strengthens any description of the non-verbal elements. However, although this provided a useful resource in terms of data transcription, it is also necessary to impose meaning and structure on the raw data, and that means consideration of approaches to data analysis.

3.4 Data analysis

A variety of tools have been developed for describing collaborative student interaction and meaning making. In this study, both activity theory and multimodal theory have been used to construct meaning and to analyse the data. The process of data transcription and its subsequent analysis are closely linked. This has a number of aspects, including the problem common to qualitative social science of how much to aggregate or disaggregate the data in terms of a taxonomy (George & Bennett, 2005) that imposes a structure that in turn is used for analytic purposes. To some extent, the key aspect is that this process is done in such a way as to support the focus of the study. However, aggregation needs to be carried out with care or there is a risk of losing some of the richness of the original information.

Engeström's (1987) development of activity theory provides a basic coding structure (Hmelo-Silver et al., 2008), especially to allow a focus on aspects such as setting group norms and the range of tools accessed in the process of collaborative learning. As discussed in Chapter Two, activity theory provides six categories that can be used to describe, theorise and analyse the raw data so in that case the challenge is to analyse the raw data in terms of those existing constructs.

In terms of multimodality, the key element is the creation of categories and there is less agreement as to what these should be. This reflects the wider debate within social sciences, as the process of creating suitable categories is a major part in the process of meaning making when faced with raw data (Brady, 2002). In some cases, gesture for example is codified in considerable detail (Xiong & Quek, 2006) while in other studies it is reduced to the simple category 'gesture'. However, even once a basic coding scheme to describe the nature of a semiotic resource has been devised, there is often a resulting need to then describe the purpose or context of that resource (Moreno & Mayer, 2007). Moreno & Mayer (2007), for example, used relatively simple categorisations of verbal and non-verbal presentations of content but developed quite a complex categorisation around the purpose of that content as shown in Figure 3-11.

Type of interactivity	Description	Example
Dialoguing	Learner receives questions and answers or feedback to his/her input	Seek help from an on-screen agent, click on a hyperlink to get additional information
Controlling	Learner determines pace and/or order of presentation	Use pause/play key or forward (continue) button while watching a narrated animation
Manipulating	Learner sets parameters for a simulation, or zooms in or out, or moves objects around the screen	Set parameters in a simulation game and run the simulation to see what happens
Searching	Learner finds new content material by entering a query, receiving options, and selecting an option	Seek information in an Internet search
Navigating	Learner moves to different content areas by selecting from various available information sources	Click on a menu to move from one Internet page to another

Figure 3-11: Five types of interactivity (Moreno & Mayer, 2007, p. 311)

As above in this chapter, this section reviews this debate in two sections, one looking at practice in other studies of students' meaning making, while the other sets out how these issues have been addressed in the current study.

3.4.1 Data analysis approaches in other studies

This section focuses on the analysis of multimodal resources in two key aspects of the interaction, the change of such resources over time and the attribution of meaning to the transaction. Jaipal (2009) offers an overview of how to create categories for speech, gesture and resources that are relatively aggregated and that construct a structure by creating an ‘event map’ composed of excerpts of talk (sequence units) coded into phase units (modalities) with these including:

> verbal language, written text, gesture, diagrams, written equations, and visual recall imagery. Visual recall imagery is a term I use to describe narratives about real events, analogies, metaphors, evocative descriptions, and demonstrations that the teacher asks students to recall, visualize, and imagine. (p. 55)

The final stage of this analysis was to relate these stages and elements to the four categories of semiotic discourse. Both analysis and reporting are very much reliant on a conventional model of creating categories and textual description.

3.4.1.1 Coding in terms of time

Some studies of classroom interaction in a PBL context have focussed on the temporal process of interaction (Hmelo-Silver et al., 2008) and how students shift between dialogue and tool use in the process of constructing knowledge. This desire to show shifts between modes of activity over time led them to argue that “a diagram is often much easier to interpret than verbal presentations of the same material and can make it easier to interpret complex patterns” (Hmelo-Silver et al., 2008, p. 411). The heart of recording and analysis is to code discourse in a disaggregated manner, first to create frequency counts and then over a time period to understand the learning process in the PBL tutorial. The elements represented include those shown in Figure 3-12.

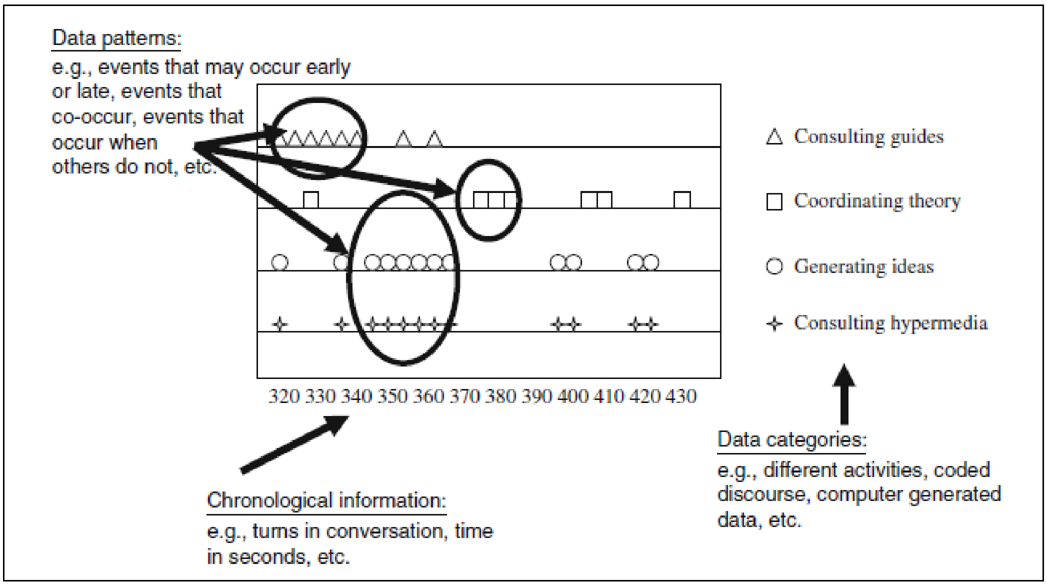


Figure 3-12: Recording structure for a PBL tutorial (Hmelo-Silver et al., 2008, p. 412)

The coding structure was detailed and complex, so that the discussion of the content and rules for the session were broken down as shown in Figure 3-13.

Category	Example
Content	
Task talk	I recommend that you spend a bit more time on discussing EACH proposal and then vote let's say late afternoon on Tuesday
Tool-related	Frank and I decided instant messenger may be useful for discussing comprised info and ideas
Concept talk	Elaborative rehearsal better equips the student with the information he is rehearsing because it becomes more accessible in his long term memory he has found ways to relate it to other instances and in his own words and he can help his peers understand it on a more simple level
Personal talk	Hey, I just wanted to let everyone know that I will might be a little late logging in on Monday morning. I will be in Connecticut until early Monday morning

Figure 3-13: Example of coding structure (adapted from Hmelo-Silver et al., 2008, p. 417)

The subsequent reporting used two main approaches, frequency counts and how many times a particular group accessed a particular tool, as shown in Figure 3-14.

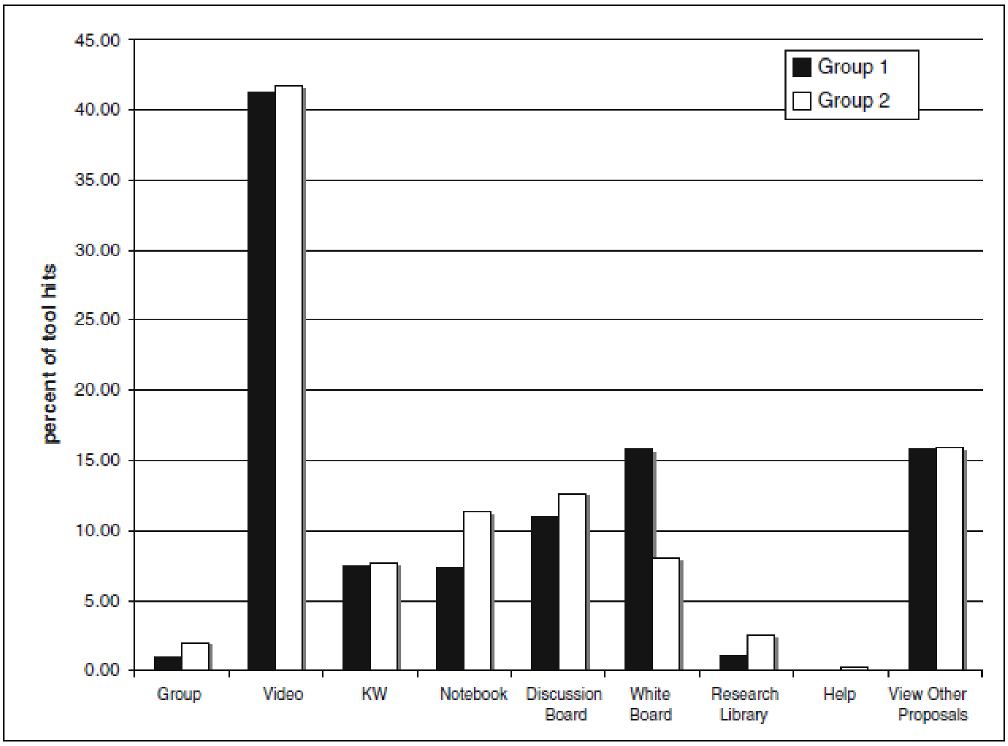


Figure 3-14: Use of different tools across a session (Hmelo-Silver et al., 2008, p. 419)

In Figure 3-14, the percentages reflect the number of times the group accessed a particular resource or tool. However, such simple counts of activity were supplemented by detailed reports showing the full range of activity over time, what actions were coterminous and what actions followed on from others.

In other research Hmelo-Silver (2003) emphasises the benefits of very fine-grained coding schemes and displaying the results both as frequency counts and as longitudinal interactions. In addition, graphical tools such used to present frequency counts and as longitudinal interactions can be supplemented by more traditional transcripts of key parts of a discussion to show not just the interaction of categories but the actual meaning-making discourse of the students (Hmelo-Silver, 2003). The practical tools for coding discourse within PBL sessions are a combination of sequences of reporting actual narrative, frequency diagrams (to show the overall range of activity within a group) and temporal diagrams to capture the flow of activity and where several actions are simultaneous. The key building block for this is the very detailed coding of the component parts of a given session (Hmelo-Silver, 2003; Hmelo-Silver et al., 2008).

Many other studies on student interaction in PBL classes rely on a broadly similar strategy of detailed reporting of key phases combined with categorisation and counting to indicate overall levels of interaction (Peterson, 2004; Remedios et al., 2008b). For example, the use and construction of scientific knowledge is an important part of PBL in Yeo & Tan's (2010) study, where students used an on-line resource to post ideas and the links between their own ideas and those of other students and formed the main means of intra-group communication. The process of analysis was designed to show how the students' understanding varied over time as they explored the problem space. In this case the categories used were provided by the research focus on how students responded to existing knowledge in the course of meaning making. Thus sessions were broken down into 'expanding the scientific field', 'deconstructing scientific semiotic tools', 'reconstructing with scientific semiotic tools' and 'questioning authoritative sources' (Yeo & Tan, 2010). Each in turn was reported as a series of detailed reports organised by time. Typical of this was the manner in which 'questioning authoritative sources' was explored as shown in Figure 3-15.

Note	Date/Time	Author	Content
34	16-08-2006/ 10:09:12	D	… given total weight of the four victims is 340 kg: … d = 127.78 = 128 (3sf)
35	16-08-2006/ 10:10:56	D	compared to a car carrying four riders of average 70 kg: … d = 128 (3sf) thus, e difference in displacement is: 128 × 128 = 0…
36	16-08-2006/ 10:50:56	D	Mass (g) … 1st try … 2nd try … 3rd try … Average 28 … 42.0 … 42.5 … 44.5 … 43.0 34 … 51.0 … 49.0 … 48.0 … 49.3[1]
38	16-08-2006/ 10:58:05	D	mass DOES not affect the stopping distance. what have we neglected in e process of driving e final equation?

Figure 3-15: Organisation of a PBL session (Yeo & Tan, 2010, p. 1750)

3.4.1.2 Creating categories based on purpose

As discussed in Chapter Two, a major issue in multimodal research is both the process of intersemiotics (i.e. the interaction between different semiotic modes) and the identification of which mode was the focal communication mode (Kress & van Leeuwen, 2006). The focal mode is the one to which other modes are deemed subsidiary (Márquez et al., 2006). One coding structure that sought to achieve this is the one shown in Figure 3-16.

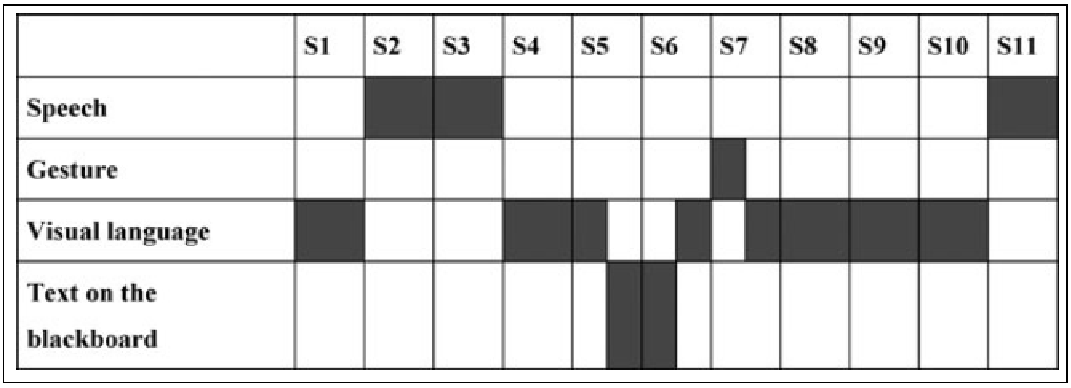


Figure 3-16: Focal mode by excerpt (Márquez et al., 2006, p. 218)

Here Márquez et al. (2006) looked to analyse meaning making and meaning transmission in the science classroom and in particular how "three communicative modes – language, gesture, and image – contribute to the construction of meaning" (Márquez et al., 2006, p. 206). They started their analysis of the basic transcriptions by identifying 'interactivity excerpts' characterised primarily by the thematic content.

Each excerpt was in turn broken down into a semiotic space and the process adopted within that space. The thematic spaces were:

> *Thematic space (TS).* Every meaning that is related to the topic under study, every process that gives meaning to conceptual aspects. So our thematic space is water circulation in nature.
>
> *Classroom management space (CMS).* Every meaning that relates to organization of the classroom as a communicative and social space where it is necessary to organize participation, time, order of the interventions etc.
>
> *Representation management space (RMS).* Every meaning that relates to the strategies used by the teacher to help students construct a water cycle diagram. (Márquez et al., 2006, p. 208)

These three spaces were then broken down to reflect the activity in each excerpt (Márquez et al., 2006, p. 209). Two of these spaces, "Processes related to properties and characteristics of water in nature" and "Processes related to water changes and causes of water circulation", can be seen as means to describe the scientific process under investigation which in the taxonomy above is the thematic space. A third space, "processes related to the control of students' participation", relates to how the classroom management space was adapted as the classes progressed and different learning and teaching modes were adopted. Finally the representation management space was broken into three specific processes:

1) "Processes of naming water cycle entities";
2) "Processes related to the management of the water cycle diagram"; and
3) "Mental processes" (Márquez et al., 2006, p. 209).

The thematic space is the underlying scientific knowledge and the representational space is the process by which the students and teacher interact to construct that understanding. Each section was then assigned to one of these modes. A secondary stage in their coding is to move away from describing the gestures in detail and instead assign the gestures to a category, with this in turn related to the relevant semiotic space. So in terms of the thematic space, gesture is often coded as indicating a dynamic process or flow, while in terms of classroom management, gesture is used to control the class, and in terms of representation, it is used to guide learning (tutor points to the diagram) or to confirm that students have given a correct answer. Overall, to achieve this they reduced the actual detailed speech and gesture to one of four semiotic resources: speech, gesture, visual language and written text (Márquez et al., 2006). This allowed an understanding both of which modes were most dominant in which spaces and processes, and how these interacted. So, for example, speech-dominated in the thematic space but gesture was the dominant mode in the classroom management space, as shown in Table 3-3.

Table 3-3: Use of different modes for different roles (Márquez et al., 2006, p. 214)

	Kind of Process	Speech	Gesture	Visual Language	Written Text	Total	Total Semiotic Space
Thematic space	Processes related to properties and characteristics of water in nature	156	5	33	0	194	
	Processes related to water changes and causes of water circulation	212	70	37	0	319	513
Classroom management space	Processes related to the control of students' participation	75	81	0	0	156	156
Representation management space	Processes of naming water cycle entities	87	0	0	70	157	
	Processes related to the management of water cycle diagram	276	103	1	12	392	773
	Mental processes	182	32	1	9	224	
	Total	988	291	72	91	1442	1442

Márquez et al. use a reduced range of descriptions to capture the semiotic resources for the process of analysis. As is shown in Table 3-3, they start from a rich, very precise description of what each gesture consists of, but for analytic purposes these are conflated into a single category 'gesture'. Since the main purpose of the paper is not to describe in detail how gesture is built up (Xiong & Quek, 2006), but instead to discuss how semiotic resources interact in the science classroom (and which, if any, are dominant at a particular stage), this is an appropriate choice. However, although this degree of aggregation is relatively common, there is little agreement as to which categories should be used. Kress et al. (1998) suggested that four modes of talk, images, gesture and the material apparatus were the key modes in the science classroom (Kress, Ogborn, & Martins, 1998). The high level coding scheme used for reporting is, as with Márquez et al., derived as much from the factors deemed to be of interest in building up the research as from any conventionally agreed listings.

This style of analysis allowed consideration of when the different modes were co-operative (i.e. used to present the same information) or different as they were used to present different information. In the example above, speech and gesture have a shared role in managing the functioning of the classroom (Márquez et al., 2006). However, in terms of the discussion of the knowledge content (thematic space), speech and gesture are playing different roles. While speech is presents the core information, gesture is being used to show the flows and dynamic element.

Jaipal (2009) developed this approach, and in particular the overarching stage structure offered by Márquez et al. (2006) by first positing that the entire communication serves, at various stages, one of four functions. Where Márquez et al. split this categorisation into their three spaces, Jaipal suggests four functions:

- Presentational Function (Conceptual Aspect of Meaning), which could be mapped onto Márquez et al.'s Representation Management Space;
- Orientational Function (Social Aspects of Meaning) which could be mapped onto Márquez et al.'s classroom management space, but includes elements such as "how the voice of the teacher and text position the learner in relation to science. For visual graphics, typographical tools such as italics and boldface emphasize importance and act as orientational tools" (Jaipal, 2009, p. 52);
- Organisational Function (Pedagogical Aspects of Meaning), which again could be Márquez et al.'s Representation Management Space; and,
- Epistemological Function (Nature of Knowledge) which broadly reflects Márquez et al.'s Thematic Space

Thus even before coding the actual semiotic resources for analysis, Jaipal (2009) has created an overarching coding scheme that can be roughly mapped onto that of Márquez et al. (2006), but also differs in key respects. This is not to argue that either is wrong, or that either is better in an abstract sense, but it does indicate that the process of creating typographies and categories to report on multimodal discourse is complex, and that there is a lack of predefined elements that are shared across even similar studies, in this case both studying how the different resources are combined to create meaning in the science classroom.

Having created the categorisation scheme (the four functions), Jaipal gathered data using a mixture of audio and visual recording, interviews as well as direct observation. The first stage of categorisation was to “identify data units where multiple modalities were used to teach different concepts” (Jaipal, 2009, p. 55). This was then broken into an ‘event map’ to show how excerpts of talk are related to specific phases of the teaching cycle. The modalities captured included:

> verbal language, written text, gesture, diagrams, written equations, and visual recall imagery. Visual recall imagery is a term I use to describe narratives about real events, analogies, metaphors, evocative descriptions, and demonstrations that the teacher asks students to recall, visualize, and imagine. (p. 55)

Again this is not a dissimilar scheme to that followed by other studies (Kress et al., 1998; Márquez et al., 2006), but it is different and reflects the focus of the particular study. An example of how these different modalities were related to the Epistemological Function is offered given in Table 3-4.

Table 3-4: Time sequence, focus and modalities in use (adapted from Jaipal, 2009, p. 56)

February 1	Chemosynthesis	1. Textbook diagram 2. Written equations 3. Visual diagrams on board 4. Recall everyday examples 5. Gestures 6. written definitions

Again, as with other studies, there is a process of gradual reduction from the rich raw data to a form that is suitable for further analysis. As an example, the following excerpt is summarised as a ‘Verbal comment and gesture to reinforce meaning of oxidation’ and grouped with other similar elements to indicate the phase of a lesson: “Teacher: It releases quite a bit of energy (moves both hands outward in a wide circle). You know the perfect example of that” (Jaipal, 2009, p. 57). In this case, the excerpt is split between ‘gestures’ and ‘recall everyday examples’. In turn, the lesson was summarised and mapped onto Jaipal’s four functions as shown in Table 3-5.

Table 3-5: Sequence of semiotic modalities and functions (Jaipal, 2009, p. 59)

Sequencing and Interplay of Modalities	Organizational (Word/Mode Sequence) Pedagogical Aspects	Presentational (Content Knowledge) Conceptual Aspects	Orientational (Relationships) Social Aspects	Epistemological (Actions and Reasoning) Nature of Knowledge
1. Visual diagram: Textbook diagram Pointing gesture	1. Initial reference to chemosynthesis Signals what to attend to	1. Shows overall process of chemosynthesis	1. Textbook as authority of science	1–3. Knowledge as given fact
2. Verbal and written declarative statement	2. Acts as an anchor for discussion of new terms Clarifies thematic relations	2. Describes process in terms of inorganic compounds and oxidation Communicates role of molecules	2 and 3. Teacher as authority and in control	
Word "energetic"	Reinforces idea of energy			
3. Verbal questions Gesture	3. Chemistry domain acts as anchor Emphasizes energy release	3. Defining oxidation as energy release	3. Formal authority of science	

Two papers discussed in some detail above (Jaipal, 2009; Márquez et al., 2006) offer useful insights into both the process of transcription from the raw material and the organisation of the transcribed information into categories that are useful to explain the nature of the semiotic interaction being studied. It is noticeable that both rely on verbal transcription and description to capture non-verbal and verbal modes (Norris, 2004a), rather than linking a text record to visual images (O'Halloran, 2011b). Both develop an analytic framework but they use two different constructs. Whether they use the concept of spaces (Márquez et al., 2006) or functions (Jaipal, 2009), both indicate what they see as the main building blocks to describe the interaction they will study. However, they make a distinction between the scientific knowledge under investigation, the process by which meaning making takes place and the domain (classroom) within which this will take place.

The papers both show the process by which they develop a coding scheme that moves from a rich, detailed description of a particular moment in the session up a hierarchy (losing detail at each stage) until both use a very abstract concept, such as 'gesture', to capture a range of different events. This process can be traced, and presumably challenged if seen to be inappropriate, from the basic material to the aggregated description. However, the key is that both studies were interested in the interaction between semiotic modes (not the detailed descriptions of how those modes were made up), and as such, a high level of abstraction was appropriate. In summary, the research focus produced the appropriate final coding scheme, not the application of an agreed classification process.

3.4.2 Data analysis in current study

Section 3.4.1 has discussed the practice of the coding and analysis of non-verbal resources followed by other studies. For example, non-verbal semiotic resources can include gesture, posture, non-speech communication (grunts, laughter, etc.), symbolic language (mathematical and scientific symbols) and materials such as visual and audio resources (Jaipal, 2009). However, the level of detail and the point of focus shifts substantially between the studies reviewed. At one extreme, coding of gesture is detailed to the point of identifying hand-height, range of motion and direction (Xiong & Quek, 2006). Other studies are content to simply identify when, for example, a 'gesture' has been used (Márquez et al., 2006) or that the resources include written diagrams or visual (OHP projected) diagrams and text (Jaipal, 2009). Jaipal (2009) makes a useful addition by linking the concept of 'gesture' to whether or not it supports, contradicts or offers a new semiotic mode to any related speech. This concept has been adopted in the discussion below (see Section 2.3.1 and Table 2-1) as it relates to the interest of the way the processes of intersemiosis (i.e. relationship between semiotic resources) and resemiosis (i.e. the drawing in of wider concepts to influence meaning making) are part of the student meaning-making process in a PBL session.

However, data analysis in this study relied on the use of the two analytic frameworks of activity theory and multimodality. Following Jewitt and Hmelo-Silver (Hmelo-Silver et al., 2008; Jewitt, 2006), these two approaches can be seen as mutually supportive. One problem, as discussed in this chapter, is that multimodal research tends to have to concentrate on short excerpts due to the complexity and depth of analysis and the need to render the results in terms of text and tables on a printed page. Activity theory offers two valuable methods here. Firstly, it can be used to review, describe and analyse the entire PBL session, and secondly, the resulting review can be used to identify particular short excerpts that allow for a focus on the multimodal problem-solving process.

The remainder of this section discusses first how the raw data was rendered in terms of the conventional categories for activity theory and then the categorisation, creation of hierarchy and data presentation approach adopted in terms of multimodality.

3.4.2.1 Activity theory

As discussed above (see Figure 2.4), activity theory models the interaction between six categories which can be mapped onto the PBL session that is the focus of this research as shown in Table 3-6.

Table 3-6: Activity theory overview

Concept	Definition	Application
Object	Underlying purpose of a task.	The task is to design a bridge that will meet certain criteria.
Subject	Individual(s) carrying out the task.	The group of five students who make up the PBL team.
Tools	Resources used in carrying out the task.	Paper and pencil, ICT, Whiteboards, laptops, mobile phones, calculators are all used at different stages.
Rules	Rules that regulate the conduct of the task.	Both the task rules and the assessment rules are discussed at various stages.
Community	Wider group involved with the task.	There are other PBL groups functioning concurrently but the only interactive outsider is the facilitator.
Division of Labour	How the various jobs required are divided between the subject and community.	At different stages the students work individually and allocate tasks between themselves, with the tutor taking on different roles.

Table 3-6 presents a broad overview of the way in which the various strands of activity theory can be used to analyse the PBL session. In particular, the concepts of task, tools, rules and community all help to explore how the students’ meaning making is informed by the wider academic and social community (in other words meaning making is not just an in-group activity). These represent the PBL activity of the observed student group and then fitted that activity into the framework of activity theory (Hmelo-Silver, 2003; Jewitt, 2006). The definition of the each category is related to the meaning making inherent in PBL, not to an abstract scheme as activity theory is a descriptive tool (Jewitt, 2006), not a prescriptive theory. Therefore each PBL session was coded in terms of these six categories. Not all these categories were present all the time so are sometimes left blank in the coding scheme. A further challenge posed by applying activity theory is that many events do not neatly fit into one or other category. Consequently, the outcome is an intertwined relationship (i.e. the same feature appears in more than one category and each category captures different features). The next sections discuss how each of the six elements was categorised for this study.

3.4.2.1.1 Definition of 'object'

Across the five video recorded sessions, the 'object' remains the same. The PBL students are required to design and construct a model bridge, using the tools provided (paddle-pop sticks and glue), that is strong enough to hold a pre-determined weight with no distortion. However, it is possible to assign interim 'objects' to the different sessions as they develop this task. In Sessions 1 and 2, the object is to carry out a set of calculations that are meant to be the theoretical underpinnings of the bridge design. Session 3 is mostly focussed on different design approaches and how these can be used to fulfil the task requirements. Sessions 4 and 5 are focussed on physically building the model. There is a staging across the five sessions from theory (around forces and angles) to concepts of design to actually designing the model. This shifting focus (object) of each session is described in more detail in Chapter Four.

3.4.2.1.2 Definition of 'subject'

The subject in this case is the five-student group, although in Session 4 only two are present as they had agreed to meet separately to the rest of the group to progress the bridge design. Due to the research focus on both individual and group learning as elements of knowledge and meaning-making construction, the various configurations of this PBL team were coded separately. Three main states were identified as follows:

- Individual working (when there is no or very little interaction in the student group and they are working on the problem as individuals);
- Sub-group interaction (usually but not exclusively one-on-one); and
- Whole-group interaction (when the bulk of the student group was engaged in active discussion).

This led to consideration of the complex role of the tutor in this PBL class. This is discussed in more detail in Chapter Four and returned to in Chapter Six but there are times when he joins the team and discusses the students' progress (or its lack) with them. However, on balance he is not part of the subject in activity theory terms as he is not one of the group of students designing the bridge for assessment in the context of the PBL class. However, as argued below, he plays an important role in setting the rules for this particular PBL task.

3.4.2.1.3 Definition of ‘tools’

The student group makes use of the different tools made available to them across the sessions. These are coded as descriptively as possible and include:

- Laptops (mostly accessing Victoria University Web-CT or Google for searches of bridge designs);
- Information on Whiteboard;
- Calculators;
- Textbooks;
- Diagrams made by the students;
- Calculations made by the students;
- Mobile phones (at one stage used to take photographs of the model as it is being designed); and
- The paddle-pop sticks used to build the model.

These tools are used in different ways at different stages. Leontev argued that the tool has both a ‘static’ nature and a varying use as the process of problem solving evolves (Leontev, 1978). Thus in this case the laptop is used variously for Google searches, to access Victoria University’s Web-CT resource, to carry out calculations and to review images of existing bridges. Similarly, the paddle-pop sticks are used at different stages to point, to suggest a suitable angle for the bridge struts, as a distraction (when students or the tutor pick them up and fiddle with them) as well as being used as the elements from which the model bridge is constructed. In consequence the tools are both used to carry out the task (for example, the paddle-pop sticks are used to build the model bridge) and are actively used in the meaning-making process (to point at objects, as something to fiddle with and to layout potential design options).

3.4.2.1.4 Definition of ‘rules’

The rules needed to carry out the object include the various discussions both within the student group and with the facilitator about the nature of the task, reflecting discussion of the timeline, the way this work needs to be fitted around other parts of their degree study, and the nature of the assessment (and how the individual and group elements will interact). In addition, at times the student group discusses the division of labour (who will build the bridge and who will write the report) and this is covered in

Chapter Four. In other instances, the rules are set by the tutor as he clarifies the task, the timeline and discusses with the students how they will meet these requirements.

This theme is developed substantively in Chapter Four as it is argued that the 'rules' set the context for the PBL task. Three different groups of rules emerge: The first can be described as engineering knowledge about stresses, forces and how to build a bridge to sustain a given load (i.e. the subject knowledge); the second set of rules are set by the tutor, such as timeline, available resources, and nature of the test to which the bridge will be subjected, with the tutor breaking down the overall object into sub-tasks that students are expected to complete at the end of each class or between classes; the third set of rules is developed by the students themselves, revolving around who will carry out which part of the task.

3.4.2.1.5 Definition of 'community'

In the sessions video-recorded the wider community can be categorised as consisting of two elements. In several sessions other student groups were present in the room at the same time, carrying out a similar task (designing a bridge using the paddle-pop sticks) and listening to the tutor make a presentation to the whole class. The second community aspect outside the 'subject' group is the PBL facilitator. The students interact with the facilitator in one of two ways:

1) When the facilitator makes formal inputs to the entire class (i.e. not just the PBL group under observation); and
2) When the facilitator joins the student group.

The wider community, as mentioned, consists of two parts – the other student groups in the room and the PBL tutor/facilitator. For all practical purposes, the different student groups in the room can be treated as being effectively separate. As discussed above, care was taken not to video-record them and their questions and discussions have not been recorded in the transcripts (for example, there were instances when they posed a question when the tutor was presenting to the entire class).

3.4.2.1.6 Definition of 'division of labour'

The division of labour can capture both the division of work and roles in the wider community and within the student group that forms the subject of the enquiry. In this study, there is a division of labour between the students and the tutor and within the student group. However, this also includes the organisation of work within the student group and allows consideration of which students play an active or passive role.

3.4.2.1.7 Example of coding structure in current study

Using this framework each of the video-recorded sessions was transcribed and the categories of activity theory were used to describe and analyse the entire PBL session. This coding involved watching the video recordings several times and breaking them down into time blocks where one of the categories was dominant. In turn this process then allowed tracing of where and when the nature of, say, the student group's work shifted and to identify the sessions used for the more detailed analysis in Chapter Five. A typical example of the coding is shown in Table 3-7. This shows a range of student activity and indicates how this related to tool selection. In this session there was no discussion of the object or the rules because, as discussed in Section 3.4.2.1.1 and shown in Table 3-1, the focus in the first PBL session was the theoretical calculations of the forces that the model bridge would be subjected to.

Table 3-7: Example of session coding process (extract from Session 1)

Time*	Description	Object	Subject	Tools	Rules	Community	Division of Labour
10.15-11.10	Discussion of possible solution between individual students		One-on-one discussions	Calculator			Discussion led by one student
11.10-11.30	Checking understand and possible solutions		One-on-one discussions	Paper, written notes			
11.30-12.55	Working on solution		Individual work	Calculator			
12.55-13.05	Tutor input		Student work carries on	Reference to text book		Facilitator-led	
13.05-13.45	Student work		Mostly individual work				
13.45-15.00	Student work		Mostly individual, some one-on-one				
15.00-16.00	Student work		Mostly individual	Notes and diagrams			
16.00-17.10	Student work		All individual working	Use of laptop by one student			
17.10-18.15	Discussion of possible solutions		More group interaction	Laptop, notes			
18.15-19.50	Student work		Individual working	Calculators			
19.50-21.45	Student work		Some interaction	Notes, one student using laptop			
21.45-21.55				Laptop review of previous lecture?			

*Beginning and End points as per camcorder's timer, with the range equivalent to minutes and seconds; the times coincide with the duration of the session, beginning with 0.00.

The excerpt presented as Table 3-7 is drawn from Session 1 and shows how a descriptive framework was developed within the parameters of activity theory. Sufficient information was recorded against each of the timed sessions to identify what actions were being undertaken. In consequence, the individual time blocks are uneven (some are very short, others span several minutes) and a new time block was created once there was a significant shift of activity. The coding thus follows the process of meaning making set out in activity theory terms rather than uses a strict regular division of time.

For example, from Timer 15.00 to 16.00 the PBL students are working individually but with short bursts of interaction (usually checking with their neighbours), and from Timer 16.00 to 17.10 this interaction has ceased. However, at the end, there is a sustained sub-group (i.e. it did not involve the entire group) discussion session on the solutions to the theoretical task they are working on.

3.4.2.2 Multimodality

Unlike with activity theory, multimodal research does not provide an agreed overarching categorisation. Thus the task is both to identify a suitable typology and to assign the raw data to that categorisation. In terms of the discussion in Section 3.4.1 it should be noted that the key goal here, especially for the non-verbal communications and the resources used in meaning making, is less a categorisation of what they consist of (i.e. a description) and more a categorisation of their purpose (i.e. how they are used in the meaning-making process). That distinction underpins the coding structure and process described in this section.

This section discusses the detailed coding structure adopted to analyse the video recordings from a multimodal perspective. The main coding process involved analysis of the spoken words (3.4.2.2.1) but attention was also paid to gesture (3.4.2.2.3) and to other semiotic resources (3.4.2.2.3). These categories are mostly drawn from the literature review, in particular sections 2.3, 2.5 and 2.6. Figure 2-6 is an important summary of this discussion and, following Hmelo-Silver et al. (2008) forms the basis for the categories and sub-categories used in this analysis.

3.4.2.2.1 Coding of speech

This section draws heavily on the discussion of student learning set out in Section 2.6, and Figures 2-6 and 2-7. Those suggest that speech can be broken down into a number of categories to capture different parts of the meaning-making process. In this research, speech was coded into seven major categories derived from Hmelo-Silver's research design (Chernobilsky et al., 2005b; Hmelo-Silver et al., 2008). Hmelo-

Silver's approach was supplemented by adding a concept of internalisation (to capture who was leading the meaning making between the students and the facilitator) and of scaffolding (Hill & Hannafin, 2001; Stålbrandt, 2007) to explore the process of learning. Each verbal utterance was coded to at least one of these categories in the transcription and analysis process. The categories were developed from the literature on multimodality discussed in Chapter Two:

1) Content of the talk;
2) Collaboration;
3) Responses of ideas/complexity;
4) Knowledge;
5) Metacognition; and
6) Interpretation.

As above the work of Hmelo-Silver et al. (2008) is important to the development of these concepts and the concepts listed are drawn from their study (see Figure 2-6 and related discussion in Section 2.6). However, these concepts are supplemented by 'internalisation' (Table 3-14), developed by the researcher in the early stages of the data analysis. In addition, the important issue of scaffolding in a PBL context (see Section 2.2) is developed from the work of Stålbrandt (2007) as it captures a critical aspect of the PBL pedagogic model.

A given stretch of speech could be coded to any number of these categories, from one to all seven, allowing for a detailed analysis of the flow, content and meaning of each block of social interaction. In turn, each of these categories was broken down into second or third order categories to ensure a detailed analysis was carried out on a consistent basis (so, for example, 'Questioning' is divided as generating either a 'short' or 'long' answer and in turn, short answers are split between categories such as simple verification or whether more information was provided). Each category was given a simple code and this was used in the tables (see List of Abbreviations and Appendix 6).[1]

[1] Some abbreviations do not follow the general principle of using the initial letter of the main terms in the full form, e.g. Task-related Talk = TT, while Tool-related Talk = TR since otherwise there would be two abbreviations TT. In other cases this benign inconsistency occurs because sometimes the initial letter of the abbreviation is taken from the main category and the second letter from the sub-category or even sub-sub-category, e.g. Interpretation (LI) where L is taken from Long Answer and I from Interpretation, or Verification (SV) where S is taken from Short Answer and V from Verification.

Content of the talk (Chernobilsky et al., 2005b; Hmelo-Silver et al., 2008) was broken down into four categories, depending on whether they were discussing the task, the tools needed to complete that task, the concepts behind the task or the talk had ceased to be task-specific, as shown in Table 3-8

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Table 3-8: Coding of content of talk

Category	**Sub-Categories**	**Example**
Content of Talk	Task-related Talk (TT)	Keep to those specifications guys
	Tool-related Talk (TR)	you need to know what your calculator is doing.
	Concept-related Talk (CT)	you can use the resolution of forces too
	Personal Talk (PT)	But it’s okay, this semester is all right. Keeping up.

The coding of collaboration required a more complex scheme to capture the full range of possible interactions (Chernobilsky et al., 2005b; Hmelo-Silver et al., 2008b). This included identifying the introduction of new ideas and their modification, agreement and disagreement, summarising the discussion, forms of collaboration by the facilitator and various modes of questioning. The full list is given in Table 3-9.

Table 3-9: Coding structure for collaboration

Category	Sub-Categories (1)	Sub-Categories (2)	Example
New ideas (N)			subtract the down…
Modifications of ideas (ModI)			for the up and down you'd go –
Agreements	Task-related Agreement (TA)		The square, yeah
	Conceptual Agreement (CA)		Yeah that's right.
Disagreements / conflicts	Task-related Disagreement (TD)		No, because this one is going down this way
	Conceptual Disagreement (CD)		10… 8.61 – no that's not it…
Acknowledgement of others' contribution (Ack)			you got it gosh…
Facilitator's input	Monitoring (FM)		Guys, you need to finish this work on your own time
	Explaining Tool-related utterances (FT)		I recommend everybody to buy the (Hugo) Statics book
	Explanations (FE)		that become a negative Y and then the Xs…
Questioning	Short Answer	Verification (SV)	Yes, I got it right for once!
		Quantification (Quant)	there's a number 275 paddle-pop sticks
	Long Answer	Interpretation (LI)	What did you end up
	Task oriented and	Group Dynamics (GD)	Or you would get 8,669…
		Self-Directed Learning (SDL)	this is Y going up and this is Y going down,
		Need Clarification (NC)	Was this done in the lecture …
	Self-answered Questions (SQ)		So then the difference between that and that, -5 for the Y,
	Questioning Facilitators (QF)		What if I put it up like that?

Thus collaboration can range from the introduction of new ideas to modification of ideas, statements of agreement or disagreement, questioning and the scaffolding of concepts and ideas in the meaning-making process.

The process of responses and idea development (Chernobilsky et al., 2005b; Hmelo-Silver et al., 2008) was designed to capture the nature of the interaction as shown in Table 3-10.

Table 3-10: Coding of responses

Category	Sub-Category	Examples
Agreement with Facilitator (AF)		Student D (replies to the facilitator): Yeah
Agreement with PBL Member (AM)		Yeah week 8 at the moment
Seeking Clarification (Clarif)		How long does the uni year go for?
Brief Answer (BA)		So we've got another six months
Elaborated Telling (ET)		Then we have another one on top and
Elaborated Explanation (EE)		And that's the sort of one that you want to plan for.
Justification of ideas	Personal Experience (PersE)	It will, but this will probably still be stronger.

In turn, knowledge (Chernobilsky et al., 2005b; Hmelo-Silver et al., 2008) was coded to indicate the basis for a statement of belief. In Hmelo-Silver's model this is described as 'justification' and coded as shown in Table 3-11.

Table 3-11: Coding of knowledge

Category	Sub-Category	Example
Knowledge	Conceptual Knowledge (CK)	Then I'll have to figure out the extraction
	Prior Experience (PE)	I thought the X one was down because

Metacognition is drawn from the concept of scaffolding (Hill & Hannafin, 2001; Stålbrandt, 2007), which relied on an analysis of the framework being adopted to justify a given statement, as shown in Table 3-12.

Table 3-12: Coding of metacognition

Category	Sub-Category	Example
Monitoring	Individual Monitoring (IM) (checking on personal progress)	: so you need to know your sine and cosine rules because in terms of the parallelograms that set up the forces,
	Group Monitoring (GM) (checking on group progress)	Listen guys, if I just uh, have your attention please,
	Self-Directed Learning (MSDL)	Then I found the S from that.
Planning	Theory-driven Planning (ThP)	So there are two ways of solving it
	Unjustified Planning (UP)	You've got to do a drawing…

Interpretation involved a judgement about the intensity of a given interaction and the extent to which it was either simple or complex, as shown in Table 3-13.

Table 3-13: Coding of interpretation

Category	Example
Low-level (IL)	Write them down
High-level (IH)	There is another way of doing this guys if you

Internalisation was coded to indicate who was directing the meaning making and learning being observed. In this case, the coding scheme in Table 3-14 was developed specifically for this research and provides a shorthand overview of the interaction between the students and the facilitator.

Table 3-14: Coding of internalisation

Category	Example
Peer-to-Peer Internalisation (IPP)	Student B: Yeah, yeah, yeah right… Yeah,.
Facilitator-to-Student Internalisation (IFS)	Facilitator: The only way you're going to get a strong sort of bond,
Student-to-Facilitator Internalisation (ISF)	Student A (to the facilitator): And then the next one is going to overlap them

Table 3-14 is not based on the literature review in Section 2.6; instead it was developed as part of the coding to indicate when the facilitator and when the students are leading the meaning-making process. This category was developed to allow an understanding of the extent of interaction within the student group and between the students and the facilitator. In practice the nature of such interactions could also studied by exploring the flow of each discussion (in other words when the active meaning making shifted from supervisor to students and vice versa) and thjs meant that less reliance was placed on internalisation in practice when completing the analysis than appeared to be the case when the conceptual categories were originally constructed.

Scaffolding (Hill & Hannafin, 2001; Stålbrandt, 2007) is an important part of PBL learning and has been coded in these transcripts. The coding scheme below has been adapted from the work of Stålbrandt (2007), as shown in Table 3-15.

Table 3-15: Coding of scaffolding

Category	Example
Conceptual Scaffolding (CS)	that I've seen in my experience have been what I call box-shapes
Metacognitive Scaffolding (MS)	in order to get the result in force you need to know the angle too
Procedural Scaffolding (PS)	8.6 squared plus 7.4 [background noise] and the square root of all these
Strategic Scaffolding (SS)	so you could actually stand on a wire frame structure.
Technical Scaffolding (TS)	you need to know your sine and cosine rules because in terms of the parallelograms that set up the forces,

Scaffolding is an important part of how the facilitator seeks to guide student meaning making within PBL. At its core, it reflects the intention to allow students the opportunity to structure their own thinking about the task rather than offer the final answers. The four categories allow a distinction to be drawn between offering a wider framework (conceptual, metacognitive and strategic) or providing more task and subject focussed information (procedural and technical).

3.4.2.2.2 Coding of non-verbal resources

Given the focus on the extent to which non-verbal and verbal resources support each other, each non-verbal element has been coded in detail using the coding scheme set out in Section 3.4.2.2.1. Thus gestures, other non-verbal communications and the resources accessed have all been coded as set out above. They are thus described as 'talk' when perhaps the term 'communication' might be more appropriate. However, the advantage of this approach is consistency in the analysis set out in Chapter Five and in the categorisation of the student learning process discussed at the end of Chapter Two.

Given the focus of this research, the nature of a gesture was seen as less important than the purpose and its contribution to the overall flow of meaning making, and, in particular, whether it confirmed the meaning indicated by speech, elaborated on it, contradicted it or was the primary means for meaning making in that instance. The raw data was transcribed in such a way as to be descriptive and from that was derived a categorisation based on purpose. Where feasible, this descriptive data was supported by the inclusion of a still from the video recordings and this is shown in detail in Chapter Five.

The decision to also code and study the interaction of non-verbal resources together with verbal resources represents a development of Hmelo-Silver's (2007, 2008) work where that relied on the verbal aspect of meaning making within PBL. In this sense, retaining the same descriptive system for both types of resources has the secondary advantage of easing an analysis of the interplay between the two and, as discussed below, allowing an exploration of the process of intersemiosis in the meaning making of the students.

3.4.2.2.3 Coding of resemiosis

The process of resemiosis and also the development of meaning making over time was addressed by constructing a table that showed each element of speech, gesture and resource use in the selected excerpt. The example shown in Table 3-16 is drawn from near the end of the first PBL class:

Table 3-16: Example of multimodal analysis structure

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
54.21	Okay boys can I have your attention please,		PT	FM	BA		GM		IFS	
		Students A and B are fiddling with the paddle-pop sticks	PT						IPP	
	Facilitator: we're just going to do some of the tricks.		TT	FE	ET			IL	ISF	
		Facilitator – gesticulates and shows paddle-pop sticks 	TR	FT					ISF	TS
54.29	Facilitator: So the tricks are in terms of strength.		CT	FE	ET			IL	ISF	
		Facilitator gestures with his hands to indicate the type of pressure that will be placed on the bridge	CT	FE					ISF	MS
	Facilitator: What you don't want to have		CT	FE	ET			IL	ISF	MS
	Facilitator: is the bridge sort of buckling underneath your load springy		CT	FE	ET			IH	ISF	MS

*Beginning and End points as per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

So in this case the left-hand column shows the time can be related back to the detailed transcriptions in the Appendix provided on CD, with short excerpts of each session in the Appendix at the end of the thesis. Speech is broken down into small excerpts and each is coded, as appropriate. The non-verbal resources are linked to this flow of speech. In some cases a purely descriptive approach has been adopted and in others a video still image has been added to exemplify what is being described. This allows a reading both of the flow of meaning making, where it shifts from the task to content, who is leading the meaning making and how the verbal and non-verbal elements interlink (which dominates, when are they complementary, when are they contradictory).

3.5 Summary

This research is grounded within the interpretivist school of research design (Briggs & Coleman, 2007; Francis & Hester, 2004; Silverman, 2010). That means accepting that the process of observation influences what is being observed and that this is due to the importance of capturing data in context. To assist this, the techniques of participant observation were adopted (Dewalt & Dewalt, 2002; Turner, 2009). A range of techniques have been developed that cover classroom observation and the gathering and analysis of multimodal data. However, the conclusion of this review is that there is no dominant mode by which this is usually carried out. Instead, different research studies use a similar framework but adopt tools for data collection and data analysis that fit their own focus. With this in mind, the next two chapters report the findings, first using the framework of activity theory and then that of multimodality. This allows both an overview of the entire PBL session and a close focus on students' meaning making at key stages. The concepts developed, and how the data was coded and analysed are discussed in each of those chapters.

Broadly, data collection has been carried out by video-recording the sessions (participant observation). From this data, two related coding schemes were used that allowed an overview of the entire session (Chapter Four) and a detailed examination of particular excerpts (Chapter Five).

Chapter Four

Activity Theory: Overview of PBL Sessions

4.1 Introduction

As discussed in Chapters Two and Three, activity theory has a particular value in allowing an analysis of the context in which a particular learning process takes place. In theory this can be done using multimodal approaches and the concept of resemiosis, but in practice this has proved difficult to achieve (Jewitt, 2006). A second problem with a purely multimodal analysis, as discussed in Chapter Three, is the difficulty in analysing long periods of interaction in those terms (O'Halloran, 2011a; O'Halloran & Smith, 2011).

In combination, this means that activity theory has a threefold role in this analysis:

- To provide an overview of the entirety of the video-recorded classes;
- To form one strand of the analysis, in particular concentrating on the importance of context in the meaning-making process; and,
- To provide a basis for selecting shorter excerpts that exemplify key parts of the meaning-making process that can, in turn, be analysed in multimodal terms.

The first two of these goals can be related to the specific research questions developed for this thesis (see Section 1.3.1). For convenience these are restated here as:

1) Understand the role of context in the PBL task, specifically, how far can the actions of both the students and the tutor be understood in terms of external constraints rather than their own preferred problem-solving / meaning-making approach;
2) Understand the role of the students in the meaning-making process, specifically, do they use different semiotic resources as the task evolves and their understanding shifts?;
3) Understand the role of the tutor/facilitator in the meaning-making process, specifically, does their use of semiotic resources vary as the task evolves and, if so, how does this affect their interaction with the students and use of scaffolding?; and
4) Evaluate the overall performance of the student group in terms of task performance and the students' construction of meaning.

The primary contribution of this chapter concerns the first goal, that of understanding the context so as to address the criticism that research into student knowledge construction and problem solving has neglected context:

> the broader learning context in which the collaboration is embedded. Research has concentrated more on participants' mental structures than on learning as a situated activity. This type of research has focused on studying the relationship between the cognitive aspects of student interaction and individual learning. Positive results of collaborative interactions have been explained by the notion that peer interaction stimulates the elaboration of knowledge and hence adds individual cognitive gains. Thus, the main interest has been in investigating how collaboration contributes to individual knowledge construction, the mental content of individual minds. Yet, contextual aspects are also important in learning. (Arvaja et al., 2007, p. 448)

In addition, this chapter presents an overview of the entire PBL class. More importantly, Hmelo-Silver (2003) and Jewitt (2006) argue that such an overall analysis can identify specific elements within the overall session that can be usefully analysed in semiotic terms so as to deepen our knowledge of students' meaning-making process. So, not only can activity theory very directly address one strand of the research question, it can also help answer the others and provide a basis for the selection of shorter excerpts that can be analysed in multimodal terms.

4.2 Overview of PBL sessions

The next six sections briefly review each of the sessions (see Table 4-1) and there is then a discussion of the overall PBL process. This provides an overview that places the subsequent analysis into context using the language and concepts of activity theory (see Section 2.3 and, in particular, Figure 2-4). This is then summarised in Section 4.3, first in terms of activity theory as a whole, then in particular in terms of the importance of the overall academic situation as providing a context for the meaning making and then in terms of the varying forms of interaction between the students and between the students and the facilitator.

The following terms are used to describe the building blocks to the overall PBL class. 'Class' is used to describe the totality of the PBL learning experience for the students (ie the five separate events considered together). Each of these separate events is called a session. Since the nature of these varied and, in particular, sessions one and three saw considerable directive input by the facilitator, these two sesions are also referred to as tutorials as they often operated in that mode, rather than the student-led approach to learning that is central to PBL pedagogy. Finally, the concept of problem is used to describe the task (the bridge design) set for the students in this particular PBL class.

Broadly, the sessions follow the logic of moving from a concentration on the theory behind the bridge design to a consideration of the practical steps involved in using the supplied materials and the test requirements. In addition, there is a transition from tutor-dominated discussions to the students working on their own (Session 4). The final session (five) is a review of the work to date and ends with the students agreeing to revise their model for the formal test.

4.2.1 Session 1 (16 September 2010)

This session lasted for just over one hour and for the bulk of the time the students were working on the mathematical problem posed by how to build a bridge strong enough to bear the weight that would be placed on it.. The session (referred to as Kevin Team 1) commenced with a presentation by the facilitator and was structured around students working on the mathematical properties of the bridge design.

Although the overall object of the session is the bridge design, at this stage the students were more concerned with working out the theoretical forces to be placed on the bridge rather than the physical design of the bridge. The students' problem solving is thus set by external requirements, in this case, of the academic task of designing and building a model bridge that will bear a set weight given the building resources provided, and in a particular the time available for this. However, within the session, especially towards the end, there is considerable discussion as to just what these rules are and how they will be applied.

The subject in this session is the group of five students. What is noticeable though is how often they worked as individuals or as sub-groups rather than as a coherent group (defined as all five students, or at least most of them, working collaboratively). The ongoing focus on solving a mathematical problem seemed to lead the students to working individually rather than collectively on this task. Across the session, the group dynamics varied as shown in Table 4-1.

Table 4-1: Group dynamics – Session 1

Type of Group Dynamics	Time (mins, sec)	Proportion of Session (%)
Group Discussion	9, 48	16.73
Individual Work	18, 10	31.94
Listening to Facilitator (whole class)	11, 47	20.24
Listening to Facilitator (only PBL group)	10, 01	17.67
Sub-Group Discussion	7, 06	13.41
Total	64, 00	100.00

In total across one hour and four minutes, the bulk of the student work was done either working as individuals or in sub-groups (see Figure 4-1). The students adopted an individualised approach to problem solving which may reflect their understanding that the goal of this specific session was to calculate the forces and angles that would be applied to their bridge once it was completed. Their time was split between periods of individual work, periods where part of the team were engaged in discussions, periods where the whole team was engaged in discussion and periods when the team was listening to the tutor (the latter including a formal presentation to the entire room and interaction with the particular PBL team under observation).

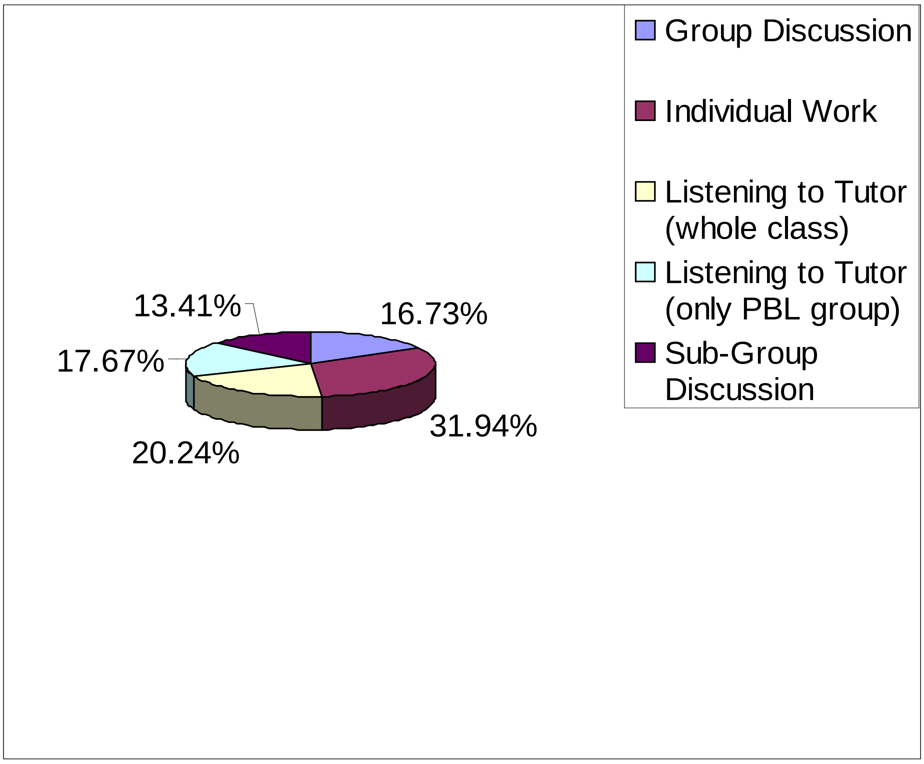


Figure 4-1: Student interaction – Session 1

Across the session the students used a number of tools in support of their problem-solving activity. The dominant tools for both recording their work and carrying out calculations were paper and pencil plus calculators. For the most part the students adopted the tools they needed at each stage. There were instances of use of textbooks, in particular with images of bridge designs that were then used to inform their calculations and design. The other main tool used was a whiteboard with an overhead screen showing relevant calculations. This was introduced early on by the facilitator (Timer 1.20-1.45) [2] to help PBL students carry out the required calculations, and consisted of notes and formulae as shown in Figure 4-2.

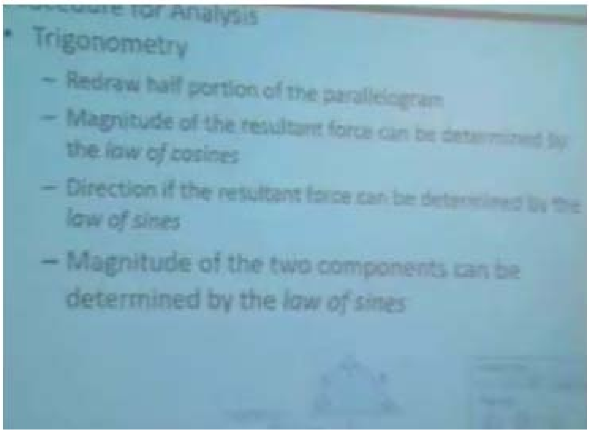


Figure 4-2: Whiteboard information

At various stages in the balance of the session, students refer back to this information either individually or as small groups. From Timer 16.00 onwards one student makes intermittent use of a laptop. At the start this seems to be to access information from a previous lecture. However, after 30 minutes, some of the team shift their focus to commence sketching out a bridge design. This sees some shift in the use of tools to include both Google and Web-CT information for examples of bridge designs as well as an increased use of the pieces of paddle-pop sticks provided by the facilitator. This search between laptop with images of bridges and physically

[2] 'Timer' refers to the camcorder's timer, and the numbers refer either to a point in time or indicate a range of time, as per the timer. For example, 16.00 means that some activity started or ended at 16 minutes, 00 seconds as per the camcorder's timer, and 52.50-58.40 means an activity lasted from 52 minutes, 50 seconds to 58 minutes, 40 seconds as per the camcorder's timer. For greater clarity, in the discursive text such numbers are preceded by 'Timer'. Since the recording of each session coincided with the beginning and end of the session, these times also coincide with the conduct of the session, such that an event marked 'Timer 16.00', for example, means it occurred 16 minutes into the session, and an activity marked 'Timer 52.50-58.40', for example, means it began 52 minutes and 50 seconds into the session and ended at 58 minutes and 40 seconds of the session.

working with the pieces of paddle-pop sticks becomes more dominant towards the end of the session and becomes the major tool being accessed from Timer 52.50 onwards.

Figure 4-3: Combination of laptop and bridge design

However, as above, at this stage, the students were not working as a group. The students testing design ideas were not looking at the laptop and the student with the laptop was not contributing to the discussion about bridge design.

The setting of the session rules was developed in various stages. An early input by the facilitator (Timer 1.15-1.45) emphasised the practical task issues and provided additional information for the students (as shown in Figure 4-1). This was followed by another Facilitator's input from around 22 minutes giving information regarding the timeline for completing the task and then a student discussion about the task process amongst themselves. This conversation was repeated in part of the group at Timer 30.25-31.20, for example at Timer 31.08: "*When are these due, next week or something*". The facilitator then provided a lengthy input on the task process and requirements at Timer 37.00-45.10 where he highlighted the importance of the design being able to handle the forces it would be subjected to. Typical of this is what happened at Timer 37.12:

> *What you're going to do is to build a bridge or a tower out of these paddle-pop sticks. You're only allowed to use the paddle-pop sticks or the glue. So the first thing that I want you to think about is how you're actually going to get a strong structure. Think back to that wire frame job.*

A final discussion of the rules (both the objective and the timeline) dominated the last 10 minutes of the session, where the focus was less on the theoretical forces and more on building the bridge to be tested.

This indicates a shifting community involved in the task. Although the five students were the problem-solving team (i.e. the subject), the facilitator intervened at different stages. Some of these interventions were addressed to the wider class (more than one PBL group was working in the room) such as at Timer 1.15-1.45, and at Timer 37.00-45.10. In each of these interventions, information was provided on the whiteboard and the focus was the theoretical knowledge needed for the task.

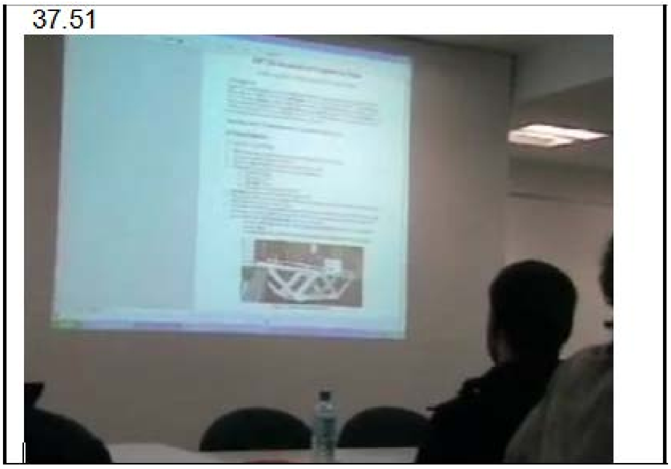


Figure 4-4: Facilitator's input – entire class

In addition there were a number of instances where the facilitator engaged directly with parts of the student group (in most of these some team members carried on working on their individual problem solving) such as at Timer 21.55-22.35 and most substantively at Timer 45.10-55.00 where at different stages he was engaged in trying to clarify the task and identifying the nature of the forces that the bridge would be subjected to.

Student discussion of division of labour (as opposed to carrying out the task) was limited in this session. It was not till the end, after Timer 57.10, that there was any discussion about how to organise the task to prepare for the following week and this was mostly in response to clear advice by the facilitator along the following lines:

> *The preliminary report is next week and then we'll see some sketches.*
> …
> *What you're going to do, yeah. I don't want you going and gluing stuff together when you've got no plans, no idea what you're doing. So think*

about what you're doing.

54.31

54.43

Figure 4-5: Facilitator-whole group interaction

What is clear in the opening session (Session 1) is the relative lack of group work between the students (at times one had asked the facilitator a question and others carried on with their own calculations) and their lack of clarity about the complete task. There were a number of interventions by the facilitator to ensure that students had some focus on issues such as design and the likely forces to be exerted on their bridge. In addition, the facilitator's interventions were intended to keep encouraging the students to think about the task rules and timelines. The absence of group working meant that the opening session was dominated by individual or one-on-one problem-solving activity and the various inputs by the facilitator.

4.2.2 Session 2 (23 September 2010)

The second session took place a week after the first session. In this session students continued to work on the mathematical aspects of the problem, but there was a greater focus on options for bridge design. However, student interaction both within the team and with the facilitator indicated uncertainty about the task they are undertaking. At the start there was a discussion between two of the students about the various tasks they are completing that included the following exchange:

> *The teachers, they haven't taught us anything but she just expects us to know all this crap. What does this… mean? …*
> *I'm not too sure, like I haven't done the class yet … she gets really angry."*

This session lasted just over 45 minutes. The object remained the same in that this session was part of the preparations to design and build a bridge capable of bearing a fixed weight. However, the specific focus shifted, with much more interest in different types of bridge designs rather than calculating forces and working with mathematical models.

The subject remained the same five students as before; however, for the first two and half minutes only two of the group were present. In this session, there was less individual working, but still relatively little all-group interaction. Instead the group regularly fragmented into small sub-groups (i.e. three to four students, but not the complete group of five) or one-on-one discussions. The group dynamics changed across the session as shown in Table 4-2.

Table 4-2: Student interaction – Session 2

Type of Interaction	Time (min, sec)	Proportion of Session (%)
Group Discussion	2, 01	4.62
Individual Work	15, 54	36.41
Listening to Facilitator (whole class)	0, 00	0.00
Listening to Facilitator (only PBL group)	9, 03	20.61
Sub-Group Discussion	16, 45	38.36
Total	45, 00	100.00

The PBL team interaction is graphically presented in Figure 4-6.

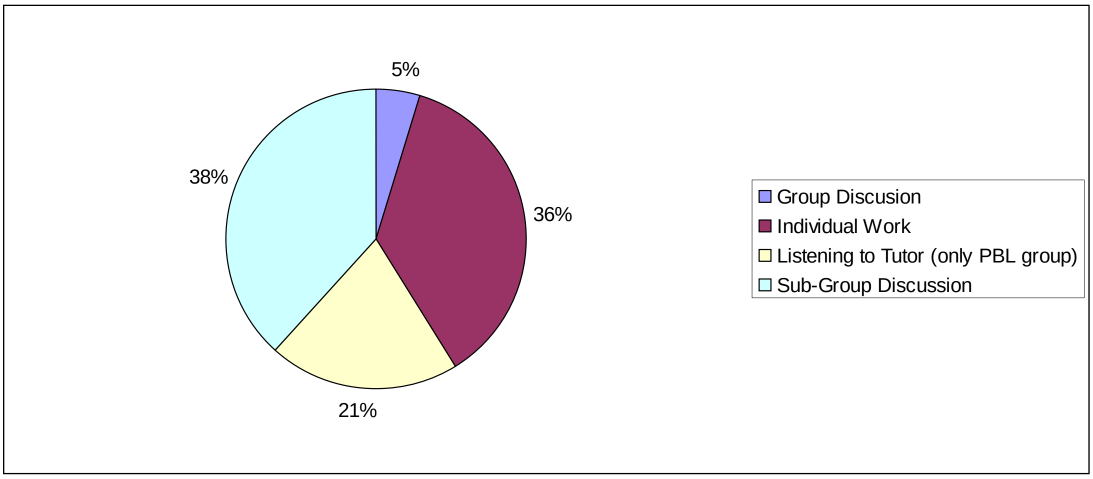


Figure 4-6: Student interaction – Session 2

For the first 18 minutes of the session, the students were mostly working individually or in pairs. There was then a very brief whole-group interaction about how to conduct the calculations, followed by another 15 minutes of mostly individual work with some one-on-one discussions (up to Timer 35.10). At that stage the facilitator joined the group for 5 minutes and led a discussion about the task requirements (while even at this stage some students continued to work on their own). The final minute was another group interaction about this new information.

Regarding the use of tools, at the start some of the group were producing detailed diagrams of bridge layouts and working with the paddle-pop sticks to test how this would work in practice. Other students in the group were either out of sight of the camera or reviewing their own notes. In this session, there was much more use of laptops and on-line resources to check calculations of forces and angles and to search for examples of bridge design. In general students made use of a broad range of tools, including drawings and calculations and exploring how to use the paddle-pop sticks and information they accessed from Victoria University's Web-CT than in the first session. This is returned to in more detail in Chapter Five, but different tools were used at different stages in the meaning-making process. In particular, the students made more use of the paddle-pop sticks when discussing the building of the model bridge.

3.39

3.45

Figure 4-7: Interaction of tools – Session 2

The session also showed considerable discussion of the rules for the task. There was a long discussion at Timer 5.10-9.55 where the bulk of the conversation was about how to carry out the task and what was being expected of them. Examples of this interaction included:

> *My plan on the holidays is to go through all those questions and finish everything, and get it back up to normal.*
> *If I email you next week, would you be able to send just the two assignments I've put in my portfolio.*
> *You should get onto that because that thing's hard.*
> *Yeah I remember last semester we were just like the last week flat out working every night…*

This was repeated at Timer 25.50-29.00 in a discussion with the facilitator, although in this case the focus was on the technical skills needed for the exercise, not about timing or work organisation:

> *So lab 2 question 2 was 26?*
> *One. So this last one is for question 2.*

Here the facilitator seeks to answer their questions:

> *What you've got is a whole lot of material, because this really is superimposed on EM1032, which was the previous introduction to design. So what we've made this as a PBL subject.*

This is one of the relatively few explicit instances of resemiosis (see Table 2-1) in the entire PBL module. Here the facilitator is referring the students to knowledge presented elsewhere as part of the framing of their meaning-making activity.

Regarding community structure, the PBL facilitator plays an active role in offering advice as to what the students need to concentrate on and the nature of the problem they are trying to solve. In particular at Timer 25.50-29.00 the facilitator is very involved in helping them to think of effective approaches to designing their bridge and at Timer 35.10-39.20 he is engaged in advising them about the types of forces they need to take account of. It is noticeable in this second session that while some students are engaged with the facilitator, others carry on working on their own. This is followed by the facilitator at Timer 39.20-44.40 focussing on how to use the paddle-pop sticks to design a bridge with the necessary strength to hold the planned weight.

Figure 4-8: Facilitator advice on bridge design – Session 2

The facilitator's demonstration of the use of the paddle-pop sticks was accompanied by a long, very directive input:

> *What it does is it makes a solid core and transpose what would have been a solid block into a core member which is just as strong – you want to make it just as strong. The test for something like this is two chairs and you can sit on it. Can you build it like that? If you look at the paddle-pop sticks, the paddle pop sticks are very strong in this direction and that direction, very weak in that direction. So if you lattice up the paddle-pop sticks into columns, you could probably build something that you could actually sit on. What you need to do is to look at the frame first of all. The frame should be very strong, with a combined surface area, that's got very good sort of joints. And the situation with the frame too is that you need somewhere for the trusses to fit into and not move, right? Because you don't want any distortion, any distortion and you'll get this. So what you need to have is a situation where these things can be put into a very strong frame. Whether you have partitions or whatever and then build it up, right…*

In this session the problem of how to categorise the role of the facilitator is an important aspect. He is clearly part of the community (comprising the students in the group under study, other groups present in the room and the facilitator) but at many stages he is also very involved with the student group (the subject). On balance it seems appropriate to describe him as part of the community not as the subject as he is not actually responsible for designing and building the model bridge, which remains the task of the student group. Nonetheless, he plays a very direct role in setting the rules for the bridge building task. This can be, as shown in the quotation above, focussed on the structure they need to ensure they have built a strong frame.

4.2.3 Session 3 (7 October 2010)

This session (Kevin Team 3) lasted just over 33 minutes and was dominated by input from the facilitator both for the PBL team under observation and more generally for the whole class. The principal focus was on practical design solutions to meet the set task. The central part of the session (Timer 16.15-29.00) consisted of the facilitator explaining good and bad features of previous designs (done by the previous year's students) and the likely flaws that would lead to a bridge failing the stress test. Therefore, as with the previous sessions, the object remains the design of a bridge that meets particular requirements. In this session, the focus was more on the practical options to design and build rather than theoretical calculations about forces and stress.

The subject remains the five-student team. Outside the facilitator dominated sessions, there was more evidence of intra-group interaction but this was still largely dominated by one-on-one or sub-group conversations rather than of the group as a whole (see Table 4-3). However, at two critical stages, following input from the facilitator (at Timer 13.20-16.15 and at Timer 29.00-32.00) the group engaged in problem solving around the nature of the task and what they had to do but this was done in engagement with the PBL facilitator. In this session there were no instances of the student group (the subject) engaged in shared meaning making that involved all its members except when led by the facilitator.

Table 4-3: Group dynamics – Session 3

Type of Group Dynamics	Time (min, sec)	Proportion of Session (%)
Group Discussion		0.00
Individual Work		13.8
Listening to Facilitator (whole class)		37.69
Listening to Facilitator (only PBL group)		44.17
Sub-Group Discussion		4.34
Total		100.00

This can be represented graphically as in Figure 4-9.

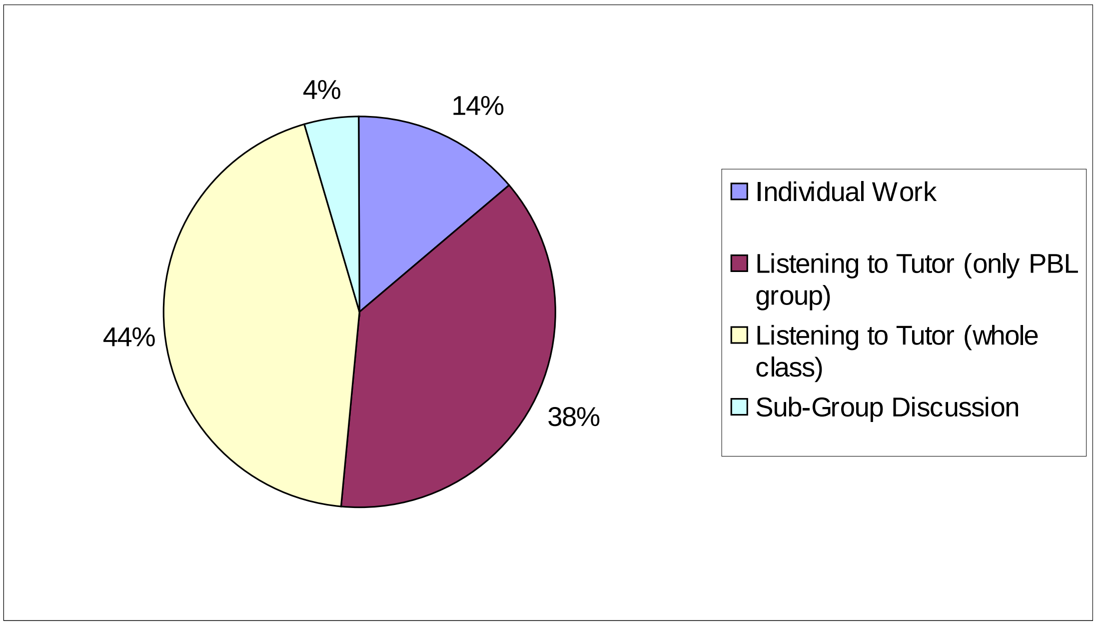


Figure 4-9: Student interaction – Session 3

The use of tools and learning resources changed from the previous sessions. There was still much reliance on paper drawn diagrams and the use of calculators to carry out calculation but there was more use of information obtained by using the laptop to surf the Internet and of information provided on the whiteboard. Particularly, the latter was used to provide information of successful and unsuccessful designs by previous groups carrying out this specific task.

The discussion about the rules broke down into three elements. There was still an ongoing discussion of the nature of the task and what was required (at Timer 3.40-4.15) and the last part of the session was dominated by a discussion (at Timer 29.00-33.35) of what needed to be done for the next week, the timeline and the nature of the report that the students needed to complete both individually and as a group. In addition there was a discussion with the facilitator at Timer 6.40-8.05 about the nature of the forces that would be applied to the bridge. The final aspect of rule setting was the group as a whole enforcing silence so they could ‘listen’ during the long presentation by the facilitator. Accordingly, the rules encompassed the boundaries of the task, information needed for the task and an imposed form of behaviour (i.e. being silent to listen).

The community in this session was as in previous sessions and included the other PBL teams and the facilitator. The facilitator directly led some 50% of this session and was active in guiding student reasoning and providing detailed instructions throughout the session. Typical of the role of guiding the student group was this input at Timer 6.42-7.09:

> *Because what you’ve got is another force, right the other force which is sine. I’m not doing it for you, I’m telling you the way that that’s resolved. Because that must be the way that it’s been resolved in terms of the particular direction of the force. Work it out in terms of the direction of the force.*

There were two types of division of labour in this session. First, the facilitator was much more directive in this session than previously, both in terms of volume of input and in the extent of direct engagement with the PBL team. The final part of the session also showed that the students divided the remaining work tasks between themselves, seeking times when they could meet as at Timer 33.11: “*Monday, like we only have an hour break there, but I don’t have (…)*”.

4.2.4 Session 4 (11 October 2010)

It should be stressed that this session (Kevin Team 4) was different to the other four. In particular, only two of the students were present and the focus throughout was on actually building the model bridge and testing out design options. The overall object remained the same. However, in this session there was a specific object, which was to test options and decide on a bridge structure. The session lasted for just under 43 minutes but the last 8 minutes were marked by a loss of focus on the task with the conversation shifting between the overall course structure and personal issues as at Timer 42.28:

> *No that's all right. Yeah I'll do that tonight. I was meant to be getting a new phone and I called them up to cancel it today. I called them up to cancel my contract yesterday.*

There were only two of the students were present. The session can be seen as highly practical problem solving and testing of design options with some reference to the sketches they had prepared earlier. At least three different design phases occurred, with one design being developed at Timer 1.55-12.20, a second one at Timer 12.20-19.55 and the final design worked on at Timer 19.55-26.40. This session also showed a shift between a concentration on the design of the struts, of the base and of the overall shape.

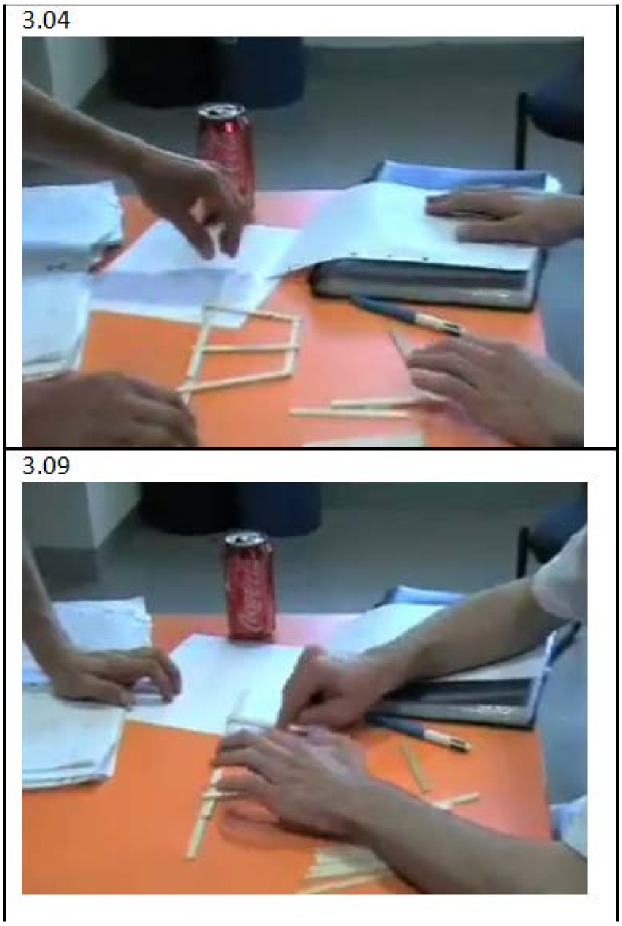


Figure 4-10: Process of bridge design – Session 4

The next stage showed more of a focus on the base of the bridge and integrating this with the struts as shown in Figure 4-11.

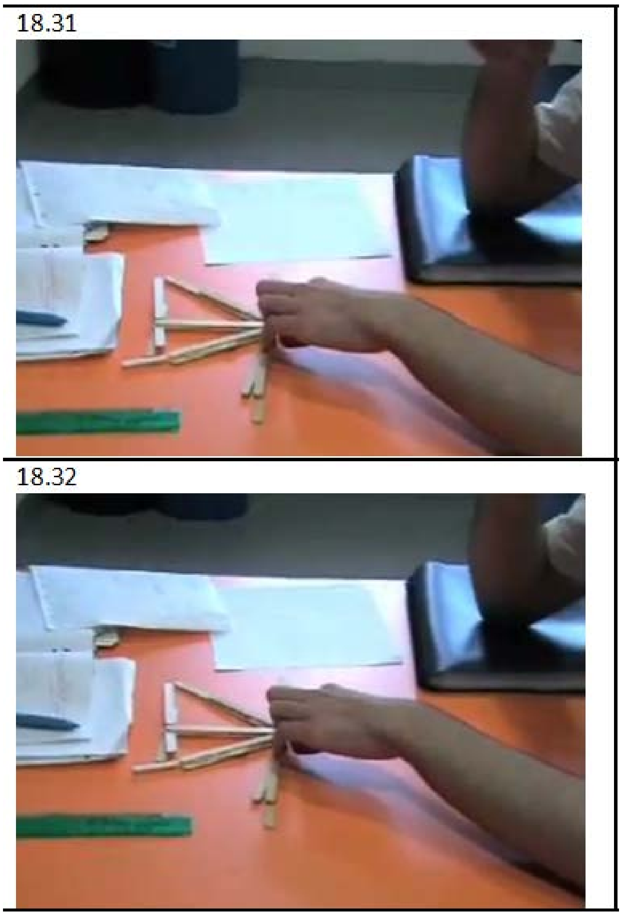


Figure 4-11: Bridge design – Session 4

In this session, the students utilised a number of tools. Some reliance was placed on hand drawn diagrams (notably no reference was made back to the earlier calculations); a ruler was used to demonstrate potential design and a mobile phone was used twice to take pictures of potential designs as this developed.

Towards the end of the session (at Timer 26.40-32.50 and at Timer 37.45-42.50) there was a discussion about the task rules. This covered what they would both do before the next group meeting, how to structure and lay out the reports and a final discussion of the overall process. In this session, there was no clear division of labour between the two students, and they shared the design process between them.

4.2.5 Session 5 (21 October 2010)

This final session (Kevin Team 5) lasted just over 35 minutes and mostly consisted of the two students from Session 4 discussing their bridge model with the other three students in their group and with the facilitator. The object of this session remained the same as it had been in the previous sessions of building a bridge that can meet the requirements identified by the facilitator such as bearing a given weight without distortion.

This session was dominated again by interaction between the subject (the student group) and the facilitator. The focus of this was mostly the model bridge that had been prepared and designed.

Figure 4-12: Model bridge – Session 5

This bridge design had been partly completed between Session 4 and Session 5 (see Figure 4-12) and appears to take little account of the theoretical work undertaken in the first two sessions, the practical advice given in Session 3 regarding what type of design was most likely to work or even the discussions between the two students and the approach they planned to take during Session 4. Across this session, the student group varied between listening to the facilitator (at Timer 9.45-13.10) and members of the group having discussions (at Timer 5.30-9.45 and Timer 16.30-21.00), interspersed with periods of individual working.

Table 4-4: Group dynamics – Session 5

Type of Group Dynamics	Time (min, sec)	Proportion of Session (%)
Group Discussion	0, 35	1.11
Individual Work	1, 45	4.61
Listening to Facilitator (whole class)	0, 0	0.00
Listening to Facilitator (only PBL group)	16, 26	42.59
Sub-Group Discussion	13, 40	51.68
Total	35, 00	100.00

The distribution of PBL group and class dynamics is also shown in Figure 4-13.

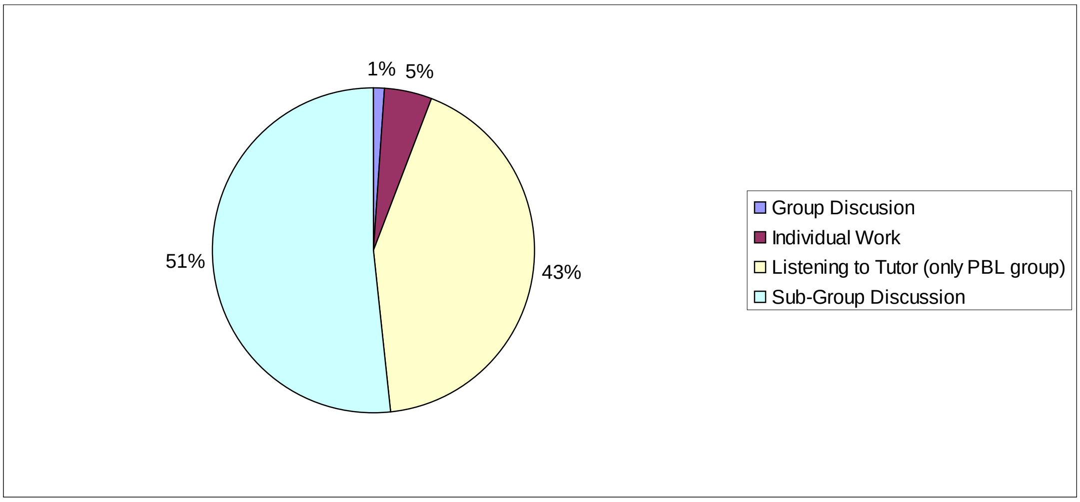


Figure 4-13: Student interaction – Session 5

The tools used included the partly completed design, information found on the Internet and in Web-CT, the students' design drawings and paper-based calculations.

Discussion of the rules was ongoing. The first 35 seconds were spent discussing what needed to be done to complete the task. From Timer 3.35 to 4.45, the discussion concentrated on the required report structure.

Regarding community, as in Session 3, there was substantial involvement by the facilitator. From Timer 9.45 to Timer 13.10, the facilitator provided another long explanation of how to calculate the forces that would be applied to the bridge and how this should have influenced their design. Later in the session (Timer 22.10-29.00) the facilitator spent a considerable time explaining why the planned model bridge was not likely to pass the stress test. This in turn led to a discussion with the student group (Timer 29.00-31.50) about different design approaches. Finally the student group returned to an internal discussion about the information provided and the task requirements (Timer 31.50-35.15). The main shift in terms of division of labour was the very active, often directive, intervention of the facilitator, in particular at Timer 22.10-29.00 when discussing why the prepared model was likely to fail the test.

4.3 Analysis

4.3.1 Overview

Activity theory has been used to discuss the overall session as it has a focus on the problem-solving and meaning-making activity of the student group and how this is mediated by the task, tools and surrounding issues (i.e. community, division of labour and rules). Following activity theory, as discussed in Chapter Two, the structure of the meaning making within the PBL session can be set out as shown in Figure 4-14.

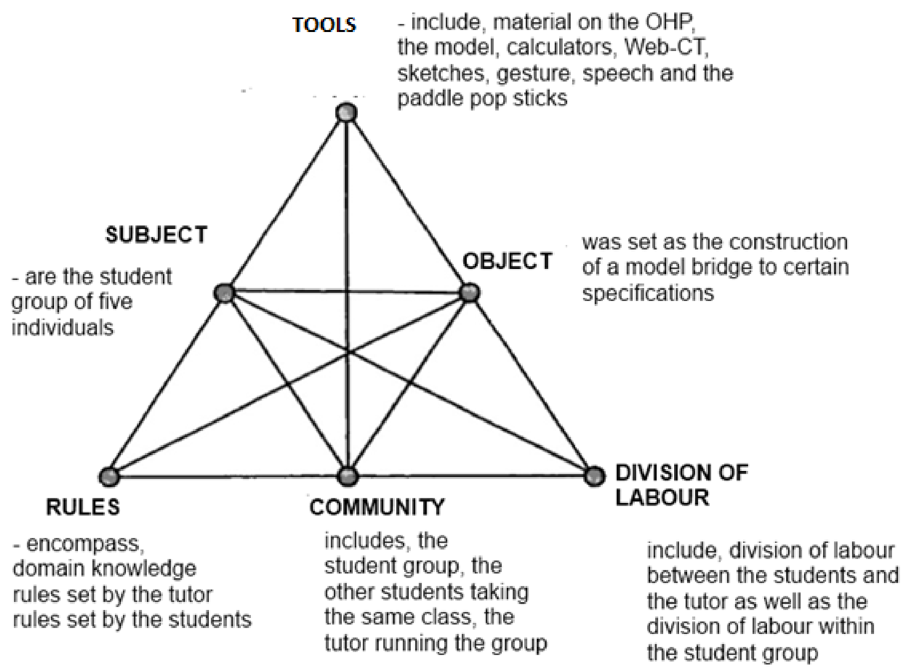


Figure 4-14: Representation of meaning making within PBL session

Figure 4-14 presents a summary of the entire session and brings together all the constraints and tools available to the student group, giving an indication of how both the task and the process of meaning making shifted over time. Thus while the underlying task (designing a bridge to meet certain specifications) was common, the particular task in each of the sessions slowly shifted (but with some overlaps and returns to earlier discussions) from the underlying theory, to sketching potential design solutions, to model-building. Almost in parallel with this, the community (i.e. the wider group that influences the meaning making of the subjects) also shifted steadily. This is most clearly exemplified in the role of the facilitator who commences in a role of providing overall advice on the nature of the task and the information the group needs (thus setting the rules). However, by the final session, this has shifted to him making a very direct critique of the design produced by the students.

Another overall issue is that the shift in problem solving is not linear. As is to be expected when faced with a complex task there is a degree of going back to earlier material. On the other hand, it appears that when the students move onto exploring bridge designs (Sessions 3 and 4), in particular in Session 4, there is only limited evidence of referring back to the earlier theoretical calculations. The process of experimenting with the design by the students in Session 4 is essentially one of trial and error and based on visual not theoretical reasoning. This was a strong feature in Session 4, and one reason for the selection of a stage in that session of detailed multimodal analysis. This process of practical problem solving may also be seen in the bridge designs explored in Sessions 3 and 4 (see in particular Figures 4-8 and 4-11) and in the model that brought to the final group session (see Figure 4-12).

The other feature brought out by using activity theory is the shifting nature of problem solving by the group. At each stage the dominant form of student activity is either that of individual problem solving or of small sub-group (usually one-on-one) discussions, rather than any engagement in whole-group problem solving. Especially in Session 1 the use of different tools by the students is fragmented as the student with the laptop does not share his information with other students in the group (this student seems to be treating the PBL task as a personal learning exercise). Mostly the students seek to understand the equations (see Figures 4-1 and 4-3) on their own, with some interaction to test their ideas.

The final issue is the role of the PBL facilitator. This has already been discussed in the context of discussing individual sessions. The division of labour between the main student group and the facilitator is complex and shifting. At the start, the facilitator adopts the role of information provider and offers contextual information. The students have the role of completing the object of the set task. In the first two sessions, this distinction is maintained by the facilitator, but over time, his role shifts. In the third, and most clearly, in the fifth session, he has become much more directive about what the students need to do and critical of progress so far. In Session 2, at Timer 35.19, he states "*There's some major problems there. This sort of scene here is a major problem. … . Well the problem there is here, and you're going to have a problem there on the truss*". On reviewing their progress towards the end of Session 3, this has become, at Timer 29.30: "*Yeah you need to give consideration to that, I mean this tells you nothing. Well I'd lift that out and sort of throw it into the rubbish, that's what I'd be doing. So what have you actually done? How many bridges are you building*?" The comments have shifted from offering advice to directly commenting on the design approach being adopted.

There is very little structured division of labour within the student PBL team in the first three sessions. In many sessions, they work as a set of individuals with limited interaction although on occasion one or the other will provide an explanation or lead the discussion, and this role shifts around the group. Session 4 is the first time a clear intra-group division of labour can be observed, with just two students meeting to discuss how to build the actual model. This model (bridge) is then prepared between Sessions 4 and 5 and brought back to the full group. This preparation of the model was not observed but the decision that one student will work on it was agreed late in Session 4, at Timer 23.13:

> *Unless, do you want to do the report and I'll see if I can do this, try and do the whole thing. And you be the one to do the report. No, I don't mind doing it, it's not that – because I hate report writing. … Yeah I've got no problem with doing the bridge if you're cool doing the report.*

This is followed by agreeing to a timeline, at Timer 30.54:

> *Yeah for sure, because I've got tonight. I'll work on it tonight and if I don't get it finished tonight, I'll definitely have it finished Tuesday night. And then I might start gluing a couple of these together. Even instead of doing five, I'll get three at the start, just to see how it is and then we'll build up on that.*

On balance, an activity theory analysis of the complete session indicates that it is likely that the bridge designed between Sessions 4 and 5 bears little resemblance to either the theoretical discussion of forces that will be applied to the bridge or the empirical discussion of different bridge designs. Even in Session 4, the two students building the bridge are laying out a very different organisation of the struts than was obviously adopted before the final session.

Figure 4-14 presents the PBL class in terms of Activity Theory and from this a number of key themes can be identified. The balance of this section concentrates on what can be understood about the interaction of context and the problem solving process (4.3.2), the different ways the students interact, within their group (4.3.3.1) and with the community (4.3.3.2), together with tool use in the meaning making process (4.3.4). Finally, the process of meaning making and knowledge development is addressed (4.3.5).

4.3.2 Importance of context in the problem-solving process

Although activity theory can be used to analyse the whole meaning-making process (a point developed in Section 4.3.3), a key goal in this research design was to follow Jewitt (2006) and use it specifically to understand the context, and the constraints that mark (Mutton et al., 2010) the meaning-making process. Following the discussion in Section 4.3.1 this is encapsulated in the context of the rules, and here the rules can be seen to form two different aspects of the meaning-making process:

- They set the focus, constraints and criteria (i.e. this is an academic task with fixed resources, a fixed timeline and predetermined assessment process); and
- They set how this task will be carried out (i.e. who will do what and when so as to meet the requirements of the object).

The concept of the rules as setting the wider environment and as a constraint on meaning making is developed relatively early in the first session above, by the facilitator:

> *Of course it will, you need to know what your calculator is doing. Okay, now there's a problem here, this particular problem is an example problem with a solution and he's used the cosine sine and cosine and in order to work out the result. (Facilitator's input, Session 1, Timer 1.18)*

However, later in the first session, he makes a further presentation that explains how the university's rules create a timeline and a set of task requirements. The first stage of this is designed to stop the students working just on the mathematical properties of the problem in the period of the formal classes: "*Guys, you need to finish this work on your own time*" (Facilitator's input, Session 1, Timer 21.56). Here we have two related uses of the rules: one sets down the process that will be needed to carry out the task and the other is an instance of where the rules are used to specify when (and where) that task should be carried out.

After 30 minutes of the first session, the facilitator joins the student PBL group and commences a discussion of who will do what to ensure the task is carried out. This starts with "*Now what we're doing guys is sorting out the technical design challenge of bridge building, so there's going to be a team of four – how many is here?*" (Facilitator's input, Session 1, Timer 30.33). In the course of arranging the students to work on the bridge design one student points to the calculations they have been making and asks, "*When are these due, next week or something?*", to which the facilitator responds, "*It's your homework*" (Facilitator's input, Session 1, Timer 31.17). So again, we have an instance where the rules are setting the nature of the problem-solving task (not just how the students will be organised to carry out the set task but also how they need to organise their learning). In this instance there are two aspects to the rules being resolved: the facilitator is imposing a task structure to carry out the bridge and a student is checking if a particular task needs to be done in the time set aside for the formal PBL classes.

Some five minutes later the facilitator returns to the group and this time commences an explanation that sets out the work they need to do, how to do it, what resources to use and when. Typical of this are the following quotations:

> *All right guys, can I have your attention please.*
> *Guys – we need to just go onto the next section which is just to describe the 20% task which you need to do for this subject, which is the third technical design challenge. The solutions here guys are all on Web CT, they're hidden at the moment, so [named individual] will inform you when she's going to unhide them. I think she'll unhide them every week or something. Now the situation with the bridge design, it's on Web CT. What you're going to do – I'll bring it up. I am bringing up the details.*
> *Okay, so the details of the bridge, please – attention just for ten minutes or so and then you can go back to your work.*

What you're going to do is to build a bridge or a tower out of these paddle-pop sticks. You're only allowed to use the paddle-pop sticks or the glue. So the first thing that I want you to think about is how you're actually going to get a strong structure. Think back to that wire frame job, the way that you actually, or the mentality that you needed in order to get a proper structure that was going to win the prize, and someone knocked off the prizes, so I'm not sure whether there's going to be a prize around for this one or not. (Facilitator's input, Session 1, Timer 35.59)

Here we have an explicit example of how the rules set and frame the PBL task. The students are expected to build the model bridge using specific tools ("*the paddle-pop sticks or the glue*") and they are expected to think back to an earlier PBL class ("*Think back to that wire frame job*"), i.e. an instance of resemiosis as information is brought in to help frame the current meaning making. Also, in this session the students are given the rules ("*20% task which you need to do for this subject*") and one possible reward ("*going to win the prize*") for the task. The process of the facilitator setting out the task rules continues with the following:

All right, so how are you going to get a very strong bridge, because the way this bridge is going to be tested – it's 500 mm span, so it's quite a span and it's going to have load applied at the centre in the Instron machine there to deform it.
And once it's deformed, then it's been [inaudible]. So you need to have everything very rigid in terms of your bridge. The bridge really is composed of a frame and a truss. The frame – think about the strength that you're going to get out of paddle-pop sticks and glue. You need to get a fair bit of surface area for a bonding for attachment to make it strong. The more paddle-pop sticks that you bind together.
(Facilitator's input, Session 1, Timer 38.38)

Here again, the task rules are used to set out the criteria, both how the bridge will be tested and how they need to use the paddle-pop sticks and glue to construct it. This presentation on the technical part of the expectations carries on and then the facilitator shifts to using the rules to set a timeframe:

So what I want to see next week from you – don't go using the paddle-pop sticks and sort of ruining them before you know precisely what you're going to do. What I want to see from you next week and indeed, I'll come around to the groups now just to explain some of the concepts, but I want to see some preliminary drawings, prelim sketches. (Facilitator's input, Session 1, Timer 41.35)

In this case, the rules set by the facilitator are used in a different way, setting out what the students now need to do (and what they should not do), and giving them a timeline. This is then followed by a discussion both about the organisation of the students within the groups of five and the need for them to be frugal in the use of resources:

> *The idea is to have two or three students per bridge in groups of about four or five, because we really don't need to distribute too many bottles of glue. Okay, you're not paying for them this time, so we've got to be pretty easy, light on with the glue – so share the glue. (Facilitator's input, Session 1, Timer 42.46)*

The final part of this opening rule setting sequence instructs the students not to use too many of the paddle-pop sticks, that they must develop an elegant design rather than one that relies on brute strength:

> *Listen guys, there's a number 275 paddle-pop sticks, now glue doesn't weigh much, so in the test procedure. The bridge is weighed. So if it's too bloody heavy it won't even get tested, you get fail. So be careful of the paddle-pop sticks, make sure that you don't go over the 275, right, and that you don't build a structure, it's like the wire frame job, the structure was so small, like a jewellery box, it could take 70 kilos but the volume wasn't there so you didn't win any prize. Here it's going to be weighed and loaded, there's a penalty for weight. (Facilitator's input, Session 1, Timer 44.03)*

Across Session 1, there is a steady repetition and development of the rules and the way in which those rules actually define the task the students will carry out. They are provided with theoretical approaches to use, a timeline and the immediate task, told what the assessment procedures are, how their model will be tested and what the limited resources are that they will have to build it.

This final presentation though is followed by a sequence of discussions among the students as they seek to process the information. Some of this is connected with what will be assessed at which stage, for example "*We have to show him a reflective as well. In two months*" (Student E, Session 1, Timer 45.54), leading to "*Two months?*" (Student A, Session 1, Timer 46.26) and "*No no no no, for the report, for the second report*" (Student B, Session 1, Timer 46.30). Shortly after this exchange, there is a discussion about what was meant about the number of paddle-pop sticks available "*Do you reckon this will be enough?*" (Student E, Session 1, Timer 47.17).

Here the student had picked up the bags of paddle-pop sticks provided. Student B then responds with "*We've got two packets each*", Student E responds "*Two Packets?*" and B completes the exchange with "*Two packets per group*".

There are further instances of discussion of the rules in later sessions as the students seek to understand what is expected and the facilitator offers guidance on the task. Some examples of this include the following exchange from the second session where again the facilitator is explaining the requirements for the model bridge:

> *The frame has got to span 500 mm it's going to be reasonably big. 500 mm is half a metre, 50 cm and you will need the frame so that it's strong. (Facilitator's input, Session 2, Timer 54.31)*

Here, the students are presented with more constraints for the task, i.e. that the bridge has to be a certain length in order to meet the test requirements. This discussion is analysed in more detail in Tables 5-11 and 5-13 as it was selected for closer multimodal analysis, but again there is a short interaction that indicates student uncertainty about the rules with "*So there's 300 pieces here you get to use?*" (Student A, Session 2, Timer 55.52), with the facilitator responding "*275*" and Student E seeking more clarification with "*What's the maximum?*". This final comment could be an instance of a student seeking clarity as to the rules (i.e. exactly how many paddle-pop sticks to use) or testing the boundary created by the facilitator (i.e. they are fully aware they are meant to use no more than 275 but are seeking to understand if this is more flexible than it seems).

As noted above, the fourth session that was video-recorded is unusual in that only two of the students were present and that they spent most of the time working on practical layouts for the bridge design. However, interspersed across this session are a number of discussions about their understanding of the rules. Two students elaborate and test the rules set by the facilitator with comments such as, "*What time is it due – when is it due*" (Student A, Session 4, Timer 22.24) and the way in which the work for the PBL class intersects with the other aspects of their programme of academic study.

The rules that define the PBL task are important in understanding the meaning making that took place. Some of these rules, as above, are concerned with the academic marking scheme in use and the overall timeline. Others set out the core aspects to the design: it must use less than 275 paddle-pop sticks, have a span of 500mm and be able to bear a set weight without distorting. Finally the rules are also used to determine what needs to be done in what order, so, for example, the students are told to prepare sketches first before they start to glue the paddle-pop sticks together.

4.3.3 Summary of forms of interaction

4.3.3.1 Student interaction within group

Student interaction within group has been a significant theme in the discussion above. Three modes of student interaction were identified:

- Individual working;
- Sub-group interaction (i.e. some of the group engaged in discussion but not all the group); and
- Whole-group interaction

Session four (see Section 4.3.4) is unusual in that only two students were present (working on the bridge design) and meaning making across that session was shared. The other four sessions mostly had all five students present (in a few some arrived late or left early); the time spent on each type of interaction is given in Table 4-5.

Table 4-5: Time spent by students within 'group interaction' by session

Students' Work	Session 1 (min, sec)	Session 2 (min, sec)	Session 3 (min, sec)	Session 5 (min, sec)	All (min, sec)
Individual	18, 10	15, 54	4, 30	1, 45	39, 9
Sub-group	8, 0		1, 25	16, 26	41, 56
All group	9, 48		0, 00	0, 35	12, 24
All in-group time	35, 18		5, 55	18, 06	60, 55

Graphically the time allocations can be represented as shown in Figure 4-15.

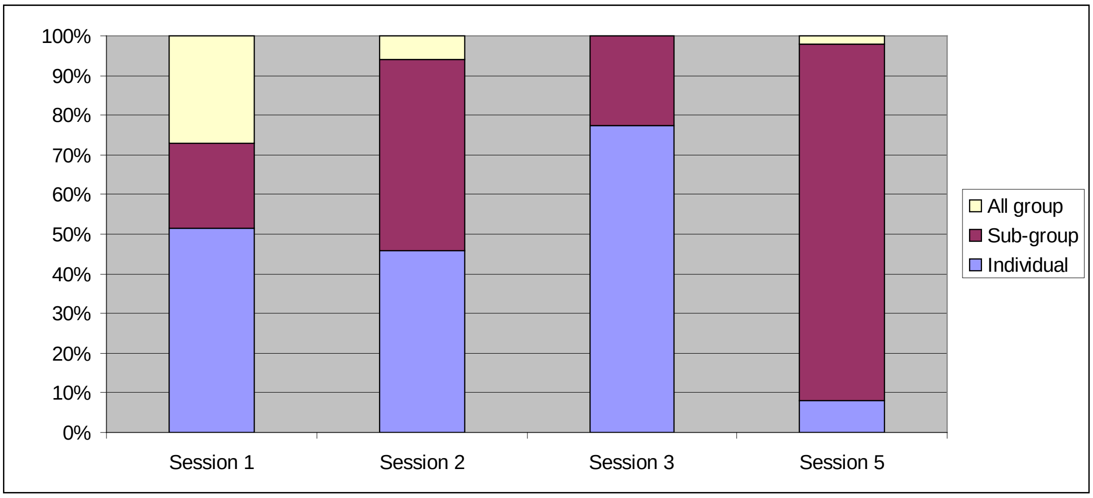


Figure 4-15: Student interaction by session

From both table and figure it is clear that the level of interaction changes across the sessions. All-group interaction is always rare, and mostly only occurs in the first session. However, the extent to which the students engage in individual meaning making or sub-group meaning making varies from session to session. Sessions 1 and 2 (see Sections 4.3.1 and 4.3.2) saw a gradual transition from the students being focussed on the mathematical properties of the problem to an engagement with the various design options that would make use of this knowledge. Session 3 (see Section 4.3.3) was largely dominated by a long input by the facilitator to the entire class. Most of this was concerned with the model design (so there is a gradual shift from theory to practice) and the students worked individually around these facilitator-led inputs.

Session 5 (see Section 4.3.5) was again dominated by interaction with the PBL facilitator. However, in this case he was working with the particular group being studied and the focus of these discussions was the model of the bridge that had been prepared by one of the students between Session 4 (see Section 4.3.4) and Session 5. The consequence was that when the facilitator was not present, several of the students were engaged in discussion about the information presented and what to do with their model.

In one sense the shift of in-group mode (from individual to sub-group meaning making) reflects the shift of the information and the focus from theory (calculating forces, angles, etc.) to practice (how to design the model). Although there are instances of shared meaning making in the early stages (and some of these are analysed in detail in Chapter Five), for the most part the student response to the theoretical presentation of the problem was to work as individuals.

4.3.3.2 Student interaction with community

This section reviews interaction between the student group (i.e. the subject) and the community (in this case the PBL facilitator). It is possible to divide students' meaning making into two types, that conducted within the group and that conducted with the community. As discussed in Sections 4.3.3 and 4.3.3.1, engagement with the PBL facilitator can be further subdivided into time spent with the student group and presentations to the entire class. In this case in-group working is the time allocation discussed in Section 4.4.2.1 and the balance of the time was spent interacting with the PBL facilitator in one way or another. Again, Session 4 is excluded as there were only two students present at that stage. The result of this attribution is shown in Table 4-6.

Table 4-6: Student interaction with community

Type of Interaction	Session 1 (min, sec)	Session 2 (min, sec)	Session 3 (min, sec)	Session 5 (min, sec)	All (min, sec)
In-group working	35, 18	34, 00	5, 55	18, 06	60, 55
Group-PBL facilitator	11, 47	9, 03	12, 18	13, 40	46, 08
PBL facilitator-whole class	10, 01	0, 00	14, 25	0, 00	24, 26

This interaction is shown graphically in Figure 4-16. Again Session 4 is excluded as the entire session can be characterised as in-group working between a portion of the student group (i.e. the two students who were present during this session).

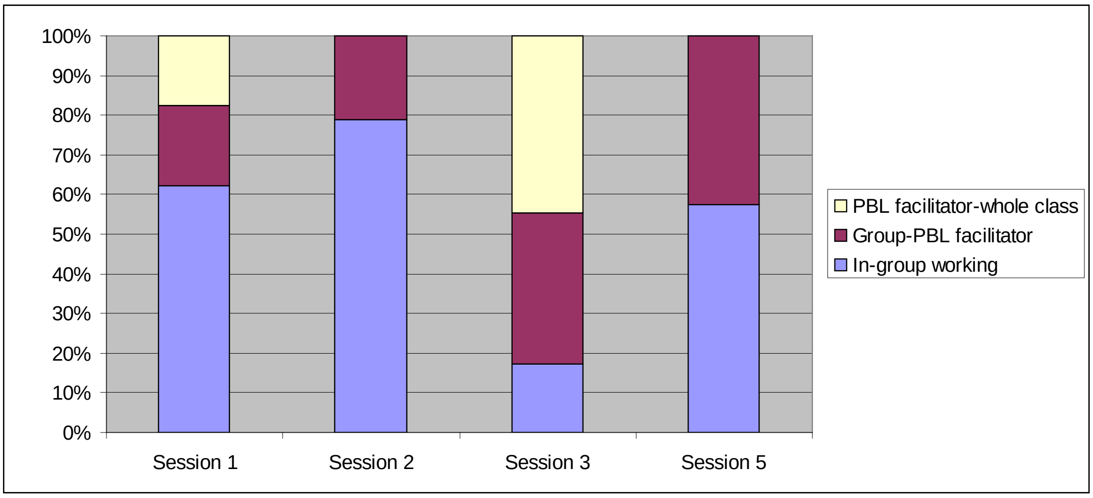


Figure 4-16: Subject-community interaction by session

Across the four sessions, both the extent of engagement with the community as and its nature varies. As discussed in Section 4.3.3, Session 3 was mostly dominated by a long presentation by the facilitator to the entire class. What is also clear from Figure 4-16 was the relative dominance of interaction with the facilitator to students' meaning making in that entire session, with less than 20% of the time spent purely within the PBL group. In turn, Session 5 was not just dominated by shared meaning making (see Section 4.4.2.1) but also by meaning making in interaction with the PBL facilitator (see Section 4.3.5).

4.3.4 Tool use

Tool use across the five sessions also follows this broad progression from understanding the underlying theory to model building and testing. In Session 1 (see Section 4.3.1) the dominant tool use by the student group was paper, pen and calculators as they sought to estimate the angles and the direction of force. There were some instances of accessing textbooks and the information placed on the whiteboard by the facilitator (see Figure 4-2). Towards the end of Session 1, there was a shift of focus to design of the model and this in turn saw some use of a laptop (see Figure 4-3) and the paddle-pop sticks.

In Session 2 there was more use of the paddle-pop sticks (see Figure 4-7) as the students mix a discussion of the model design with theoretical consideration of the task. Towards the end, when showing the students how to design their model, the facilitator makes considerable use of the paddle-pop sticks in meaning making (see Figure 4-8). Thus in general, when the focus is on the theory, the tools are paper and calculator plus information sources (textbooks and OHP images), but as it shifts to the practice of model building, different tools are accessed to sustain the meaning making (discussed in more detail in Chapter Five).

In Session 3, the main tools are the whiteboard/OHP display presented by the facilitator. In addition the students have sketched out potential designs and there is use of the laptop to access images of bridge designs. In turn, Session 4 sees considerable use of the paddle-pop sticks as the tools to explore potential designs. This can be seen in the transition from Figure 4-10 to Figure 4-11, where different layouts are created as the students explore the problem space. Again this insight has driven the selection of sessions for Chapter Five. Session 5 was focussed on the bridge model as the main tool (see Figure 4-12) and the various sketches the students had prepared. In turn, the paddle-pop sticks were often accessed by students and the facilitator to indicate variations to the prepared design.

4.3.5 Meaning making and knowledge development

Meaning making and knowledge development again is a theme returned to in more detail in Chapter Six as it requires consideration both of trends across all five sessions and a focus on the multimodal nature of the meaning-making process. The end point (the object) is to design a model bridge that is theoretically sound and meets the imposed task limits (the number of paddle-pop sticks available were limited). As discussed in Sections 4.4.2.1-4.4.2.3, there is a progression across the sessions from a focus on the theoretical underpinnings to a focus on the practical task of model building. These are often mixed together (which is explored in Chapter Five) but by Session 3 the student group (subject) is engaged more with the model building than the underlying theory. This, in turn, places the focus on the shifting nature of the bridge design.

This starts in Session 1 (see Figure 4-3) with the facilitator using the paddle-pop sticks to indicate the layout of the bridge and the nature of the force it will have to bear (this particular excerpt was selected for more detailed analysis in Chapter Five). In Session 2, the students are seen sketching out potential layouts and experimenting with the paddle-pop sticks. Figure 4-8 shows the facilitator using the sticks to indicate part of the design (in particular the struts needed to bear the weight). Session 3 is dominated by a long presentation on the bridge design and examples of successful and failed model designs. Session 4 sees two of the students developing and changing a potential layout (see Figures 4-10 and 4-11), and, again, this is returned to in more detail in Chapter Five, as they experiment. However, between Sessions 4 and 5 one of the students built a model bridge (see Figure 4-12) that bears little resemblance to the advice received in Sessions 1-3 or their own experiments in Session 4. The facilitator indicates that in his opinion this final design will not meet the stress test when the weight is placed on it.

4.4 Selection of excerpts from sessions for multimodal analysis

Another reason to use activity theory in this context is that it provides an overview that can then be used to select particular sessions for multimodal analysis. This selection can be informed by a desire to both select examples that are typical of the range of meaning making and that exemplify particular themes. Thus the empirical approach to bridge design in Session 4 adopted by the students is analysed in detail by selecting a key excerpt. Table 5-1 sets out the logic for the seven excerpts that were selected. These capture the progression from discussion of the underlying theory to model building, periods when the facilitator was dominant (either presenting to the entire class or interacting with the student group), and these allow a tracing of the development of the model. These address both the research questions not covered in this chapter and deepen the analysis by adding a multimodal approach to the activity theory analysis adopted so far. The intention in Chapter Five is thus to present a detailed multimodal analysis of the shifting meaning making within the PBL class, developing the themes set out in Section 4.3.

4.5 Summary

This summary briefly pulls together the analysis in this section in the context of the four specific research goals for this thesis. This summary is then mirrored in a similar analysis at the end of Chapter Five and forms the basis for the longer discussion of the implications of the empirical findings that forms Chapter Six (effectively bringing together Chapters Four and Five and the material in the literature review in Chapter Two).

4.5.1 Importance of context

The importance of context has been covered in some detail in Section 4.3.2. Jewitt suggested that this part of the analysis of any educational process gains from adopting elements of activity theory (Jewitt, 2006). In Section 4.3.2 it is stressed how the context and the rules surrounding this task are critical in framing the student meaning-making task. This is not the same as the theoretical material that is covered but instead sets out how the particular activity is to be conducted and how the meaning-making process can be understood in the context of this PBL class. At various stages, rules are set that indicate how the work will be assessed (directing students' attention to the relative importance of the sub-parts of the task, including the actual model construction, their logs and report on the academic task); what they need to do and when (sometimes, again this breaks the overall task down such as the instruction to complete sketches between Sessions 1 and 2); how the bridge should be built (length, the fixed resource they have available); and how it will be tested. Thus at one point (session 1, 21.56) the stress is on how they will have to work outside the scheduled classes, followed by (session 1, 30.33) instructions about how they are to work as a group on the task. Later on (session 1, 35.59), the rules for testing the task are set out as well as the resources they can use for building their model.

Thus what we observe is this particular student group carrying out this particular task with its own unique set of rules. So the meaning-making process may not be typical of a different group doing the same task or the same group doing a different task. Returning to the discussion on research approach in Chapter Three, this stresses the importance of reviewing meaning making in a real context and entering into a real task in order to gather the raw material.

4.5.2 Students' meaning making

Section 4.3.3 summarises various elements of students' meaning making, how the group interacts and whether their meaning making varies in terms of the actual task being performed. Figure 4-15 indicates there is a shift in terms of the extent to which the student group (when it is not interacting with the facilitator) relies on individual working as opposed to group working (showing that they rarely engage in whole-group working). The only session where some form of group working dominates in Session 5 is where they are concentrated on discussing the model bridge that has been prepared. A feature of this session (see Section 4.2.5) is that the facilitator joins and leaves at a number of stages and that when he is absent the students are discussing the latest information or guidance. Figure 4-15 is clear that there is very little instance of whole group problem solving by the students. This occurs a few times in session 1 when they are discussing how to complete the calculations but is absent once the practical task is started. At that stage (and this is explored in Chapter five), two of the students tend to dominate the active problem solving and discussions.

4.5.3 Facilitator's role in meaning-making process

The facilitator's role in the meaning-making process too can be traced as shifting across the five sessions. As Figure 4-16 indicates, he spent 20% of Session 1 presenting to the entire class and roughly the same again with the student group being studied. As indicated in Section 4.3.2, this initial interaction with the group is mostly in terms of setting out the task rules so they understand the nature of the task (these rules encompass sub-goals, time frames as well as the available resources). His interaction with the student group in Session 2 is similar in that he is seeking to provide the information they need to complete the task but there are a few instances where his input is more directive such as the long input after 39 minutes that is cited in Section 4.2.2. Just before this, at Timer 35.19, he states: "*There's some major problems there. This sort of scene here is a major problem. … . Well the problem there is here, and you're going to have a problem there on the truss*", as he seeks to ensure the students take a valid approach in their problem solving.

In the third session, his time is mostly taken up with a long presentation to the whole class (this took over 13 minutes) where he provides information on the technical nature of the task (how it will be assessed) and shows images of both real-world bridges and other student projects that exemplify the strengths and weaknesses he is seeking to explain. Outside this, there is a routine to the student group work, where the facilitator will join them, discuss progress or provide information and then they will engage in a discussion that includes varying numbers (but never all) members of the student group. However, by this stage, the facilitator has become more direct in his evaluation of their progress (Timer 29.30): "*Yeah you need to give consideration to that, I mean this tells you nothing. Well I'd lift that out and sort of throw it into the rubbish, that's what I'd be doing. So what have you actually done?*" Here the facilitator has become very focussed on the product and his understanding of the assessment; however, he still invites the students to offer their own explanation and elaboration of their meaning making.

In Session 5, the facilitator sees the model that was constructed by one of the students after the end of Session 4. A key stage in his evaluation is covered in Chapter Five, but overall he has shifted tone to become very directive as he seeks to ensure the students can produce a design that will meet the task requirements.

4.5.4 Analysis of task performance

The strongest evidence for task performance is the facilitator's response in Session 5. Here he firmly indicates that the bridge as designed will fail the task rules. The model designed (see Figure 4-12) bears little relationship to their experiments in Session 4, to the images and information provided in Session 2 or to the sketches and calculations made earlier. The key part of Session 5, where the model is reviewed in detail, is one of the excerpts selected for deeper analysis in Chapter Five.

Chapter Five

Multimodal Analysis of Students' Meaning Making

5.1 Introduction

Chapter Four has partially addressed the process of analysing the nature of student interaction and meaning making. This chapter shifts the focus of that analysis by concentrating on the multimodal aspects of that process. In turn, Chapter Six will bring both strands of analysis together and will be combined with the material in the literature review (Chapter Two). As discussed in Chapter Four, the other goal of using activity theory was to identify specific sections of the PBL session that would then be analysed in closer detail using multimodal techniques.

Seven excerpts were selected for more detailed analysis. This approach follows the basic design suggested by Jewitt (2006) of using activity theory to explore the totality of an interaction and then selecting small sections that exemplify key shifting dynamics for more detailed exploration using a multimodal approach.

The first excerpt was selected as it sets out the key themes that are explored across the rest of the analysis. The other excerpts allow a focus on shifting aspects of students' problem solving and use of the multimodal resources. In addition, the excerpts selected capture the transition of the facilitator's role from facilitating the students' understanding to a very direct engagement in what needs to be done to carry out the task and critique the final product. The excerpts are selected from across the five recorded sessions and are summarised in Table 5-1.

Table 5-1: Selection of excerpts for closer analysis

Excerpt # (Section No.)	Session #	Time*	Focus
1 (5.2.1)	1	01.25-04.00	Facilitator-led, focus on theory behind bridge design task
2 (5.2.2)	1	24.27-27.38	Interaction within student group, focus on theory behind bridge design task
3 (5.2.3)	1	54.21-56.27	Group-facilitator discussion, shift of focus from theory to model building task
4 (5.2.4)	2	30.50-36.15	Interaction within student group, followed by a group-facilitator discussion; shift of focus from theory to model building task
5 (5.2.5)	3	08.26-13.10	Shifts from student group, to facilitator's input to group-facilitator discussion. Most of the focus is on the theory behind the bridge design
6 (5.2.6)	4	19.47-23.26	Two of the students discussing how to build the model
7 (5.2.7)	5	22.20-26.40	Group-Facilitator discussion focussed on the model designed between sessions 4 and 5

*Beginning and End times as per camcorder's timer, with range corresponding to minutes and seconds into the session; the times coincide with the duration of the session, beginning with 0.00.

The first excerpt shows the facilitator adopting a traditional role in the PBL framework of presenting information that the students will use to scaffold their learning as they deal with the task. The second and third excerpts show various modes of interaction between the students and the facilitator and within the student group as they tackle the theoretical aspects of the bridge design. This alternation between in-student group interaction and interaction with the facilitator is repeated in Excerpts 4 and 5, but at this stage the focus is more on the practical design of the bridge model rather than the underlying theory. Excerpt 6 is atypical (as was the whole of the fourth student session) in that only two students are present and the focus throughout was on model building. The excerpt shows both the process of using tools to construct meaning and their planning as to how to complete the task. Excerpt 7 is again mostly concerned with student-facilitator interaction and forms a review of the work undertaken in Session 4 (and subsequently when one of the students worked on the model in his own time).

The selection of excerpts is done on the basis of several criteria. The researcher sought to capture the flow of the entire PBL class, hence the focus on the facilitator's initial presentation; on the students' (facilitator-assisted) meaning making, first in terms of theory and then in terms of the model design; on an aspect of the session (the third) when only two students were present but actively engaged in testing possible model structures; and on the final session (the fifth) where the facilitator was involved in reviewing this work. There is a balance between facilitator-led excerpts, those that just involve the student group and those that see interaction between the student group and the facilitator (as discussed in Chapter Four). Finally, the individual selections or excerpts (called 'blocks') were kept to around 3-4 minutes to allow detailed analysis (O'Halloran & Smith, 2011) and were chosen to meet all the above criteria, but also as particularly rich instances of multimodal problem solving (the *analysis* that underpins Chapter Four was invaluable in allowing this selection).

In summary, across this selection of excerpts, it is possible to track the shift of focus from underlying theory to model building, the changing approaches to problem solving by the students and the shifting relationship between the student group and the facilitator.

As discussed in Chapter three (3.2.2.2 and 3.2.2.3), the students gave their approval to be videotaped as they carried out this task. As far as possible, their identity has been kept confidential, but a number of images are included that show their body posture and interaction. This is inevitable given the need to provide evidence, especially for the non-verbal element to their meaning making.

5.2 Analysis of individual excerpts

5.2.1 Excerpt 1: Session 1 (2 min, 35 sec)

5.2.1.1 Overview

Excerpt 1 was selected as it sets the scene for the project and allows an early consideration of the main themes developed. The period of time selected is mostly focussed on the facilitator introducing some basic concepts and providing information the students will need to use for the task. He makes reference to information on the whiteboard and a number of slides as he talks the students through the task. While he is presenting information, and in the gaps in his presentation, there is some discussion between the students and they carry on working individually on the calculations required. The analysis in this excerpt is slightly different to that adopted subsequently. Since most of the period is dominated by the facilitator speaking, only one block has been selected for a detailed semiotic or multimodal analysis (see Table 5-10) and instead a number of themes such as student interaction and the process of intersemiosis are explored in specific tables. This session was, in terms of the multimodal resources deployed for meaning making, repetitive and a single detailed investigation suffices to show this.

At the start, at Timer 1.25-1.59, the facilitator seeks to catch their attention with "*Listen guys, if I just uh, have your attention please, I've just got the computer working*". This is followed by a discussion of the basic calculations needed as "*The cosine law and the sine law are those two laws which are in the little box there. … Write them down in terms of your solution*". Up to this point, two of the students (Students D and E) had been discussing the calculations, whereas while he was speaking Students A, B, C and D are carrying out their own calculations and Student E is browsing the pages of his text book.

From Timer 1.33 onwards, there is more interaction between the facilitator's presentation and questions and statements by the students, with the facilitator presenting a model solution. The student group both engages directly with this presentation and returns to working on the problem by themselves. The facilitator from Timer 2.10 onwards is sketching out alternative solution methods on the whiteboard. The students' work consists of diagrams and related calculations to estimate the direction of forces. This presentation carries on to Timer 3.18. At this point the students are working on a combination of their own notes, a worksheet that has been handed out, and cross-checking with a textbook. From then to Timer 3.31 the students are working on the problem with some in-group interaction. At that stage the facilitator checks understanding and what has been covered so far in the formal lectures. This excerpt ends at Timer 4.00 with the student group working as individuals on the task set.

This section is valuable for three reasons. First it introduces the role initially adopted by the PBL facilitator. Second, it shows the extent that the student group uses individualised rather than group problem solving at this stage in the PBL process. Third, the discussion of forces, and the theoretical concepts are key to the bridge design.

5.2.1.2 Role of PBL facilitator

In this session the PBL facilitator mainly adopts the role of setting out some basic concepts that the students need to address before they can commence the process of building the model bridge. At the start, the discussion revolves around the rules for calculating the sine and cosine with use made of both OHP slides projected from a computer and calculations and diagrams written on a whiteboard. The style is initially a combination of explanatory and directive:

> *The cosine law and the sine law are those two laws which are in the little box there. (Facilitator points to a place on the OHP)*
> …
> *Write them down in terms of your solution.*

This is followed by checking that the students can use their calculators (in response to a student from another group who posed a question) and providing a model answer for a different problem:

> *Of course it will, you need to know what your calculator is doing.*
> …
> *Okay, now there's a problem here, this particular problem is an example problem with a solution and he's used the cosine sine and cosine and in order to work out the result. (Facilitator points to the slide now on the OHP)*

Having completed this explanation, the facilitator then moves to the whiteboard and starts to write out a different calculation process based on a diagram that shows the forces and their angles as shown in Table 5-2. The coding structure used follows the discussion in Chapter three (especially Section 3.4.2.2) and the full set of codes are set out in Appendix 6.

Table 5-2: Excerpt 1 – Facilitator presentation (1 min, 12 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
2.00	Facilitator: There is another way of doing this guys if you		CT	ModI	ET	CK		IH	IFS	SS
	Facilitator: you can use the resolution of forces too.		CT	FE	ET			IL	IFS	
	Facilitator: So if you've got a situation,		CT	LE	ET	CK		IH	IFS	
		Image on whiteboard	CT	FE	ET	CK			IFS	CS
	Facilitator: where you've got your force in one direction		CT	LE	ET	CK		IH	IFS	TS
	Facilitator: if you've got an X-Y plane,		CT	FE	BA			IL	IFS	TS
		Facilitator writing on Whiteboard, matches verbal resources	CT	FE	ET	CK			IFS	CS
	Facilitator: and you've got a force up here F1		CT	FE	BA			IL	IFS	
		Diagram to show angle of force	CT	FE	ET	CK			IFS	CS
	Facilitator: and you've got a force here F2,		CT	FE	BA			IL	IFS	
	Facilitator: then you can resolve their forces at F2X, F1X		CT	FE	BA	CK		IL	IFS	
	Facilitator: and add them to get a resultant FRX.		CT	FE	BA	CK		IL	IFS	TS
	Facilitator: And similarly you've got an F1Y and an F2Y,		CT	FE	BA	CK		IL	IFS	TS
	Facilitator: which you can add to get your resultant FRY.		CT	FE	BA	CK		IL	IFS	TS

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Facilitator: And of course the result between FRY and FRX		CT	FE	BA	CK		IL	IF S	TS
		Students look at textbook	CT			CK			IP P	
	Facilitator: FRY and FRX gives you your overall resultant FR.		CT	FE	BA	CK		IL	IF S	TS
		Student writes down the diagram from the whiteboard	CT			CK				CS
	Facilitator: So there are two ways of solving it		CT	FE	BA	CK	ThP	IL	IF S	SS
	Facilitator: You do need to know the angles.		CT	FE	BA	CK		IL	IF S	SS
	Facilitator: So what I've done is to resolve these forces into an X and Y… X and Y, Y and X components		CT	FE	ET	CK		IL	IF S	TS
	Facilitator: in order to get the result in force		CT	FE	BA	CK		IL	IF S	MS
3.12	Facilitator: you need to know the angle too.		CT	FE	BA				IF S	

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

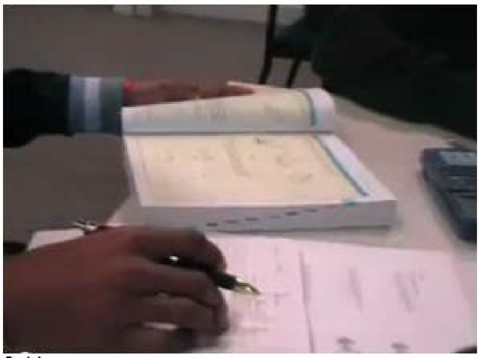
At this stage of the PBL process, the facilitator is providing background information and the session is dominated by talk about the Concept-related Talk (CT) as is to be expected from a formal presentation by the Facilitator's Explanation (FE). Meaning is built up primarily by Technical Scaffolding (TS), in other words, the material is interrelated to help students grasp the essentials. However, scaffolding is deployed at almost every utterance as information is presented and the students are encouraged to understand not just the exact process but the related conceptual thinking.

As discussed below, the change in content of his presentation is also marked by a change in semiotic resource. In particular in this excerpt, the non-verbal resources in use are all complementary to the spoken words. One problem with this section of the video is that the camera concentrated on the student group when it is the facilitator who is leading the meaning making (leading to a lack of focus on what semiotic resources, except speech, the facilitator was using in his meaning making).

5.2.1.3 Process of student learning

Student learning in this session almost all occurs at an individual model. The students are using either their workbooks, some prepared worksheets or, in one case, a textbook, to carry out the required calculations. Thus while the facilitator is making the first part of his presentation, the students individually are working as shown in Figure 5-1.

2.13



2.14

2.26

Figure 5-1: Student – individual work

This individualised model of learning is sustained even when the facilitator changes tack (as in Table 5-2) and introduces an alternative calculation approach. This is shown in Figure 5-2.

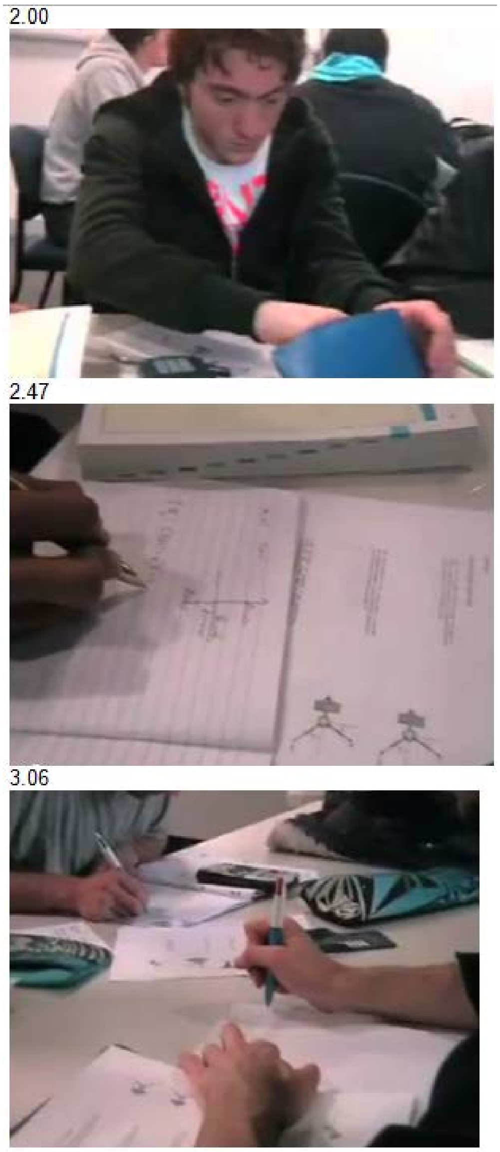


Figure 5-2: Student focus – second part of presentation

The dominant form of student learning and problem solving is individual across this session as already explored in Chapter Four. At the start, different students can be seen to be doing a variety of things as shown in Table 5-3.

Table 5-3: Student activity, start of session

Student	Focus
A	Solving the problem and using the calculator.
B	Solving the problem on the sheet and also using the calculator. He is rummaging in his pencil case to find his pencil.
C	Solving the problem on his notebook using the calculator and the pen. He is also drawing a diagram for the forces and angles he is going to measure.
D	Drawing the diagrams again in his notebook.
E	Browsing the pages of the textbook.

After one minute, the facilitator shifts mode and presents the worked example; the student activity has changed slightly to that set out in Table 5-4.

Table 5-4: Student activity, mid-session

Student	Focus
A	Looking at the slide, then back at his notebook, then he is picking up his calculator.
B	Rummaging in his pencil case. Student B from time to time is using different colours of pens to drawing the diagram.
C	Solving the problem on his notebook using the calculator and the pen.
D	Making notes in his notebook.
E	Starting writing but he is not solving the problem. He is copying a diagram from the textbook.

Towards the end of the second calculation, at Timer 3.12, explanation is the first instance of student interaction, with a conversation as in Table 5-5.

Table 5-5: Sequence of comments, end of second presentation by facilitator

Student	Sequence of comments
E	The square root yeah?
B	The square root of them both ways.
A	The square, yeah.

This sequence is a rare instance of group interaction. In terms of the overall categorisation process discussed above, this brief interaction can be seen as an example of collaboration and a short answer that forms a Verification (SV) of the original question.

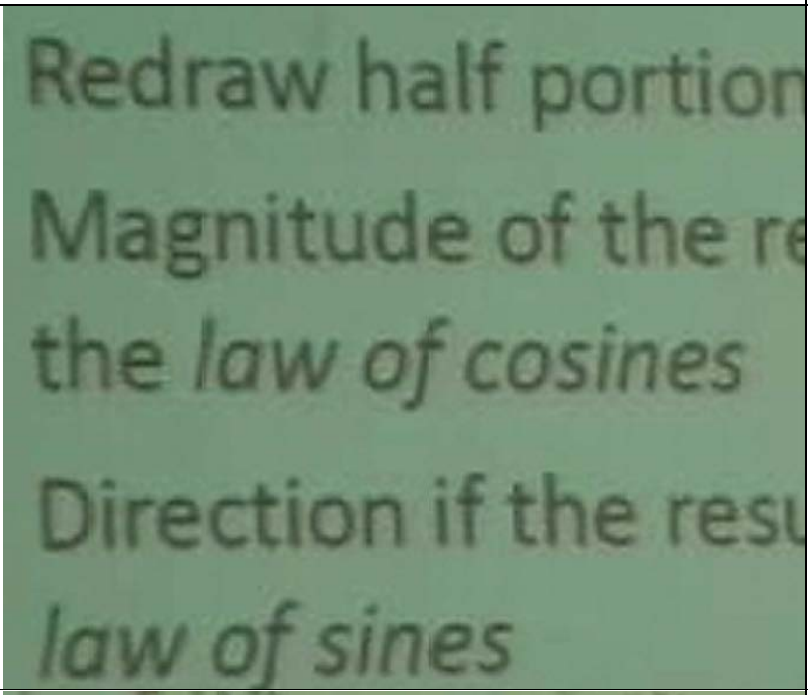
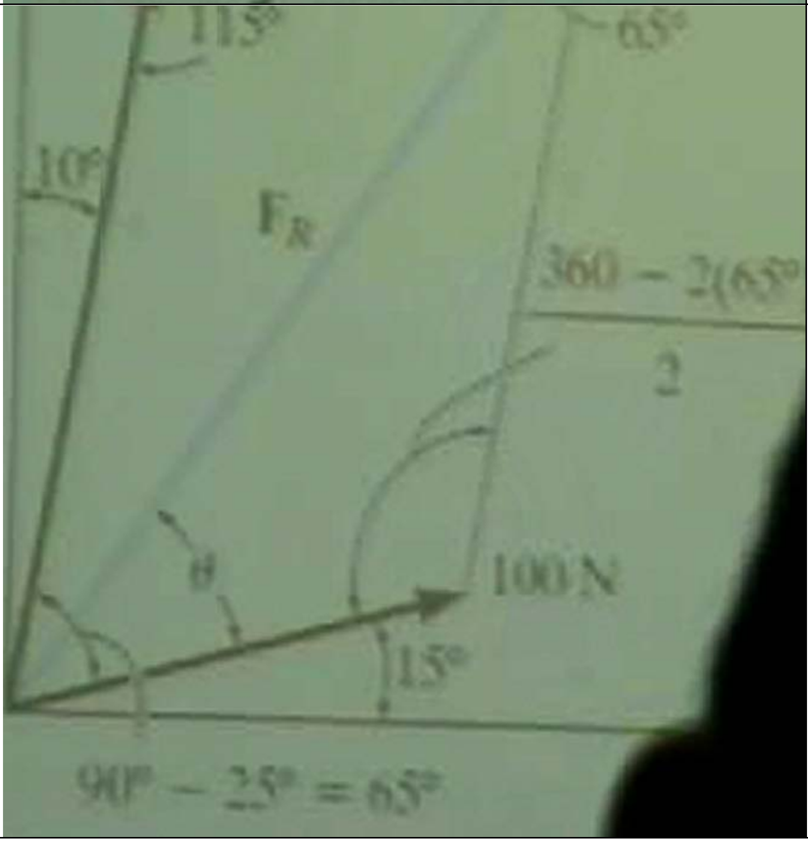
In addition, this excerpt can be seen as fitting the model of scaffolding usually suggested for PBL (Choo, 2012; Hmelo-Silver et al., 2007). That approach argues that a key role for the facilitator is to present enough information so that the students commence their problem solving with sufficient information to carry out the task. The goal is to ensure they are clear as to the nature of the task and what they are expected to do for themselves. Thus in Table 5-2, the facilitator commences with an instance of Strategic Scaffolding (SS) with the statement "*There is another way of doing this guys*" as he prepares to offer them a different approach to solving the problem. Subsequent to that, there is a steady process of offering Technical Scaffolding (TS) as he uses speech to explain the equations and Conceptual Scaffolding (CS) where he uses the images that are displayed. The verbal resources are used to state the nature of the calculation they need to complete and the non-verbal resource shows the calculations that need to be adopted.

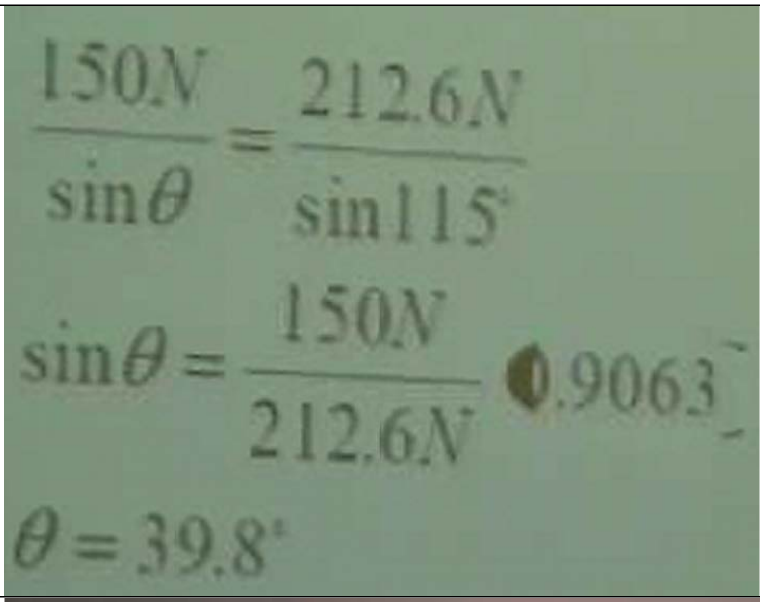
5.2.1.4 Intersemiosis and resemiosis

As discussed above, resemiosis (i.e. drawing meaning and context from a wider framework) is mostly implicit in this session. There is a single direct instance towards the end of the facilitator's presentation, at Timer 3.40, when he does so deliberately with the questions: "*Is everybody okay with that work example? Was this done in the lecture?*" posed to the group. The wider issue is that the purpose of these calculations is to underpin the concepts needed to design a model bridge that will meet the task requirements.

Intersemiosis occurs more often in this session, especially throughout the facilitator's presentation. Thus at the start, a number of slides are projected while at the same time the facilitator is working on a whiteboard to show how these concepts can be calculated. The following sequence of images shows this.

Table 5-6: Examples of intersemiosis

Time*	Image	Commentary
1.38		OHP showing underlying rules and logic
1.39		Worked example showing actual calculations

1.43		Maths formula
2.07		OHP presentation supplemented with text on the whiteboard

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

At the point of the final image, the facilitator has also started to offer a new explanation and approach that can be adopted. This is introduced by "*there is another way of doing this guys if you – you can use the resolution of forces too*". The two options for calculating the work example are contrasted, with the expectation that the students will adopt whichever proves the easiest for them. The facilitator is deploying the two resources – his speech and the equations on the OHP/Whiteboard – in a similar manner. The speech leads the meaning making and the written information supplements what he was saying as well as acting as a permanent resource for the students (to which they refer later on as discussed below).

5.2.2 Excerpt 2: Session 1 (3 min, 11 sec)

5.2.2.1 Context

This excerpt takes place approximately 20 minutes later in the first session. It was selected as it is an example of the nature of inter-group work by the students as they check understanding and carry out the required calculations. At this stage, the students are still focussed on understanding the theoretical basis of the task. As such it is mostly a mixture of individual work and sub-group interaction as the students construct meaning and understanding. It starts with the students either working on their own or in small groups on the calculations that were commenced in Excerpt 1. This excerpt has no direct intervention by the PBL facilitator but provides evidence of the approach to bridge design adopted by the group. Since the focus here is on the meaning making and on social interaction, the excerpt is broken down into three distinct blocks (as the students commenced and ended phases of collaboration) and is coded using the structure outlined in Chapter Three.

5.2.2.2 Excerpt development

The excerpt commences with an interaction between two students:

Table 5-7: Block 1, Excerpt 2 – student interaction at start (25 sec)

Time*	**Verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
24.27	Student B: Can I use your calculator?		TR	NC	Clarif					
24.28		Student A moves calculator towards Student B, but makes no comment 	TR						IPP	
24.29	Student B: Thanks mate.		PT	ACK						
24.33		Students A, D, E using calculators	TR							TS
24.52		Student E using both calculator and laptop and is working independently 	TR							TS

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

At this stage the student group carries on working as individuals with no interaction. All meaning making is individual with no conversation or interaction. By Timer 25.28 the group starts to discuss their findings but do so as sub-groups not as a complete group. Of importance is the use of resources such as calculators (and in one case, a laptop) to provide Technical Scaffolding (TS) to their problem solving.

Table 5-8: Block 2, Excerpt 2 – student discussions (43 sec)

Time*	The verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
25.28	Student D: Did you get negative 45 for when you calculate the [inaudible] at your set point?		CT	NC	Clarif					
25.35	Student C: I had that would be 180 plus, is 225.		CT		BA				IPP	
25.35		Student C points at his notebook with a pen as they discuss the calculations 	CT	TA	AM					CS
26.00	Student B: Which was the resultant force V or U?		CT	NC	Clarif					
		Student B: Focus is on both a small diagram and the calculations they have made. Focus indicated by pointing with a pen.	CT	TA						CS
	Student A: The resultant force		CT		BA					
		Student A points at Student B's sheet with their pen 	CT	TA	Clarif					

Time*	**The verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Student A: it's just saying calculate formula that way.		CT		BA			IL		
		Student A points at line on paper as he describes this process	CT	TA						
26.11		Students A and B return to working with paper and calculators 	CT							TS

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

The students had a brief period (less than a minute) of discussion and shared meaning making followed by a return to individual work. As discussed in Chapter Four, one student was silent throughout this discussion although the other four were active at different stages. Again, the non-verbal resources are complementary to the verbal resources. As noted above, at several stages students emphasise the meaning making by pointing at a part of a work sheet or the relevant line in their calculations. There are two specific instances of scaffolding in Table 5-8, one of Conceptual Scaffolding (CS) where the students review the diagram one has drawn, and at the end, shown in Table 5-7, where they use calculators as an element of Technical Scaffolding (TS) as they carry on with their meaning making.

Table 5-9: Block 3, Excerpt 2 – final interaction (34 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
27.04	Student B: Wouldn't it just be the same?		CT	NC	Clarif					
		Student B gesticulates to attract Student A's attention			Clarif					
27.08	Student A: You can point it counter-clockwise it from there to there…		CT		ET			IH	IPP	
		Student A points to Student B's working sheet with a pen 	CT	TA		CK				
27.09	Student B: Yeah that's the same.		CT	CA	AM				IPP	
		Student B points to own working sheet with the pen 	CT	TA		CK				
	Student A: But it's asking you that way.		CT	NC	Clarif					

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Student A again points to Student B's working sheet with a pen. Pen motion is used to indicate direction of the force 	CT	TA		CK				
27.13	Student B: Yeah but what I'm saying		CT	SDL	BA			IH		
	Student B: is that the values would be the same.		CT	SDL	BA					
		Students A and B are pointing with pens at the calculations one of them has made	CT							
27.17	Student A: Yeah they'll be the same		CT	CA	AM				IPP	
27.24	Student A: yeah.		CT	CA	AM					
		Student A turns and points to Student B's working at the same time	CT							
27.38		Student A uses calculator 	CT							

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

This final part of the excerpt is dominated by a discussion between two of the students (hence the relative frequency of utterances coded as Peer-Peer Internalisation (IPP) and concludes with Student A using the calculator in a collaborative manner to seek to resolve their questions. As such this is a different pattern of use than earlier when each student was working on their own solution. However, the other three students took no part in this discussion. The process of combining verbal and non-verbal resources is mutually supportive across Table 5-9 as gesture and pointing is used to either indicate the direction of a force or which part of the working notes they are concentrating on. At the start, the statement "*wouldn't it just be the same*" is accompanied by a gesture to attract attention.

However, from Timer 27.09 on, where Student A asks "*But it's asking you that way*", there is an instance where meaning making is multimodal with both verbal and non-verbal resources central to the meaning making and complementing each other. Without the non-verbal aspect, it would be hard to understand what is meant and the pointing at calculations on the worksheets is as important as the verbalisation of their approach to problem solving.

5.2.2.3 Meaning construction

In terms of the content of communication, the majority of the speech can be described as Concept-related Talk (CT). Across this excerpt, with few exceptions, speech was used for meaning making about the task rather than for social interaction. Even though this excerpt was chosen for its relative richness of student interaction (collaboration) it is clear that for substantive periods the students were engaged in individual work.

In Table 5-7, collaboration is limited to a simple request, "*Can I use your calculator*", followed by an Acknowledgement (Ack). In response the calculator is offered but not subsequently used. Table 5-8 shows several instances of students Needing Clarification (NC), followed by Brief Answers (BA) to complete the relevant interaction. Table 5-9 shows a richer interaction than Table 5-8 as the excerpt starts with Needing Clarification (NC) followed by Conceptual Agreement (CA). This is followed by a process of Self-Directed Learning (SDL) that concludes with Conceptual Agreement (CA) and then leads into a collaborative use of the calculator to resolve the question. In the second block, there is a process of Seeking Clarification (Clarif), following by a Brief Answer (BA). Table 5-9 shows a request for Clarification (clarify), followed by an Elaborated Explanation (ET) before it returns to a sequence of Brief Answers (BA) and Agreement with PBL Member (AM).

The shift shown between Tables 5-8 and 5-9 is marked by a difference in the process of interpretation in use. In Table 5-8 the interpretation process was mostly at a Low level Interpretation (IL), while in Table 5-9 it was at a High-level Interpretation (IH), as the two students engage in a detailed discussion of the concepts they are trying to solve. This is also an example of Peer-to-Peer Internalisation (IPP) collaborative meaning making and learning, of the type of interaction desired in a PBL class.

There are isolated instances of scaffolding of learning across this excerpt, mostly by the facilitator but with some instances of the students using resources such as calculators to support learning (TS) at the end of Table 5-7. In Table 5-8 there is an instance, at Timer 26.00, where examination of a sketch diagram is a key step in building understanding before they return to individualised learning.

5.2.2.4 Interaction of verbal and non-verbal resources

This session sees the students making use of a number of semiotic tools. Notably there is much use of their calculators and one student is using his laptop (and takes no part in the wider discussions). Thus at Timer 24.38 they can be seen to be doing more individual calculating work, as shown in Figure 5-3.

Figure 5-3: Excerpt 2 – semiotic resources in use (24.38)*
*At particular point in time

However, across the excerpt, two students are working collaboratively and to do this they use a range of non-verbal and verbal resources. Thus there are examples of students pointing at the calculations of another student to emphasise their meaning or to clarify just what they are referring to. In this case the process of intersemiosis can be seen to be complementary, with gesture and speech being used for the same meaning-making process surrounding the calculation of forces that will affect their bridge design. Both are deployed, as discussed in connection with Table 5-9, to build up the same meaning, with the various characterisations of semiotic resources deployed in constructing meaning and exploring their understanding of the problem.

5.2.3 Excerpt 3: Session 1 (2 min, 6 sec)

5.2.3.1 Context

This excerpt was selected as an example of facilitator-student group interaction which occurs almost at the end of the first video-recorded session. It contains instances of shared meaning making between the students and facilitator but with the emphasis on the facilitator explaining the task as well as seeking to relate the model building that they now need to start to the theoretical work already carried out. As in Section 5.2.2, the first section sets out a detailed multimodal description of the development of the excerpt and this is then discussed and analysed in terms of the process of students' meaning making, the role of the facilitator and the nature of the bridge model design.

5.2.3.2 Excerpt development

This excerpt opens with the facilitator dominating the discussion and providing the student group with information to allow them to move from the mathematical and theoretical analysis of the forces that will affect the bridge to consideration of the requirements for model building.

Table 5-10: Block 1, Excerpt 3 – opening discussion (9 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
54.21	Okay boys can I have your attention please,		PT	FM	BA		GM		IFS	
		Students A and B are fiddling with the paddle-pop sticks 	CT						IPP	
	Facilitator: we're just going to do some of the tricks.		TT	FE	ET			IL	IFS	
		Facilitator – gesticulates and shows paddle-pop sticks 	TR	FT					IFS	TS
54.29	Facilitator: So the tricks are in terms of strength.		CT	FE	ET			IL	IFS	
		Facilitator gestures with his hands to indicate the type of pressure that will be placed on the bridge	CT	FE					IFS	MS
	Facilitator: What you don't want to have		CT	FE	ET			IL	IFS	MS
	Facilitator: is the bridge sort of buckling underneath your load springy		CT	FE	ET			IH	IFS	

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
			CT	FE					IFS	
	Facilitator: so think of something strong.		CT	FE	ET			IH	IFS	MS
	Facilitator: Think in terms of the frame		CT	FE	ET			IH	IFS	

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

Table 5-10 shows the facilitator setting out the basic elements of the model building task and attempting to frame the students' comprehension ("*think of something strong*"). This is then developed in Table 5-11 as he provides additional information that needed to be considered. This in turn is related to the calculations and theoretical work that had been done so far. Again, gesture is used by the facilitator to reinforce the verbal information he is passing on. Scaffolding takes on two forms. There is a single instance of Technical Scaffolding (TS) where the facilitator makes use of the non-verbal resources (in this case the paddle-pop sticks) to emphasise what he means. Towards the end there are a number of instances of Metacognitive Scaffolding (MS) where the facilitator presents an idea, or a direction for further investigation to the students. So, for example, he urges them to "*think of something strong*".

Table 5-11: Block 2, Excerpt 3 – detailed instructions (30 sec)

Time*	**The verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
54.31	Facilitator: the frame has got to span 500 mm		CT	FE	BA			IL		TS
	Facilitator: it's going to be reasonably big		CT	FE	BA			IL		TS
54.40	Facilitator: 500 mm is half a metre		CT	FE	ET			IL		TS
		Facilitator demonstrates this distance by using 2 paddle-pop sticks	CT							
	Facilitator: 50 cm and you will need the frame so that it's strong.		CT	FE	ET			IH		TS
54.44	Facilitator: It's going to be sections of components that are glued together		TR	FT	ET			IH		PS
	Facilitator: a paddle-pop stick is generally quite strong		TR	FT	ET			IH		PS
		Facilitator demonstrates strength by trying to bend/break one	TR							
	Facilitator: when I pull on it,		CT	FE	BA			IL		
	Facilitator: you couldn't pull it to separate it		CT	FE	BA					
	Facilitator: G force		CT	FE	BA			IL		
54.56	Facilitator: But not very good in terms of any applied load		CT	FE	ET		GM	IH		

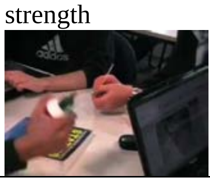
Time*	The verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Facilitator demonstrates by placing paddle-pop stick across his fingers 	TT							
	Student B: Compression.		CT	QF	Clarif					

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

Table 5-11 shows the facilitator making use of non-verbal gestures, mostly connected with the paddle-pop stick to demonstrate distance and points of weakness. He also uses purely non-verbal gestures to indicate the direction of force that the bridge will need to bear. Here, again, the non-verbal semiotics resources are deployed in support of the meaning making of the verbal semiotic resources. At this stage, the facilitator then shifts focus from the forces to the construction of the bridge frame to ensure it can hold this weight. Excerpt 3, reported in Table 5-11, commences with a substantive element of scaffolding as the facilitator seeks to frame the task for the students. It starts with a number of instances of Technical Scaffolding (TS), both verbal and non-verbal, where the constraints for the bridge are set out and then shifts to Procedural Scaffolding (PS) as the process of actually constructing the model is discussed, for example "*a paddle-pop stick is generally quite strong*".

Table 5-12: Block 3, Excerpt 3 – construction of the frame (39 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
55.03	Facilitator: So you've got your frame to consider		CT		ET			IH	IFS	TS
	Facilitator: and you've got the truss members		CT		ET			IH	IFS	TS
		Facilitator demonstrates with sticks, by holding them in a splayed pattern	CT	FE					IFS	TS
55.09	Facilitator: which are going to sort of makeup effectively the load taking capacity of the bridge.		CT	FE	ET				IFS	
55.16	Facilitator: So if you build your frame		CT	FE	ET			IL	IFS	
		Facilitator demonstrates a layout of the frame with the paddle-pop sticks	CT	FE					IFS	TS
	Facilitator: so that you have quite a decent sort of structure		CT	FE	ET			IL	IFS	
	Facilitator: a decent strong sort of shape		CT	FE	ET			IH	IFS	
55.27	Facilitator: and you then have a series of trusses		CT	FE	ET				IFS	

Time*	**Verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Facilitator demonstrates how the trusses with interact with the shape by moving paddle-pop sticks in the air	CT	FE					IFS	TS
	Facilitator: they're the trusses		CT	FE	BA			IL	IFS	
55.31	Facilitator: sort of 30 degrees or whatever		CT	FE	BA			IL	IFS	
		Facilitator demonstrates what angle 30 degrees will be	CT	FE					IFS	TS
	Facilitator: it can actually sort of fit in very strongly		CT	FE	BA			IL	IFS	
		Facilitator demonstrates by knocking a paddle-pop stick onto the table – gesture to indicate strength 	CT	FE					IFS	TS
	Facilitator: then you'll have a strong one.		CT	FE	BA			IL	IFS	

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

In this part again most of the non-verbal resources are deployed to help the students visualise what is being presented verbally. The exception is the gesture following "*it can actually sort of fit in very strongly*" where the facilitator emphasises the concept of strength by banging one of the paddle-pop sticks on the table. Again, Technical Scaffolding (TS) is an important part of the interactions shown in Table 5-12, with this carried out both verbally and non-verbally (although mostly by using visual examples). As shown in Table 5-11, the facilitator seeks to ensure the students are aware of the properties of both the desired model and the tools they have to hand.

The final block in this excerpt sees the discussion being led partly by the students to the practical elements of the model building task.

Table 5-13: Block 4, Excerpt 3 – model building (39 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
55.48	Facilitator: You can do anything with a paddle-pop stick		TE	FT	BA			IL		PS
	Facilitator: you can't do anything else.		TR		BA			IL		
	Student A: So there's 300 pieces here you get to use?		CT	NC	Clarif				ISF	
	Facilitator: 275.		CT	FM	BA					
	Student E: What's the maximum?		CT	NC	Clarif				ISF	
	Facilitator: 275 paddle-pop sticks.		TR	FT	BA					
	Facilitator: You've got 25 ways to…		CT	FE	BA				IFS	
55.58	Facilitator: I wouldn't worry about that		CT		BA					
		3 students have picked and are fiddling with the paddle-pop sticks	PT							
	Facilitator: it's paddle-pop sticks.		TR	FT	ET			IL		
	Facilitator: The main thing is with the joints		CT	FE	ET			IL		

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Facilitator demonstrates with the paddle-pop sticks 	CT							
56.17	Facilitator: the joints have to be strong		CT	FE	ET			IL		CS
		Facilitator demonstrates how the joints should intersect	CT							CS
	Facilitator: they have to failsafe in a situation		CT	FE	ET			IL		
		Facilitator demonstrates the various angles that need to be taken into account	CT							TS
	Facilitator: even if you've got the applied load on top of them		CT	FE	ET			IL		
		Facilitator demonstrates by gesture showing the angle of the load and pressing down with force 	CT							TS
56.12	Facilitator: then that's sort of glued		TR	FT	ET			IL		

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Facilitator demonstrates shifts angle to clarify how they should appear	CT							MS
	Facilitator: that’s strong enough you don’t need any spaces		TR	FT	ET			IL		
		Facilitator demonstrates by lowering hands to show the lack of space 	TT							TS
		Student B picks up glue	PT							
	Facilitator: Fill those spaces on the paddle-pop sticks too.		TR	FT	ET			IL		
	Student B: We can build this outside of class as well?		TT	NC	Clarif					
56.27	Facilitator: Yeah, definitely.		TT	FM	BA				IFS	

*As per camcorder’s timer; the times coincide with the duration of the session, beginning with 0.00.

Here again, non-verbal and verbal resources are deployed in tandem. The spoken meaning is either exemplified (such as at Timer 56.12) or emphasised by non-verbal gestures, usually involving two or three of the paddle-pop sticks. In some instances the non-verbal resources are dominant, so the meaning around “*then that’s sort of glued*” is given more by the gesture (showing how the sticks will look at this stage) than in the verbal element. Again, scaffolding is used to frame and reinforce the meaning making in Table 5-13. This is done both in Concept-related Talk (CT) "*the joints have to be strong*" but most often in Technical Scaffolding (TS). In Table 5-13, notably almost all the instances of scaffolding are related to the use of non-verbal resources.

5.2.3.3 Meaning construction

The four blocks that this excerpt have been divided into (Tables 5-10, 5-11, 5-12 and 5-13 respectively) reflect a shift from the facilitator first setting out some broad principles, then explaining the nature of the force to be applied to the model, followed by a discussion of a specific aspect of the bridge design (the trusses). The final block sees the students interacting, in particular with a focus on the actual model building now required. Overall it was an excerpt largely dominated by speech and the use of non-verbal resources was to reinforce the meaning introduced in speech (demonstrations of how to lay out the designs using the wooden paddle-pop sticks).

In the first block, the content varied from a general Personal Talk (PT – "*okay boys*") to a focus on the Task-related Talk (TT) but was dominated by explaining the concepts (Concept-related talk (CT), such as in the statement "*think in terms of the frame*"). The pattern of collaboration was aligned to these shifts in content starting with Facilitator's Monitoring (FM – "*okay boys*"), shifting to Facilitator's Explanation (FE) for the rest of the block. Again a similar pattern can be found in the level of complexity being explored, with this dominated by Elaborated Telling (ET) as the facilitator sets out the concepts. The opening phrase is in a way atypical and was used by the facilitator to gain Group Monitoring (GM) and to ensure the students were aware that he had joined the group for a purpose. The level of interpretation varied from Low level Interpretation (IL) at the start with a discussion around 'tricks' to High level Interpretation (IH) once the concept of bridge buckling was introduced. Overall this block can be seen as setting out the issues that will be explored, very much facilitator-led and dominated by the key concepts.

The second block sees a shift in content to the actual bridge specification ("*the frame has got to span 500 mm*") and the load it will need to bear. The block ends with a shift of discussion to the model building process. The content of each phrase follows this with the early excerpts dominated by Concept-related Talk (CT), followed by a brief shift to Tool-Related talk (TR) in terms of how to combine the paddle-pop sticks into a design. The facilitator's presentation, in terms of collaboration, matches this shift, with it mostly being about Facilitator's Explanation (FE) and a short excerpt of explaining the tools. The only break is the very short statement by Student B at the end where he Questions the Facilitator (QF). In terms of explanation, the bulk of the block is dominated by Elaborated Telling (ET) but with elements of Brief Answer (BA) where a particular gesture is used. This particular pattern is reflected in the shifts between Low-level Interpretation (IL) and High level Interpretation (IH). Student learning is supporting by scaffolding (i.e. relating concepts) and in the early stage this is in Technical Scaffolding (TS) as it fits with the discussion of length and forces and shifts to Procedural Scaffolding (PS) to demonstrate how the bridge can be constructed. Again, this session is facilitator-dominated and mostly concerned with the technical aspects (theoretical and design) of the task the students are to undertake.

The third block (see Table 5-12) develops the final excerpt shown in Table 5-11 by shifting attention to how to build the frame. All the speech elements are in terms of concepts (Concept-related Talk (CT) or Facilitator's Explanation (FE)) as the facilitator shows how to relate the frame design to the task. One shift is from the Elaborated Telling (ET) that dominates the early part ("*So if you build your frame*") to Brief Answers (BA) towards the end. This is also mostly mirrored in terms of interpretation, with the presenting shifting from High level Interpretation (IH) to Low level Interpretation (IL) as it progresses with the scaffolding provided by Technical Scaffolding (TS). The block is dominated by speech, with limited use of gesture or of the paddle-pop sticks to explain meaning. Where this happens, it is to clarify and emphasise the spoken instructions.

The final block (see Table 5-13) sees a change of style. The students focus on the practical issues around the model building and there is more interaction. The content varies from Concept-related Talk (CT) to Tool-Related talk (TR) as the students focus on the actual model building process. The first two student interventions, such as by Student A: "*So there's 300 pieces here you get to use*?", are direct questions in terms of the use/availability of the paddle-pop sticks, and the facilitator then returns to a relatively technical discussion of how to build the bridge joints, for example with "*the joints have to be strong*". The final student question is about when they are expected to build the model. The student focus here is on the practical issues of model building; however, the facilitator has remained focussed on the technical design issues.

One key issue found across this excerpt is the consistent use of scaffolding. This is variously designed to try and frame the students' thinking as in "*think of something strong*" (see Table 5-10), to providing concrete examples, such as "*the joints have to be strong*", to allow them to move on to designing an effective solution. As noted in the discussions above, there is a tendency, when seeking to use Technical Scaffolding (TS), providing concrete examples, to rely on non-verbal resources. There are instances were this was done verbally, but most often it was linked to the use of a non-verbal resource such as a diagram, gesture or the layout of the paddle-pop sticks.

In terms of the intersemiosis between speech and gesture, mostly in this excerpt, speech is dominant and gesture is used to clarify or expand on what has been said. However, in Table 5-13, there are instances where speech is used to hold attention but the main meaning-making tool is the gestures and the presentation of the paddle-pop sticks. Meaning making is primarily through the use of the paddle-pop sticks, not the spoken words.

In this excerpt, the facilitator can be seen to be interacting directly with the student group for the first time in this session. In Excerpt 1 (see Section 5.2.1) his role was one of presenting information to all the PBL groups in the room, while in Excerpt 2 he is interacting with the students more directly. However, as is clear from the detailed analysis, this excerpt is dominated by the facilitator explaining the bridge design requirements in theoretical and design terms. This varies between Concept-related Talk (CT) and Task-related Talk (TT) as the focus shifts, and some use of Tool-Related talk (TR) as he discusses how to use the paddle-pop sticks.

5.2.4 Excerpt 4: Session 2 (5 min, 25 sec)

5.2.4.1 Context

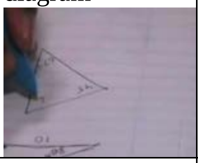
In general, as discussed in Chapter Four, Session 2 can mostly be seen as a continuation of the first session. For most of the time the students were working on the calculations of stress and force they had commenced in Session 1. This particular excerpt was selected as an example of the student group undertaking an interactive approach rather than the dominant mode of individual working and problem solving.

It commences shortly after another period of group interaction with the facilitator. This also includes a discussion between two of the students engaged with another student seeking information provided in a previous lecture. This is not covered in this analysis (it lasted from Timer 32.45 to 34.30) as the third student was from another PBL group and was thus not part of this study. The final block of Excerpt 4 sees the facilitator again interacting with the group about their proposed bridge design and expressing concern at their plans.

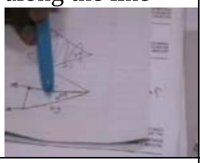
5.2.4.2 Excerpt development

This excerpt opens with the students' discussion of the material and their continuation of calculations. The first part is a discussion between two of the students as to how to complete and interpret the calculations.

Table 5-14: Block 1, Excerpt 4 – initial student interaction (1 min, 9 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
30.50	Student A: So this is 45 –		CT		BA	CK				
		Student A draws in notebook  As part of own calculations	CT							
	Student A: if this is 15 degrees,		CT		BA	CK				
	Student A: that’s 45, 180, minus 45.		CT		BA	CK				
	Student B: 135…		CT		BA	CK			IPP	
		Student A Completes drawing of the triangle with the various angles being calculated	CT			CK				
31.05	Student A: Divided by 2, is 67.5		CT		BA	CK				
		Student A draws diagram 	CT							
31.10	Student A: – FA – actually no,		CT	CD	BA					
		Student A ‘actually no’ is emphasised by erasing that particular triangle	CS	CD						

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Student A: that's not going to work.		CT		BA					
	Student B: … you have to go to…		CT		BA				IPP	
31.14	Student B: because they're different angles.		CT		ET	CK			IPP	
		Student B points with pen to emphasise; followed by silence	CT							
31.20	Student B: I don't know why that doesn't work,		CT		ET	CK			IPP	
	Student B: like the cos thing,		CT		ET	CK			IPP	
	Student B: because in theory that should		CT		ET	CK	Thp		IPP	
	Student B: I don't see why it doesn't.		CT		ET	CK			IPP	
	Student B: It just doesn't.		CT		ET	CK			IPP	
	Student A: Oh this is why		CT	NC	Clarif					
		Student A adds new angle to the diagram to reflect this insight	CT	NC						
31.37	Student A: – yeah?		CT	SQ	BA					
31.41	Student A: If all 10k newtons was on the resultant in FA…		CT		ET	CK				

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Student A draws 	CT							
	Student B: But it still has the Y direction and you need…		CT		ET	CK		IL		
31.48	Student A: Exactly,		CT		ET	CK			IPP	
		Student A points at own diagram 	CT	CS						
	Student A: it still has this one here.		CT		ET	CK				
		Student A emphasises by drawing pen along the line 	CT							
	Student A: So to get FA it has 10 minus that.		CT		ET	CK				
		Student A points at the key angles and elements to the diagram 	CT	CS						

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Student B: Oh yeah.		CT		AM				IPP	
31.56	Student B: I see what you're saying.		CT		BA				IPP	
	Student A: Yeah.		CT	TA	AM				IPP	
	Student B: I don't know how you –		CT		ET					
31.59	Student B: that would be real long.		CT		ET					

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

The meaning process shown in Table 5-14 is discussed in more detail below. However, it should be noted that while this is an example of shared meaning making by two of the students, the other three students took no part and carried on working on their own. In terms of the interaction between verbal and non-verbal resources this is a rich excerpt. Consistently both sets of resources are deployed in the same meaning-making process. However, the relative emphasis contained in "*it still has this one here*" is developed by a very strong movement of the pen by Student A "along the line", as quoted in Table 5-14. Equally, at Timer 31.10, "*actually no*" is emphasised by scribbling over that particular diagram. So as in Table 5-21, there are instances were the meaning making is informed more by the non-verbal than the verbal resources even if, overall, speech is the dominant mode. In contrast to the various discussions with the facilitator that marked Excerpt 2 (see Section 5.2.3) there are no clear instances of scaffolding in that exchange. This reflects the extent to which the students are creating meaning as they progress, hence the high incidence of Peer-to-Peer Internalisation (IPP) as a style of learning interaction, but neither has the additional knowledge that would allow them to guide and shape the meaning making in a particular direction.

Table 5-15 shows this shared discussion carrying on, but with a loss of focus on the task.

Table 5-15: Block 2, Excerpt 4 – loss of focus (44 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
32.01	Student A: So let's work this out.		CT		ET	CK			IPP	
		Student A starts to write 								
32.06	Student B: It's too hard.		CT		ET				IPP	
		Student B emphasises this by moving the pen away	CS							
	Student B: I've just got learn the law of parallelogram addition or whatever it is.		CT		ET					
		Student B turns to look at slide on the OHP as he says this	CT							
32.14	Student A: Is this on Web CT?		TR	NC	Clarif					
		Student A points at slide 	TT							
	Student A: I want questions and solutions.		TT		BA					

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
32.27		Student A laughs and turns to slide 	TR							
	Student B: That's what I asked too.		TT	TA	AM				IPP	
32.36	Student A: Parallelogram,		TT		BA					
		Student B writes in notebook 	TT							
	Student A: okay.		TT		BA					
	Student B: Yeah.		TT		BA				IPP	
32.45	Student B: So you write up…		TT		BA					

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

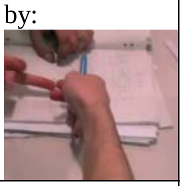
In Block 2 of Excerpt 4 (Table 5-15), the two students draw on an external resource (the instructions of how to carry out the calculations on the OHP). Again, mostly the non-verbal resources are deployed in support of speech, but there are two exceptions. At Timer 32.06 the statement "*It's too hard*" is emphasised by the speed at which the pen is removed from the paper. More significantly, the laughter of both students at around Timer 32.27 indicates that neither has been given the information they have expected or asked for. Again, since this covers just the two students (the reliance on Peer-to-Peer Internalisation (IPP) as a mode of interaction), there is no clear instance of scaffolding. Their meaning making is exploratory, reaching for understanding, rather than guided, with someone attempting to aid them in their problem solving.

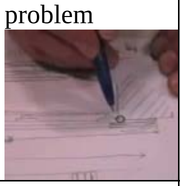
At this stage, a third student joins their discussion, looking for information and material from an earlier lecture. After two minutes of this discussion the facilitator joins the group to review their progress with the bridge design.

Table 5-16: Block 3, Excerpt 4 – model review by facilitator (1 min, 45 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
34.30	Facilitator: Now what have you done in terms of your bridge…		TT	NC	Clarif				IFS	
	Student A: This is our first idea…		TT		BA				ISF	
	Student A: So it's kind of a flow through		CT		ET				ISF	
	Student A: and we tested it out		CT		ET				ISF	
		Facilitator is sketching this as he speaks 	CT						IFS	
34.53	Student A: and it's pretty strong		CT		ET				ISF	
	Student A: and that's the second one		CT		ET				ISF	
34.57		Student A shows working to facilitator 	CT						ISF	
35.01	Student A: where [inaudible] connected up using [inaudible].		CT		ET				ISF	
	Facilitator: There's some major problems there.		CT	FE	ET	CK		IL	IFS	

Time*	**Verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Facilitator: This sort of scene here is a major problem.		CT	FE	ET			IL	IFS	
		Facilitator is sketching out his concern with their design 	CT	FE	ET				IFS	TS
	Facilitator: The joints of the paddle-pop sticks [inaudible].		TR	FE	ET			IL	IFS	
	Facilitator: Well the problem there is here,		CT	FE	ET	CK		IL	IFS	
		Facilitator is drawing out the problem 	CT						IFS	
	Facilitator: and you're going to have a problem there on the truss.		CT	FE	ET	CK		IH	IFS	
		Facilitator continues to sketch out his concerns with their design (cannot see exact movements)	TT						IFS	TS
35.26	Student C: And then we're going to have another one down there		CT	FE	ET	CK		IH	IFS	

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Student C points at diagram 	CT						ISF	
	Student C: and then we're going to join these two going that way.		CT	FE	ET	CK		IH	ISF	
		Student C demonstrates direction with a hand movement	CT						ISF	
	Facilitator: And this span is 5…		CT	FE	ET	CK			IFS	CS
	Student C: So yeah,		CT	FE	ET				ISF	
	Student C: like we have that one, that's…		CT		ET				ISF	
		Student C demonstrates the space between the struts with a hand gesture	CT						ISF	
	Student C: that's…		CT		ET				ISF	
		Student C reinforces this by: 	CT						ISF	
35.44	Facilitator: So effectively you're going to have the force applied in the centre…		CT	FE	ET			IH	IFS	CS

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Facilitator draws as: 	TR						IFS	
	Student A: And these beams will be a little bit…		TR	FT	ET			IL	ISF	
	Facilitator: So you really need to sort of think about paddle-pop stick		TR	FT	ET			IH	IFS	MS
		Facilitator continues to sketch out the nature of the problem 	TR						IFS	
	Facilitator: even the strengthening situation that you can do here to make that very strong		TR	FT	ET			IH	IFS	MS
		Facilitator points to the key element of the sketch Emphasises with several lines	TR						IFS	
	Facilitator: That one.		TR	FT	ET				IFS	
36.15	Facilitator: This situation here is no good.		TR	FT	ET			IL	IFS	

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

In Block 3 (see Table 5-16), the facilitator is shown to use non-verbal communication (in this case amending the sketch or working on his own) as the primary tool for meaning making. The words are used almost as a means to draw attention to his actions. The strength required – "*even the strengthening situation that you can do here to make that very strong*" – is emphasised by drawing a series of short heavy lines on the diagram. Across the discussion there are some instances of scaffolding, and as discussed above, where this takes the form of Technical Scaffolding (TS) this relies on non-verbal sketches.

5.2.4.3 Meaning construction

The three blocks analysed in detail in this excerpt see very different student approaches to problem solving. The first is a relatively task-centred discussion between two of the students, the second a discussion that loses focus between the students and the final stage sees another student-facilitator interaction.

In the first block (see Table 5-14) the content of their talk is consistently Concept-related Talk (CT) and about Conceptual Knowledge (CK). However, there is an instance of Conceptual Disagreement (CD), verbalised as "*actually no*", Needing Clarification (NC) and Self-answered Questions (SQ) as they collaboratively work on the problem. In terms of complexity it commences with a series of statements as Brief Answers (BA), usually in terms of the numbers that need to be assigned, and then shifts to a more Elaborate Telling (ET) *"because they are different angles"* as the students work out an interpretation. Towards the end they reach some agreement between themselves, coded as Agreement with PBL Member (AM). Thus this block is an example of Peer-to-Peer Internalisation (IPP) as a strategy of learning in a collaborative manner with almost all the speech related to the task. They carry on working out the answer and drawing sketches as they work but again the non-verbal communication is subordinated to speech and complementary in terms of meaning making. However, within this there are two moments were the non-verbal resources carry the meaning-making process. The first is when the student stops working with a dramatic gesture to emphasise the error he was making and the second is when a particular line on the diagram is heavily emphasised with a pen movement.

The second block (see Table 5-15) starts with the same discussion about Concept-related Talk (CT) but then shifts to a discussion with Task-related Talk (TT) and Tool-Related Talk (TR). Their speech becomes a rapid sequence of Brief Answers (BA) and Agreement with PBL Member (AM) as they lose their earlier focus. This excerpt sees the use of additional tools (the slides from the OHP), a statement that they need more information, "*I want questions and solutions*", with this point reinforced by one of the students laughing after the final word. At that stage (not covered) the discussion further breaks up into a conversation with a third student about access to lecture notes and when they can meet again.

The third block (see Table 5-16) sees the facilitator rejoin them to check progress. Unlike in Excerpt 3, where the conversation was dominated by the facilitator, here it is interactive as the students seek to explain their design. The discussion commences with a focus on the Task-related Talk (TT) and then the students explain their Concept-related Talk (CT). In turn the facilitator first expresses concern with this Concept-related Talk (CT) and Conceptual Knowledge (CK) as he says "*There's some major problems there*". He then continues to focus on the concept and to explain how they could carry out the Concept-related Talk (CT). The students then shift the conversation back to their design ideas as Tool-Related Talk (TR) and the facilitator concludes by stating "*This situation here is no good*". Almost all the discussion across this block is a complex of Elaborated Tellings (ET) as various solutions are discussed and explained. There is considerable use of non-verbal resources (especially sketched drawings) and these are often used to emphasise the meaning of any speech and to indicate areas of particular concern.

It is worth noting that in the two student-student blocks (Tables 5-14 and 5-15), meaning making is led by Peer-to-Peer Internalisation (IPP) as an approach of discussion and there is a complete lack of scaffolding. This supports a view that the students are unable to construct a framework that will aid their problem solving and instead they are trying to solve the task by piecemeal iteration. Their frustration with this is apparent in Table 5-15. When the facilitator joins them (see Table 5-16) there are some instances of him using scaffolding to create a framework but in this instance his focus too is on the practical issue of how to complete the immediate task.

The facilitator's role in meaning making is a consequence of him working with two of the students on their design. At first he asks them to explain their ideas (which they were working on at the start of the excerpt) but he then indicates a concern with their plan. In particular, he states that their design will not be able to bear the load that will be imposed. He concludes with a clear statement of concern as to their intentions. His role shifts from information provision to being more directive as he indicates just what they need to do.

5.2.5 Excerpt 5: Session 3 (4 min, 44 sec)

5.2.5.1 Context

This excerpt commenced with the group reviewing their calculation of the forces and the theoretical basis of the bridge structure. After the selected excerpt, there is a long input by the facilitator showing examples of both model and real-life bridge designs. Some of the models are selected as examples of failed designs and others as examples of successful designs. The selected excerpt comes at the end of the student review and again involves an engagement with the facilitator about progress and their understanding. The final inter-student discussion shows different group interaction and deployment of different semiotic resources, characterised in various ways.

5.2.5.2 Excerpt development

This excerpt opens with a discussion between one of the students and the facilitator about the focus point for the calculations. This short part ends with the students returning to individual working on the problem.

Table 5-17: Block 1, Excerpt 5 – initial interaction (28 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
08.26	Student D: Does it matter which point we get first		CT	NC	Clarif					
		Student D turns and points to whiteboard 	TT							
	Facilitator: Yes of course		TT	TA	AM				IFS	
		Facilitator emphasises with a circular hand gesture	TT							
	Facilitator: because what you're doing		TT		ET		GM	IL		
	Facilitator: is working out the point		CT		ET			IL		
	Facilitator: that's actually got the force on it.		CT		BA			IH		
08.27	Student D: Oh so that's where we start…		TT		BA				ISF	
		Student D points again 	TT							
	Facilitator: Yeah that's right		TT	TA	AM				IFS	
	Facilitator: doesn't matter?		TT	NC	Clarif					

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Facilitator: Yeah, right,		TT	TA	AM				IFS	
08.33	Facilitator: so you work out the force against the other members		CT	FE	ET		GM			TS
		Facilitator points downwards to emphasise the direction of the force	CT							
	Facilitator: and then you're going back to the point		CT	FE	ET		GM	IH		TS
08.36		Facilitator points: 	CT							
	Facilitator: that you know that force is the opposite		CT	FE	ET		GM	IH		TS
	Facilitator: on that 45 degrees,		CT	FE	BA			IL		TS
		Facilitator emphasises with gesture 	CT	FE	BA					TS
	Facilitator: how come the arrow is pointing up,		CT	FE	Clarif		GM			
	Facilitator: it should point downwards from that to…		CT	FE	ET	CK		IL		

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
08.54		Student B returns to working on own 	TT							

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

In the first block of Excerpt 5 (Table 5-17), the facilitator combines verbal and non-verbal modes to impart meaning. In particular, all the statements about direction of force are represented by a sequence of hand gestures showing direction and intersection. After this meaning-making interaction, the student group works individually for a short period until Timer 09.15, at which stage the dialogue with the facilitator starts again.

Table 5-18: Block 2, Excerpt 5 – facilitator explanation (50 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
09.15	Facilitator: What you're asking is		CT		ET				IFS	
	Facilitator: whether it's in tension compression		CT		BA		GM		IFS	
	Facilitator: Why is it tension,		CT	NC	Clarif		GM		IFS	
	Facilitator: why is it in compression		CT	NC	Clarif		GM		IFS	
	Facilitator: Sometimes it's intuitive,		CT	FE	BA			IL		
	Facilitator: you've got P1 sort of down,		CT		BA		GM	IL		
09.26	Facilitator: right		TT	SC	BA					
		Student C starts to sketch out what is being said on a sheet of paper	TT							TS
	Facilitator: it depends on the relative circumstances being P1 and P2,		CT	FE	ET					
09.35	Facilitator: so really in this sort of instance,		CT	FT	ET			IH		
09.40	Facilitator: what you need to do is to work out a balance		CT	FE	ET		GM	IH		TS
		Workings are shown on the OHP	CT							TS
	Facilitator: right,		CT	FE			GM			

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Facilitator: of the forces.		CT	FE	BA					TS
	Facilitator: So it's saying there that FY…		CT	FE	BA					TS
	Facilitator: It's falling apart.		CT	FE	BA					
	Facilitator: see what you've done is in the Y direction,		CT	FE	ET			IL		MS
10.05		Facilitator points at screen 	CT	FE						MS

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

A problem with Block 2 is that the recording does not show the facilitator until the final image. It can be assumed he is reinforcing the meaning making by pointing at parts of the OHP display that shows a bridge design and the theoretical issues. The facilitator continues to develop this explanation for the next minute up to Timer 11.19 when the meaning making returns to an interactive mode. Table 5-18 though does show a balance between the earlier part (up to Timer 09.26) where the facilitator is being quite direct in the provision of information and the latter section where there is a significant amount of scaffolding in his comments and gestures. Unlike in some other sections, here Technical Scaffolding (TS) is largely verbal as opposed to the reliance on non-verbal resources in this respect noted in many other blocks.

Table 5-19: Block 3, Excerpt 5 – Interactive meaning making (48 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
11.19	Student D: So how can we say that's compression then?		CT	NC	Clarif					
		Student D points at board 	CT	QF						
	Student A: I said it's compression.		CT	ACK	BA				IPP	
	Facilitator: It's not compression on that member.		CT		BA				IFS	
11.28	Student D: Wouldn't it be compression?		CT	NC	Clarif					
		Student D points at board 	CT	CA						
	Student D: because there's a force coming down on the object		CT		ET	CK			IPP	
11.37	Student D: which is compressing the material		CT	NC	Clarif					

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Student D continues to point at the material on the board	CT	CA						
11.44	Student D: Because if there was just the force going up		CT		ET	CK			IPP	
		Student D demonstrates direction of force by a hand movement	CT	CA						
	Student D: then it would be in tension,		CT		ET	CK				
	Student D: but because it's coming down,		CT		ET	CK			IPP	
	Student D: and it's pushing down,		CT		ET	CK				
11.49	Student D: isn't that compressing it?		CT	NC	Clarif				IPP	
		Student D looks at other student as he asks the question	PT							
	Student C: How come the X one…compression		CT	NC	Clarif					
		Student C points: 	CT	CA						
	Student D: The X one is in tension.		CT		BA					

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
12.02	Facilitator: So just look at the force at D there,		CT	FE	ET	CK				TS
	Facilitator: have a look at the force in D		CT	FE	ET	CK			IFS	TS
12.07	Facilitator: because D must be opposite to the force at A.		CT	FE	ET	CK				TS
		Facilitator walks to the board to point at what he means	CT	FE						

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

In this block of the Excerpt 5, meaning making is interactive (a lot of questions are posed) and mostly verbal. Non-verbal gestures are used to point to the parts of the OHP that are under discussion (effectively emphasising the meaning making and reducing the scope for ambiguity). At this stage there is another very short interlude and then the students discuss the problem among themselves. Again the facilitator starts by answering direct questions, as in the following exchange: Student A: "*I said it's compression*"; Facilitator: "*It's not compression on that member*". However, at the end he returns to trying to structure the students' problem solving with his utterances after Timer 12.02. Again, these are all instances of verbal Technical Scaffolding (TS).

Table 5-20: Block 4, Excerpt 5 – student discussion (56 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
12.14	Student A: Why is X compression		CT	NC	Clarif					
		Student A indicates compression by squeezing hands together	CT	CA						CS
	Student A: there's nothing pushing on it?		CT	NC	Clarif					
	Student A: There's tension,		CT		BA	CK				
	Student A: there's nothing pushing.		CT		BA					
12.21	Student D: Because A to D there's no force that's pushing.		CT		ET	CK			IPP	
		Student D demonstrates the intended range of movement by hand gestures	CT	CA						CS
	Student D: Like if you move onto the diagram		CT		ET	CK			IPP	
		Student D then points at OHP to identify the important piece of information	CT	CA						
	Student D: there wasn't any force going to A or D,		CT		ET	CK			IPP	

Time*	**Verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Student D: there's a force just coming down,		CT		ET	CK			IPP	
		Student D shows: 	CT	CA						
	Student D: which is opposite to Y going up.		CT		ET	CK				
		Student D uses hand gestures to show what this means in practice	CT	CA						
	Student D: Because you have to work out for the pin,		TR		ET	CK				
	Student D: yeah?		CT	NC	Clarif					
		Student D gesticulates 	CT	CA						
	Student D: For that pin because		CT		ET	CK				
12.42	Student D: the Y direction is up and down,		CT		ET				IPP	
		Student D emphasises by hand gesture moving up and down	CT	CA						

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Student D: there was a force coming down which compresses it.		CT		ET	CK				
		Student D points downward with one hand	CT	CA						
12.46	Student D: But because there was no horizontal force,		CT		ET	CK				
		Student D demonstrates with a hand gesture pointing up	CT	CA						
	Student D: it's in tension		CT		ET	CK				
	Student D: because it's being pulled.		CT		ET					
		Student D's hands pulled apart to emphasise this	CT	CA			MSDL			
	Student A: Yeah.		CT		BA					
12.51	Student D: Do you know what I mean?		CT	NC	Clarif					
		Student D gestures towards the other student	PT							
	Student A: Yeah.		CT		BA				IPP	
	Student D: I don't know if that makes sense.		CT		BA				IPP	
	Student D: See for B		CT		ET	CK	MSDL			

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Student D: it's relative compression as well,		CT							
		Student D points at whiteboard to indicate point of interest	CT	CA			MSDL			
	Student D: the force coming down on the object.		CT		ET	CK			IPP	
		Student D again emphasises: 					MSDL			TS
13.10	Student A: It's confusing stuff.		CT		BA					

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

Across Block 4 of Excerpt 5, non-verbal and verbal resources are deployed in a complementary manner. Almost every statement about compression and direction of forces is accompanied by hand gestures designed to show visually what is meant by the spoken words. In addition, gestures are used to emphasise which parts of the OHP screen contain the information that is being used in meaning making.

5.2.5.3 Meaning construction

The opening block of this excerpt (see Table 5-17) commences with a student asking a question and then sees an explanation delivered by the facilitator. The conversation in terms of content shifts from Concept-related Talk (CT) to Tsk-related Talk (TT) and back again as the facilitator starts to offer guidance ("*so you work out the force*"). The opening phase sees collaboration in terms of questions and Task-related Agreements (TA); however, after the statement "*so you work out the force*", there is a related shift in the nature of collaboration with the rest of the block dominated by the Facilitator's Explanations (FE). This divide in the block is also shown in the relative complexity of each semiotic element. At the start this is dominated by Agreement with PBL Member (AM) and Brief Answers (BA), but the second part is dominated by Elaborated Telling (ET) as the concepts are discussed. This latter portion is also dominated by instances of Technical Scaffolding (TS).

The second block in this excerpt (see Table 5-18) sees the facilitator explaining the forces and calculations that are needed. As such it is dominated by Concept-related Talk (CT), but the facilitator also poses a number of questions, so there is a degree of collaboration as he is looking to the students for clarification whether Needing Clarification (NC) for the content or seeking Clarification (Clarif) in terms of his statements. However, the final part is again dominated by the Facilitator's Explanation (FE). On the other hand, unlike in the excerpt shown in Table 5-17, the speech is dominated by Brief Answers (BA), in particular in conjunction with pointing at the information on the whiteboard. The block is dominated by checking on the group's progress via Group Monitoring (GM). The second portion sees a reliance on Technical Scaffolding (TS) to ease meaning making with some instances of metacognitive scaffolding (MS).

The third block (see Table 5-19) sees much more interaction between the facilitator and the students. The focus is still firmly on the concept-related Talk (CT) but the style of collaboration is different to the excerpts in both Table 5-17 and Table 5-18. It is dominated by Needing Clarification (NC) and Acknowledgements (Ack) and it is only at the end that it is dominated by the Facilitator's Explanation (FE), in part relying on Technical Scaffolding (TS). Despite the openness of the dialogue, it is dominated by Elaborated Telling (ET) as complex questions are posed and explored.

The final block (see Table 5-20) sees two students engaged in meaning making and referring to the slides left visible on the whiteboard as they do so. Again, the bulk of the comments relate to Concept-related Talk (CT) and Conceptual Knowledge (CK) so the student interaction is content-focussed rather than involving personal discussion. Their collaboration is one of posing issues that Need Clarification (NC) as to the difference between tension and compressor. The responses vary in complexity between posing questions that seek Clarification (clarify), Brief Answers (BA) as they explore the subject matter and some Elaborated Telling (ET) as one or the other seeks to explain their understanding. This block sees considerable use of non-verbal resource of gestures to emphasise how the student who is explaining the dynamics understands how it is working. The meaning-making process is a balance of speech and gesture with both deployed to the same end.

Across Excerpt 5, the facilitator makes less use of scaffolding than in the earlier discussions. In this excerpt the facilitator is seen to play three slightly different roles in the various selected blocks. In Table 5-17, he starts with being interactive and leading students' meaning making but towards the middle shifts to providing an explanation. The latter portion is facilitator-led and dominated by a complex of Elaborated Tellings (ET). In the block shown in Table 5-18, the facilitator again leads the meaning-making process (most of the utterances are coded as Facilitator's Explanation (FE)), but the type of statement has shifted. There is substantial use of the information on the whiteboard (by pointing and gesture) and, perhaps in consequence, is dominated by Briefer Answers (BA). The third block (see Table 5-20) sees a much greater reliance on shared meaning making with responses to student questions.

5.2.6 Excerpt 6: Session 4 (3 min, 39 sec)

5.2.6.1 Context

Session 4 features two of the students testing a variety of practical bridge designs. The selected excerpt sees them recommence this process with a second potential layout. Shortly after the completion of this excerpt, the conversation becomes personal rather than task-centred.

5.2.6.2 Excerpt Development

The session can be broken down into three phases. The first sees one potential layout for the model bridge explored, the second sees this revised and the third sees a shift of focus to the timetable to complete the design and a discussion of the other tasks they have to undertake.

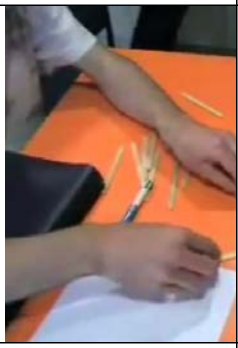
Table 5-21: Block 1, Excerpt 6 – opening discussion (1 min, 57 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
19.47	Student A: I think that's probably the best angle for transporting weight or whatever,		CT		EE			IH	IPP	
		Student A uses protractor to assess the angle that is needed	CT							
		Student C fiddles with the paddle-pop sticks 	PT							
	Student A: it's so tough		CT		ET					
	Student A: it will transfer it evenly.		CT		EE			IH		
19.48	Student C: Yeah		CT	CA	AM	CK			IPP	
		Students A and C are using the sticks to map out their design	CT	CA						
		Student C is still using the sticks 	CT	CA						
	Student C and they'll both…		CT		BA					
	Student A: Yeah.		CT	CA	AM				IPP	
19.50	Student C: Take them apart		CT		BA					

Time*	**Verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Student C re-organising the paddle-pop sticks 	CT	CA						
	Student C: so we don't have three…		CT		BA					
19.52	Student A: Yeah.		CT	CA	AM				IPP	
	Student C: So the middle of the bridge…		CT		ET	CK				
		Student C Emphasises by use of the paddle-pop sticks 	CT	CA						
	Student A: Then we'll have two to work out.		CT		ET				IPP	
20.14	Student C: But we want to just not put it on top at this stage now.		CT		ET	CK				

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Both students work with the sticks: 	CT	CA						
	Student A: Yeah fair enough,		CT		ET				IPP	
		A design is laid out and then adjusted as they speak	CT							
20.19	Student A: but we'll have them touching just in the corners,		CT		ET					
			CT	CA						
	Student A: yeah?		CT	NC	Clarif					
20.22	Student C: So that's one there.		CT		BA	CK			IPP	

Time*	**Verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
			CT	CA						
	Student A: Have a look it's coming out… Yeah see that's about 45, I touched it, but…		CT		ET					
		measuring angles 	CT		ET					
20.47	Student A: I touched it, but…		CT		ET					
	Student C: Yeah [inaudible – background noise].		CT	CA	AM	CK			IPP	
	Student C: And then that's going to touch there,		CT		ET	CK				

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
21.38			CT	CA						
	Student C: but now we also need the other one to come back up to 45.		CT		ET	CK				
	Student A: Oh yeah.		CT	CA	AM				IPP	

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

Block 1 (see Table 5-21) sees the students using the paddle-pop sticks as the main meaning-making resource. Their speech is a verbalisation of their actions as they pick up and deploy the paddle-pop sticks and develop their layout of the bridge frame. Block 2 reported in Table 5-22 below sees them review this design to take account of their understanding of the task and the flaws in their design so far.

Table 5-22: Block 2, Excerpt 6 – revision of design (34 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
21.47	Student C: Which I forgot about that one,		CT		BA				IPP	
			CT	CA						
	Student C: going back up.		CT		BA					
		Student C points with pen across the working design to indicate the focus of this point	CT							
21.48	Student A: Only one coming back up,		CT	NC	Clarif					
			CT	CA						
	Student A: yeah?		CT	NC	Clarif					
21.52	Student C: On each side.		CT		BA	CK			IPP	
			CT	CA						
	Student C: And these are just going to		CT		ET	CK				
		Student C starts adding new sticks to one side to show what is meant	CT		ET					
	Student C: – and then…		CT		ET	CK				

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
21.59	Student A: So we have to leave a gap for those to come up?		CT	NC	Clarif					
			CT	CA	ET					
	Student C: Yeah.		CT	CA	AM				IPP	
22.06	Student A: There's got to be a way to figure it out exactly,		CT		ET					
		Student A - Hand gesture is used to indicate the area that is seen to be a problem	CT	CA						
			CT	CA						
	Student A: so we now how far it all has to be.		CT		ET					
	Student A: I guess if you just have two 45s…		CT		ET				IPP	
	Student A: So we have to leave a gap for those to come up?		CT	NC	Clarif					

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
	Student C: Yeah.		CT	CA	AM				IPP	
			CT	CA						

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

As with Block 1 (see Table 5-21), Block 2 (see Table 5-22) sees the shifting layout of the paddle-pop sticks as the main meaning-making resource. The paddle-pop sticks are adjusted as they discuss the design. In places, gestures using a pen or hand are used to indicate either a direction of a force or the exact area of their concern. The final block of Excerpt 6 sees a radical change of focus as the students shift from discussion of the design to discussion of the complete task and the work they need to do in the following weeks.

Table 5-23: Block 3, Excerpt 6 – discussion of wider task (1 min, 2 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
22.24	Student A: What time is it due – when is it due,		TT	NC	Clarif					
		Student A holds head in hands	PT	TA		UP				
		Students sit back: 	PT							
	Student A: not next week yeah?		CT	NC	Clarif					
	Student C: Yeah next week.		TT	TA	AM				IPP	
22.32	Student A: Are we in week 11 now?		TT	NC	Clarif					
		Student A sits back and crosses arms	PT	TA						
			PT	TA						
	Student C: Yeah.		TT	TA	AM				IPP	
	Student A: Oh no,		PT		BA				IPP	
	Student A: have you started your portfolio yet?		PT	NA	Clarif					
	Student C: Yeah, kind of.		PT	TA	AM				IPP	
	Student A: I'm stuck on week five		PT		BA				IPP	
		Student A places head in hands again	PT							

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
22.39	Student A: yeah it's going to be a busy week or two.		PT		BA					
			PT							
	Student C: Unless,		TT		ET					
	Student C: do you want to do the report		TT	NC	Clarif					
	Student C: and I'll see if I can do this,		TT		BA					
	Student C: try and do the whole thing.		TT		ET					
23.13	Student C: And you be the one to do the report.		TT		ET					
			TT							
23.26	Student A: If you want,		PT		ET				IPP	
			PT							

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

In the excerpt shown in Table 5-23, verbal and non-verbal resources are deployed collaboratively but in an unfocussed manner. Thus the statements of frustration or concern at the workload, such as "*I'm stuck on week five*", are accompanied by gestures, such as the student putting his head in his hands (a non-verbal indication of worry or concern). While in the excerpt shown in Table 5-22 the two students use the paddle-pop sticks to reinforce the meaning, here one sometimes picks them up at random and the other fidgets in his seat. The loss of focus in Table 5-23 is clear both from the speech and the non-verbal gestures.

5.2.6.3 Meaning construction

The first block is dominated by Concept-related Talk (CT) and Conceptual knowledge (CK) as the students focus on the bridge design. This block also sees a range of multimodal resources deployed in terms of meaning making, in particular one or both students using the paddle-pop sticks to develop a potential design. Across the block, the students work collaboratively with frequent indications of Conceptual Agreement (CA) and Agreement with PBL Member (AM). The responses are often based on an Elaborated Telling (ET) but in places this is also the development and working out of new Elaborated Explanations (EE) such as "*it will transfer it evenly*" as they develop the design.

The second block (see Table 5-22) sees a revision to this design introduced. Again there is use of semiotic resources other than speech as they explore, elaborate and revise their potential design. However, their discourse remains Concept-related Talk (CT) and concerned with Conceptual Knowledge (CK). Again they work collaboratively as is clearly shown through the use of Peer-to-Peer Internalisation (IPP) as the design is revised. Agreement is also utilised whether Conceptual Agreement (CA) or Agreement with PBL Member (AM). Apart from the start where the shift of focus is signalled as Brief Answers (BA), most of the speech is related to Elaborated Telling (ET) telling and Elaborated Explanation (EE). In this block the non-verbal meaning making of the shifting layout of the paddle-pop sticks is critical and the speech is a form of verbalising these gestures.

The final block (see Table 5-23) sees a shift from the task to consideration of the wider timetable and other constraints on their time. Non-verbally this is signalled by sitting back and no longer using the paddle-pop sticks to construct potential patterns. Verbally there is a shift, first to Task-related Talk (TT) and then to Personal Talk (PT). Their speech becomes less complex, coded as Brief Answer (BA), but is still marked by frequent agreement, coded as Seeking Clarification (Clarif). In this block, the gestures become less task focussed, and instead characterised by indications of concern (such as placing head in hands).

5.2.7 Excerpt 7: Session 5 (4 min, 24 sec)

5.2.7.1 Context

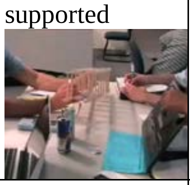
Excerpt 7 was selected from Session 5 where the two students who had been present in Session 4 return to the PBL class with the model of the bridge they constructed after Session 4 had ended. The main focus was on the bridge design and an evaluation of the model constructed by the students since the discussion explored it, as shown in Excerpt 6 (see Section 5.2.6). The opening block is an initial evaluation of the design and this is followed by a discussion of how to improve on that design, in particular how to support the basic frame that has been designed.

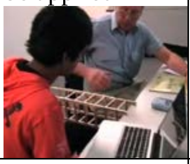
5.2.7.2 Excerpt development

In the first block the facilitator joins the student group and reviews the model constructed since Session 4.

Table 5-24: Block 1, Excerpt 7 – review of model (1 min, 35 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
22.20	Facilitator: What we are going to start doing now is talking about the bridge.		CT	FE	ET			IH		
	Facilitator: Any modifications that have to be done should be done now.		TT		ET			IH		PS
	Facilitator: If the bridge is off centre at all		CT	FE	BA	CK				
	Facilitator: it will not be supported by the joints		CT	FE	ET			IH		
	Facilitator: will it?		CT		BA					
22.26	Facilitator: Lets have a look at it now….		TT		BA		GM			CS
			TT	FT						
	Facilitator: And that's what you call just a box spring		TR	FT	ET		GM			
	Facilitator: that's all it is.		TR		BA			IL		
		Facilitator picks up model 	TR	FT						PS
	Facilitator: OK so how are you going to fit this into the unit?		TR	FT	ET		GM	IH		PS

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
22.57	Facilitator: What's the total torque?		CT	FE	BA			IL		CS
	Student A: Well it will be supported right here		CT		BA				ISF	
	Student A: and we will push it into here.		CT		BA				ISF	
23.04		Student A picks up model to demonstrate how it will be supported 	CT	TD						CS
	Facilitator: That's going to have no support		CT	FE	BA			IH		CS
	Facilitator: that situation.		CT	FE	BA					
	Facilitator: The only way that this idea would work is		CT	FE	BA			IL		
	Facilitator: if the pre-tension was calculated into it.		CT	FE	ET	CK		IH		CS
	Facilitator: It will have to be an angular shape		CT	FE	ET	CK		IH		CS
	Facilitator: you will have to force it in		CT	FE	BA	CK				CS
	Facilitator: and have an applied force to counteract the dip.		CT	FE	ET	CK		IH		CS
	Facilitator: That's not going to work, that way.		CT	FE	ET					

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Facilitator: So yeah, it's going to have to be cut to fit.		CT	FE	ET			IL		CS
23.21	Facilitator: But look at the force;		CT	FE	BA			IL		
		Facilitator gestures with his hand in a triangle shape to demonstrate where the force would have to be applied 	CT							CS
23.27	Facilitator: it's going to be applied in the centre.		CT	FE	ET			IH		
		Facilitator places hand on model to indicate position 	CT							CS
23.42	Student A: So the centre is here?		CT	NC	Clarif					
		Student A points to the centre 	CT	SF						CS
	Facilitator: Right here is typical of the sort of issue you see.		CT	FE	ET			IH		

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Facilitator points again at the centre of the model	CT							CS

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

In Table 5-24, meaning making is heavily influenced by non-verbal resources. The bridge model is the focus and both students and facilitator indicate the focus of their meaning by pointing at parts of the model or using it to physically demonstrate what they mean. So, for example, at Timer 22.26 the facilitator picks up the bridge shortly after he states *"lets have a look at it now"*. He then asks *"how are you going to fit his into the unit"*, so by holding the model he is emphasising the relevance of his verbal comments and ensuring that the students are aware of the nature of the problem he has identified. After Timer 22.57 Student A repeats this pattern by picking up the model as he states "*we will push it into here"*. So again the spoken meaning is reinforced by use of the model. After Timer 23.21, the facilitator makes a series of statements such as "it's going to be applied in the centre" and each time gestures at the model to indicate what he is referring to. Both the facilitator and the students engage in this form of reinforcement of meaning making, stating what they are seeking to do (or their concern) and picking up or pointing at the model as they do so.

Here, both verbal and non-verbal resources are used in a supporting manner, with speech containing the detail and non-verbal resources being used to emphasise what is being said or to provide a context. With the completion of this phase of the interaction, the focus moves onto how the model needs to be redesigned. In the excerpt shown in Table 5-24 the facilitator is making a substantial use of scaffolding, both Procedural Scaffolding (PS) and Conceptual Scaffolding (CS), as he tries to bring the students to an understanding of the problem with their model.

Table 5-25: Block 2, Excerpt 7 – model development (1 min, 9 sec)

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
23.59	Facilitator: You have the load		CT	FE	BA			IL		CS
		Facilitator puts pen across middle of bridge to demonstrate load issue	TR							CS
	Facilitator: which is going to be effectively taken up at an angle on this frame.		CT	FE	ET			IH		
		Facilitator puts his hand on the frame: 	TR							CS
	Facilitator: The frame is strong		CT	FE	ET					
	Facilitator: You have no problem with the frame.		CT	FE	ET			IL		
	Facilitator: The worry is that there's no um		CT	FE	ET					
	Facilitator: … what's the word…?		CT		BA					
		Facilitator makes gesture with hands to show whole length of bridge	TT							CS

Time*	**Verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
	Facilitator: How many popsicle sticks did you use in total?		CT		BA		GM			
24.26	Student A: 119		TR		BA					
		Student A has picked up model and laid it against the edge of the desk 	TT	N						PS
	Facilitator: Well you got plenty of those.		TR		BA		GM			
	Student A: Well, what I'm thinking we should do		TT	QF	BA					
	Student A: is instead of here like that…		TT	QF	BA					
24.32		Student A places the bridge, with the end resting on the table edge 	TT	SC						
	Student A: What if I put it right here?		TT	QF	BA					

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
24.34		Student A raises the model so the base now rests on the table 	TT	SC						
	Facilitator: You can't just have it sitting on the frame;		TT		BA	CK		IL		PS
	Facilitator: it's got to be below.		CT		BA	CK				
24.45	Facilitator: It's a bridge;		TT		BA					
	Facilitator: it's effectively a platform that you can go across.		TT		ET			IH		
		Facilitator runs hands across bridge to indicate the motion of travel	TT	SC						
		Student A returns bridge to resting on the desk from the top 	TT							
	Student A: So it can't be like that?		TT	QF	BA					

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Student A demonstrates by moving the bridge so it all rests on the table 	TT	SC						
24.57	Facilitator: No, no….		TT	TD	BA					
	Facilitator: I think if you read the instructions it would become clear.		TT		BA			IH		PS
		At this point the facilitator turns partially away from the student 	PT	TD						
		Student A picks up the bridge to examine it	PT							

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

Again this interaction is marked by the use of multimodal resources. Students and facilitator use different layouts of the bridge model to exhibit what they mean and in this respect, again, verbal and non-verbal resources are used supportively to build up meaning. For example, in the discussion at Timer 24.26, the student is answering the question about the use of the paddle-pop sticks but is placing the bridge in anticipation of the next discussion (concerning how it should rest on the table). The second episode comprises the facilitator's comment and his body language at Timer

24.57. Here he is telling the students that they have effectively not read the instructions and completes this statement by saying "… *It doesn't really matter*" as he turns away. In combination, speech and gesture indicate displeasure by the facilitator and this moment ends with the students looking at the bridge and the facilitator now at the table. In a continuation of the themes in Block 2 (see Table 5-25), there is some use of Procedural Scaffolding (PS) as the facilitator tries to ensure that the students are able to see the context for his concerns but in this case this is mostly framed in terms of the task set rather than because of intrinsic flaws of the bridge.

At this stage, the discussion is still about the revision of the model, but shifts to how to build in adequate support for the element already constructed.

Table 5-26: Block 3, Excerpt 7 – supporting the frame (1 min, 32 sec)

Time*	**Verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
25.12	Facilitator: It's the truss.		CT		BA					CS
	Facilitator: I would definitely try to straighten up the corners		CT	FE	ET			IH		CS
		At this stage the Student A puts down the bridge in the middle of the table. 	PT							
	Facilitator: and would try to give some stability to the frame		CT	FE	ET			IH		CS
25.21	Facilitator: so it doesn't deform in this direction…		CT	FE	ET			IH		CS
		Facilitator takes a paddle-pop stick, places it against the support beams on the side of the bridge and moves it in an arc 	CT							CS
	Facilitator: Also here,		CT	FE	BA					
25.26	Facilitator: so it doesn't deform in that direction.		CT	FE	BA			IH		CS

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Facilitator takes a paddle-pop stick and places it against the top and bottom lines of beams 	CT							CS
	Facilitator: So what your going to do is bind the frame in.		TR	FT	BA			IH		PS
25.28	Facilitator: You could do away with these central beams		TR	FT	ET			IH		PS
		Facilitator points at parts of bridge 	TT							CS
	Facilitator: but it’s up to you…		TT		BA					
	Facilitator: What you need to do is start to strengthen the truss.		CT	FE	ET			IH		CS
25.53	Student A: What if I like		CT	QF	BA					
		Student A gestures at bridge with finger and then pen. 	CT							CS

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
26.00	Student A: we chuck one in here?		CT	NC	BA					
		Student A picks up bridge and places popsicle stick in middle of bridge 	CT							
26.07	Facilitator: It would be very tight,		CT	FE	BA			IL	IFS	
	Facilitator: what we call a force fit.		CT	FE	BA	CK		IL	IFS	
	Facilitator: So in this situation you only need to be a fraction of a millimetre over		CT	FE	ET	CK		IH	IFS	
	Facilitator: So I would be strengthening these sections in each direction.		CT	FE	ET	CK		IH	IFS	
		Facilitator moves bridge, indicates placement of reinforcing - as he is explaining these, he points to the support beams along the bridge 	CT							CS

Time*	Verbal semiotic resources (speech)	Other synchronous non-verbal semiotic resources	Resource category							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
26.22	Facilitator: take the glue and put it over here and here.		TR	FT	BA					PS
		Facilitator picks up red bull can and waves it to show where glue should go 	TR							
			TR							
	Facilitator: Then when you are finished		TR	FT	BA					
	Facilitator: you are going to let it sit		TR	FT	BA					
26.28	Facilitator: and the glue will slide all the way in here.		TR	FT	BA					
		Facilitator slides finger along top of bridge 	TR							CS
	Student B: I see….		TT	AF	BA					
		Students indicate agreement by nodding head	PT	Ack	BA					
26.34	Facilitator: So I would be strengthening all these sections in each direction.		CT	FE	ET		GM		ISF	CS

Time*	**Verbal semiotic resources (speech)**	**Other synchronous non-verbal semiotic resources**	**Resource category**							
			Content	Collaboration	Responses of ideas/ complexity	Knowledge	Metacognition	interpretation	Internalisation	Scaffolding
		Facilitator points, moves hands to indicate 	CT							CS
	Facilitator: Then you have to start to reinforce the corners so that they do not break		CT	FE	ET	CK		LA		
		Facilitator gestures to corners, points to the middle of the bridge 	CT							CS
	Facilitator: But you got plenty of sections here…		CT	FE	BA	CK				PS
	Facilitator: It's a strong frame.		CT	FE	BA					
		Student A agreement indicate by nodding head	PT	Ack	AM					
26.44	Facilitator: The frame is good.		CT	FE	BA					

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

In this block the meaning making is led by the facilitator who is seeking to explain the flaws in the current bridge design and what needs to be added to make a robust model. In this case, again, the non-verbal resources are very important as much of the exposition involves pointing at parts of the model to indicate what is meant and the speech is used to support the same message. It is notable that in many instances pointing at parts of the bridge is used to scaffold the students' knowledge and understanding through the use of Conceptual Scaffolding (CS). For a minute after the beginning of this transcript, the discussion shifts to how the model will be tested and then Student A offers an alternative design and the discussion shifts to reviewing that model. Again the facilitator makes considerable use of scaffolding, both Conceptual Scaffolding (CS) and Procedural Scaffolding (PS), as he tries to ensure the students understand the context of his concerns and why he is indicating that their current design will not meet the expectations of the task.

5.2.7.3 Meaning construction

This period of analysis is drawn from the fifth PBL session and covers the facilitator discussing the development of the bridge model with the students. The first block (see Table 5-24) commences with a review of the model. In terms of overall content it sees a transition from Task-related Talk (TT) about the model to Concept-related Talk (CT) in terms of problems with the actual design. This cycle is then repeated as the facilitator raises two issues in turn (how the bridge will be supported and the torque). The non-verbal resources (mainly pointing at parts of the model) are used to complete the concepts introduced verbally so speech is dominant but meaning making is heavily dependent on the model as a semiotic resource. Throughout this block, Conceptual Scaffolding (CS) is used to assist with learning as concepts are introduced and built upon, with the goal of ensuring the students understand why their current design does not meet the task requirements.

The second block (see Table 5-25) starts immediately after the transcript reported in Table 5-24 breaks off. Again this period commences with the introduction of a concept (how the force will be applied to the frame) and then this leads into a discussion about the structure of the model. As with Table 5-24, one consistent element is that the non-verbal gestures are often used to complete speech and that learning is being structured using Conceptual Scaffolding (CS). The student response at Timer 24.26-24.34 is an attempt to use various positions for the model to explore what the facilitator had said earlier. The response it turn is quite direct ("*You can't* *just have it sitting on the frame … It's a bridge*") and relies on Procedural Scaffolding (PS) for learning. When the student repeats the earlier ideas, the second response by the facilitator at Timer 24.57 is even more direct ("*I think if you read the instructions it would become clear*"), in particular when combined with turning away from the student after saying this.

The final block (see Table 5-26) follows on from this exchange at Timer 25.12 as the facilitator begins to try and explain what the problem is. He starts by setting out a number of concept-related Talk (CT) and by Timer 25.28 this has again become a process of showing what is meant by adopting Task-related talk (TT) Tool-Related talk (TR) using the bridge design. Student A then, at Timer 25.53, returns the discussion to the concepts until Timer 26.22 when again this becomes a discussion of the practical processes needed to apply these ideas. The session then comes to an end from Timer 26.34 onwards with the reintroduction of new concepts concerning the aspects of the model that now need to be strengthened.

Tables 5-24 and 5-25 can be broken down into a series of very short interactions where a concept is introduced (using both verbal and non-verbal resources) and then the focus shifts to the practical application (again using both verbal and non-verbal resources). This entire session sees verbal and non-verbal resources deployed to support each other in meaning making, indeed one common transition is that the non-verbal gestures are used to complete a process of meaning making that was commenced with a verbal statement.

In particular, Block 1 reported in Table 5-24 sees the facilitator making considerable use of scaffolding whether with Conceptual Scaffolding (CS) to indicate why the bridge design does not meet the earlier discussions or with Procedural Scaffolding (PS) as he relates the problems with the current design to the nature of the task the students were set. In Table 5-25 there is less use of scaffolding and it is all Procedural (PS). Table 5-26 sees a return to the use of a mix of Conceptual and Procedural Scaffolding (CS and PS) as he seeks to enable the students to understand, using their own reasoning, why the current bridge design fails to meet both the concepts provided in Sessions 1 to 3 and the procedural nature of the task they have been set.

5.3 Analysis of semiotic content of all seven excerpts

The various parts of Section 5.2 have seen seven selected excerpts of the five PBL sessions extracted and analysed in terms of their semiotic content. Each excerpt in turn has been broken up into two or more excerpts depending on shifts either in meaning-making process or focus. Across the seven excerpts selected for detailed multimodal analysis there are 21 individual blocks, each containing an excerpt from the transcripts chosen as they exemplify either a key step or the different approaches to meaning making. These are categorised using the distinction adopted in Chapter Four between:

1) Student interaction – i.e. dominated by discussion within the student group;
2) Facilitator's presentation to the whole class; and,
3) Facilitator's presentation just involving the PBL group.

Some excerpts contain elements of more than one of these types of interaction but have been selected so that, as far as possible, one is dominant. The other difference across the various excerpts is a shift of focus from theory to model design (with these remaining interlinked at certain stages). This is summarised in Table 5-27.

Table 5-27: Session coding and allocation

Table #	Block #	Excerpt #	Session #	Time*	Focus	Theory or Model Building	Dominated by
5-02	-	1	1	01.25-04.00	Facilitator Presentation (Whole class)	Theory	Facilitator
5-07	1	2	1	24.27-27.38	Student Interaction	Theory	Students
5-08	2	2	1	24.27-27.38	Student Interaction	Theory	Students
5-09	3	2	1	24.27-27.38	Student Interaction	Theory	Students
5-10	1	3	1	54.21-56.37	Facilitator Presentation (PBL group)	Model Building	Facilitator
5-11	2	3	1	54.21-56.37	Facilitator Presentation (PBL group)	Model Building	Facilitator
5-12	3	3	1	54.21-56.37	Facilitator Presentation (PBL group)	Model Building	Facilitator
5-13	4	3	1	54.21-56.37	Facilitator Presentation (PBL group)	Model Building	Facilitator (some student involvement)
5-14	1	4	2	30.50-36.15	Student Interaction	Theory	Students
5-15	2	4	2	30.50-36.15	Student Interaction	Theory	Students
5-16	3	4	2	30.50-36.15	Facilitator Presentation (PBL group)	Model Building	Facilitator (some student involvement)
5-17	1	5	3	08.26-12.51	Facilitator Presentation (PBL group)	Theory	Facilitator
5-18	2	5	3	08.26-12.51	Facilitator Presentation (PBL group)	Theory	Facilitator
5-19	3	5	3	08.26-12.51	Facilitator Presentation (PBL group)	Theory	Students (some facilitator involvement)
5-20	4	5	3	08.26-12.51	Facilitator Presentation (PBL group)	Theory	Students
5-21	1	6	4	19.47-23.26	Student Interaction	Model Building	Students
5-22	2	6	4	19.47-23.26	Student Interaction	Model Building	Students
5-23	3	6	4	19.47-23.26	Student Interaction	Model Building	Students
5-24	1	7	5	22.20-26.44	Facilitator Presentation (PBL group)	Model Building	Facilitator (some student involvement)
5-25	2	7	5	22.20-26.44	Facilitator Presentation (PBL group)	Model Building	Facilitator (some student involvement)
5-26	3	7	5	22.20-26.44	Facilitator Presentation (PBL group)	Model Building	Facilitator (some student involvement)

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

Table 5-27 is important to the discussion that follows as it allows selection of individual blocks that can be used to compare the changes and the type of description that the use of semiotic resources leads to, either by different combinations of participants or for different purposes. The combination of ‘focus’ (column 7) and ‘dominated by’ (column 9) allows exploration of two styles of facilitator interaction – where he dominates the meaning making and where this is interactive with the students.

In particular it quickly summarises two key transitions within the PBL class:

1) The transition of focus from the theoretical concerns to model design; and
2) Who the session was dominated by, mostly following the ‘focus’ column but which allows separation of the facilitator’s interaction with the PBL group into sessions where only the facilitator is involved in meaning making from those that are marked by a degree of interaction.

The columns in Table 5-27 allow for comparison and contrast between the multimodal resources deployed when, for example, the facilitator is speaking to the entire class, interacting with the PBL team (with a theory focus) and interacting with the PBL team (with a model building process). Equally, the similarities and differences in the use of multimodal resources by the student group can be traced as they move from theory to model building and in their interaction with the facilitator compared to when acting on their own. In turn the coding of the individual extracts allows for both some quantitative analysis as well as helping to structure the raw data to allow for comparison using qualitative approaches. As discussed in Section 3.2.1, both approaches to analysis are useful (Mercer et al., 2009) and, for example, Hmelo-Silver et al. (2008) have used counting to show how tool use varies according to purpose and Márquez and colleagues (Márquez et al., 2006) have used counting to indicate which semiotic mode is dominant for a particular purpose. However, most research (Jaipal, 2009; Maher, 2011; O’Halloran, 2011a) supplements such quantitative approaches by a qualitative analysis that reports on the interaction between multimodal resources. This combination of quantitative and qualitative reporting has been adopted in the discussion below.

5.3.1 Students' meaning making: transition from theory to practice

This part of the analysis looks at how the process of meaning making by the students varies as the sessions develop. The first focus is on the shift of meaning making and use of semiotic resources and the preferences they create as they move from the theoretical discussions to a focus on building the model.

5.3.1.1 Content and complexity of the semiotic resources

As discussed above, the first part of this analysis applies some simple quantitative analysis to understand whether the semiotic resources accessed and their characteristics and functions vary according to the shift of students' meaning making from theoretical discussions to those of model building. The categorisation of 'focus' is drawn from Table 5-36, and this part of the analysis excludes those sessions coded as being 'dominated' by the facilitator (in other words, it includes sessions where only the students were involved and those in which they were active along with the facilitator). This means that in the various tables summarised in Table 5-27 there are 345 separate items of semiotic coding (102 non-verbal and 243 verbal).

The first step of the analysis looks at variations in terms of the content of these resources as used by the students. Primarily, as set out in Chapter Three, these fall into the four categories of Concept-related Talk (CT), Task-related Talk (TT), Tool-Related talk (TR) and Personal Talk (PT) with these reflecting a focus on the concepts behind the bridge design (usually a focus on theory), on how to construct the model or non-task related matters respectively.

The coding of the verbal semiotic resources varies as shown in Figure 5-4.

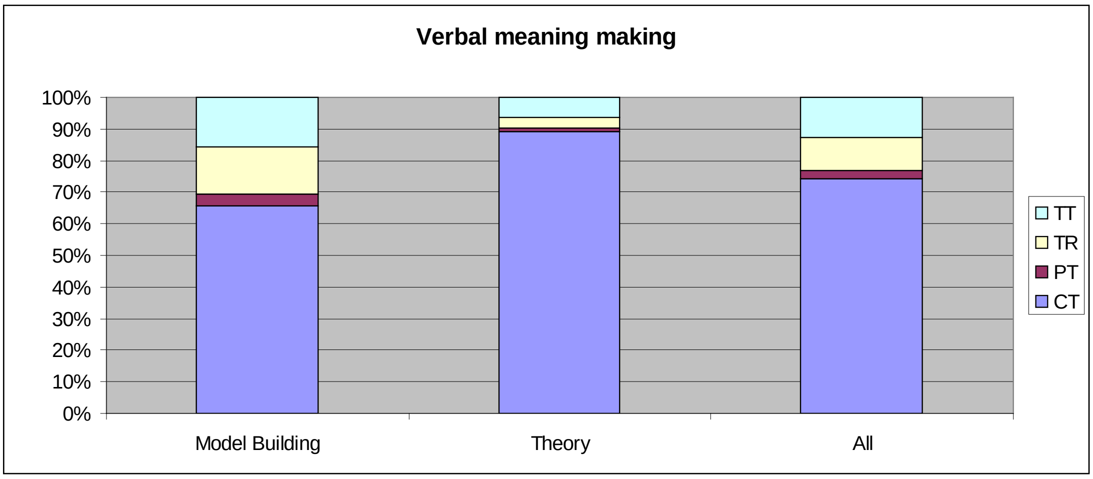


Figure 5-4: Content of students' verbal semiotic resources (N=257)

In the excerpts discussed above it is clear that the bulk of the spoken elements related to Concept-related Talk (CT). However, while this dominated the periods when the focus was on the theoretical issues (almost 90%), the periods with a focus on model building saw a greater use of Task-related Talk (TT) (some 65% of utterances were concept-related (CT) and 20% were Task-related (TT)). It is noteworthy that there is very little evidence of sustained Personal Talk (PT) even though, as noted above, this was a feature in Session 4 when the two students worked on their own.

In the non-verbal element of meaning making, conceptual semiotic resources again dominated (some 60% overall) but to a much lesser extent than in terms of the verbal resources. In the sessions where the focus was on model building this shift is clearly represented by both the much greater use of Task-related Talk (TT) as well as the use of gestures, in particular as part of personal, non-task related meaning making.

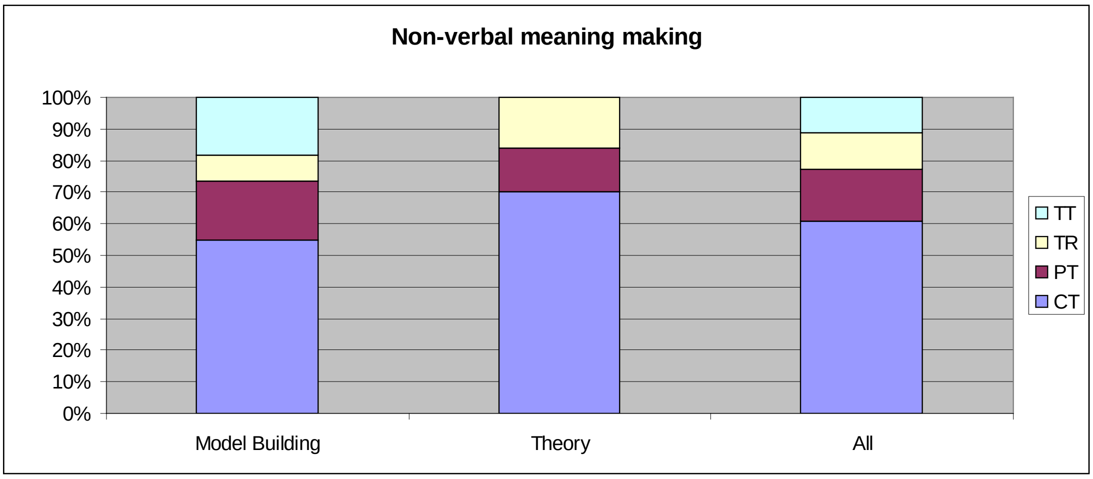


Figure 5-5: Content of students' non-verbal semiotic resources (N=102)

Across all these sessions, Concept-related Talk (CT) is the dominant category for both verbal (see Figure 5-4) and non-verbal (see Figure 5-5) semiotic resources. However, in those blocks where the focus is on the underlying theory, Concept-related Talk (CT) dominates completely, accounting for 85% of all semiotic resources, while when the focus is on model building other characterisations, in particular, Tool-related Talk (TR) and Task-related Talk (TT) are far more common. There is very little difference between the verbal and non-verbal elements in that both are dominated by Concept-related meaning making (CT).

A second useful summary table can be drawn up representing the complexity of these resources, in particular, how many times a response could be described as Elaborate Explanation (EE) or Elaborate Telling or (ET), Brief Answer (BA), Seeking Clarification (Clarif) or Agreement with PBL Member (AM).

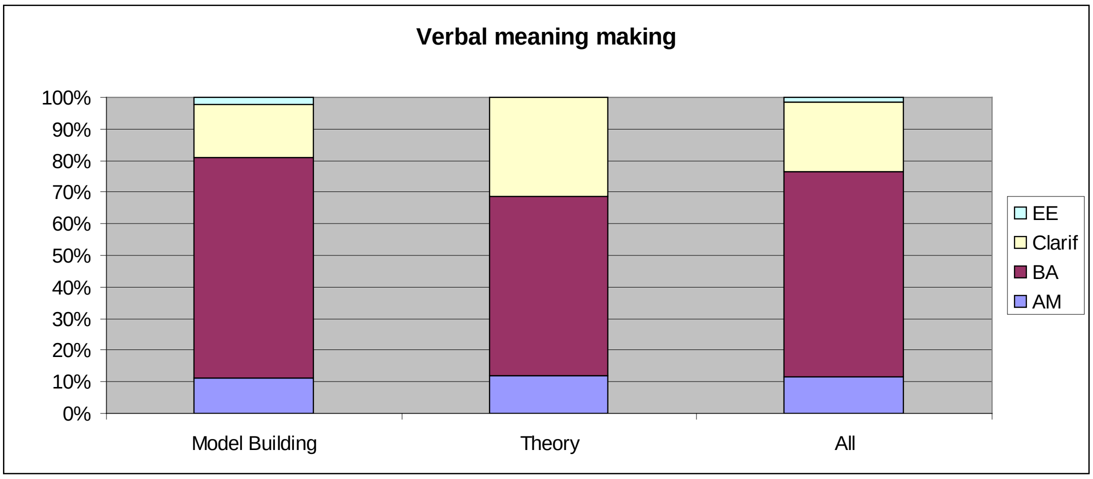


Figure 5-6: Students' meaning making – verbal complexity of resources (N=254)

In terms of verbal complexity, Brief Answers (BA) dominated, reflecting the interactive nature of much of the student discussions. However, as indicated in Figure 5-7, for non-verbal instances, there is a split between elaboration and agreement. For the most part, agreement was shown by physical gestures and the elaboration was a product of using the paddle-pop sticks, or drawn diagrams, to elaborate solutions to the problem of the bridge design. One key difference between the verbal and non-verbal resources, as shown in Table 5-7 below, is that a higher proportion of such resources is coded as elaborate.

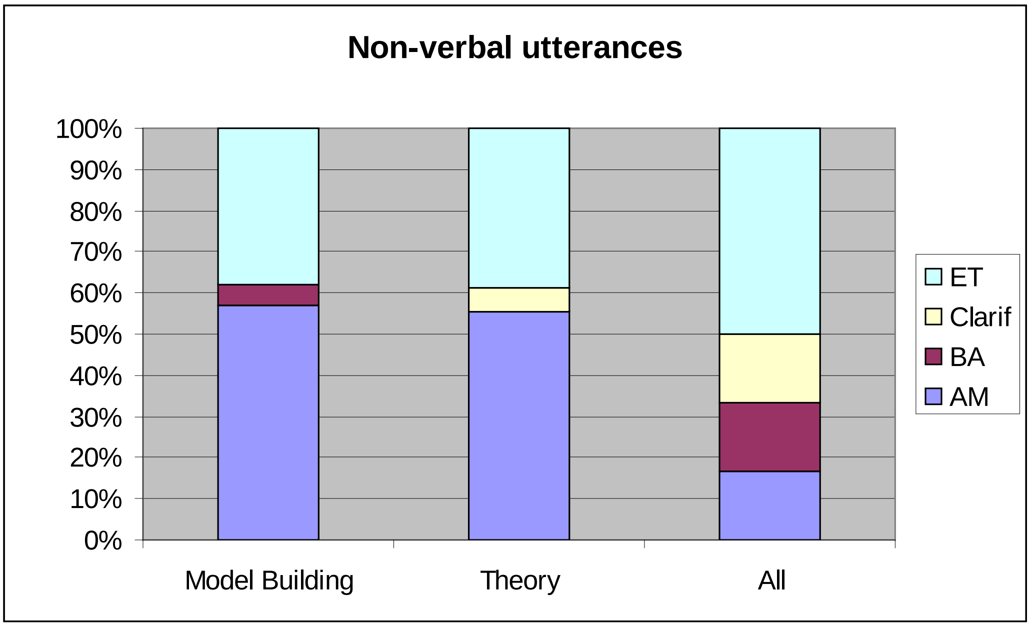


Figure 5-7: Students' meaning making – non-verbal complexity of resources (N=20)

Thus there is a difference between speech (mostly used for Brief Answers (BA)) and non-verbal resources (used for a mixture of indicating agreement or elaborating a possible solution). It is also noticeable that while speech makes use of Elaborated Explanation (EE), the non-verbal meaning making replaces this with Elaborated Telling (ET). The other elements to the coding structure (see Section 5.2) are not amenable to this form of analysis as relatively few verbal or non-verbal resources are coded in those terms. While such quantitative reporting can be useful for indicating broad trends it can also obscure the meaning-making process. Frequency of incidents is not an indicator of the quality or importance of the incidence of such elements. This can be explored by looking at the various use of verbal as opposed to non-verbal resources.

5.3.1.2 Use of verbal and non-verbal resources

A simple quantitative analysis shows that non-verbal resources played a greater role in meaning making in the theory-focussed sessions rather than in those concerned with the model building, as illustrated in Figure 5-8.

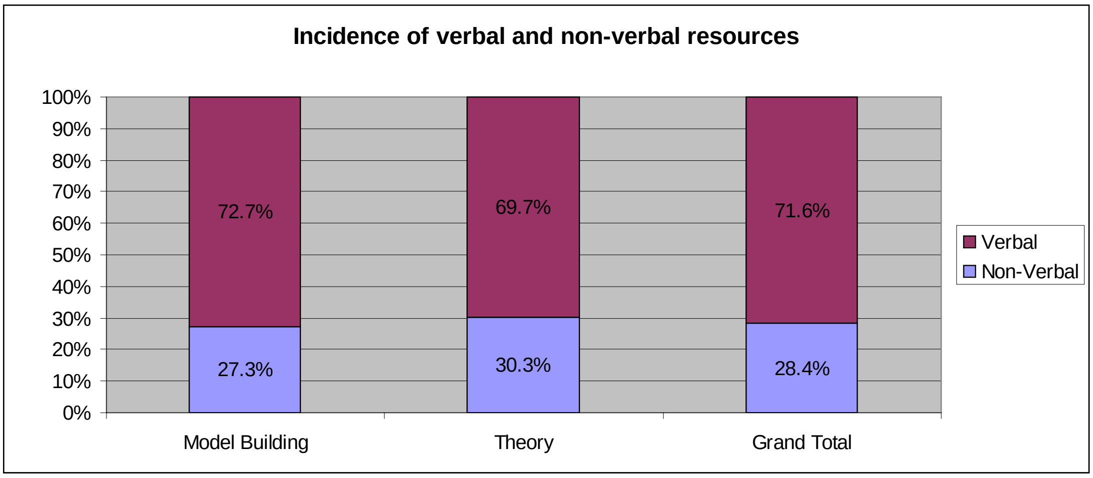


Figure 5-8: Variation in quantity of verbal and non-verbal resources (N=359)

However, the nature of the use of the non-verbal resources alters substantially between the two types of session. An example can be drawn from Table 5-14 which reports on student interaction while discussing the theory behind the design. Here Student A verbalises their calculations with "*if this is 15 degrees*", followed by "*that's 45, 180, minus 45*", and the Student B supplies the answer: "*135…*". The non-verbal element to this is drawing the requisite angles onto a triangle as they are calculated. This is then followed by a sequence where the students realise that the initial calculation was incorrect, starting with Student A's "*FA – actually no*," supported by a non-verbal resource described as 'erasing that particular triangle'. This is then followed by a discussion as to why this was in error, comprising Student B's "*that's not going to work*", "*you have to go to…*" and "*because they're different angles*", and the final utterance followed by a non-verbal resource described as 'Student points with pen to emphasise … followed by silence'. Thus meaning making is multimodal, the tools pen, paper and recording information on the diagram are key parts of their meaning making as is gesture 'scribbling out an incorrect version, pointing at the problem with a pen', but speech is dominant.

A different theory-orientated excerpt is shown in Table 5-20 and this also has portions where the non-verbal element is used to reinforce the verbal reasoning. Where the student uses hand gestures to emphasise the spoken resource, as in Student D's "*the Y direction is up and down*", the related non-verbal element is described as 'Emphasised by hand gesture moving up and down', and similarly, Student D's "*there was a force coming down which compresses it*", is described 'Points downward with one hand'. Here, the inter-semiosis between speech and gesture can be seen as reinforcing each other but the non-verbal element is integral to the meaning-making process. Thus, again meaning making is multimodal and the non-verbal element is being used to exemplify the meaning conveyed in the speech (so the verbal element is dominant).

This finding can be contrasted with two instances drawn from excerpts where the focus is on model building. The first is drawn from Block 2 of Excerpt 6 where the two students are discussing how to build their model bridge (see Table 5-22) and the second from the subsequent discussion with the facilitator (see Table 5-26). In Block 2 of Excerpt 7 (see Table 5-25), the shifting deployment of the paddle-pop sticks is the main tool with which the students set out their ideas and the verbal resources are secondary. This can be exemplified by the extract shown in Table 5-28.

Table 5-28: Interaction of verbal and non-verbal resources in model building – Example 1

Time*	Verbal	Non-verbal
21.52	Student C: On each side.	
		
	Student C: And these are just going to	
		Starts adding new sticks to one side to show what is meant
	Student C: – and then…	
21.59	Student A: So we have to leave a gap for those to come up?	
		

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

Here the students are verbalising their physical actions and meaning (i.e. a potential bridge design) is being indicated by the shifting layout of the paddle-pop sticks.

In turn, in Block 3 of Excerpt 7 (see Table 5-26), there is a superficially similar interaction of verbal and non-verbal resources as shown in Table 5-29.

Table 5-29: Interaction of verbal and non-verbal resources – Example 2

Time*	Verbal	Non-verbal
	Facilitator: and would try to give some stability to the frame	
25.21	Facilitator: so it doesn't deform in this direction…	
		He takes a paddle-pop stick, places it against the support beams on the side of the bridge and moves it in an arc 
	Facilitator: Also here,	
25.26	Facilitator: so it doesn't deform in that direction.	
		Takes a paddle-pop stick and places it against the top and bottom lines of beams 
	Facilitator: So what your going to do is bind the frame in.	
25.28	Facilitator: You could do away with these central beams	
		Point at parts of bridge 

*As per camcorder's timer; the times coincide with the duration of the session, beginning with 0.00.

Here, again, the non-verbal resources are central to the meaning making as the facilitator and students pick up, move or point at the model. However, speech carries a substantial amount of meaning. In Table 5-28, speech can be seen as essentially verbalising the actions adopted, while in Table 5-29 speech sets out the core concepts and these are reinforced by gesture and the use of the model.

5.3.1.3 Use of scaffolding by the students

As discussed in the detailed analysis of each excerpt, there are very few instances where the students' utterances are described as scaffolding. The implications for the type of problem solving they are undertaking compared to that of the facilitator are discussed below. This strand of the analysis fits more appropriately within that fuller discussion. Overall, student use of scaffolding falls into two categories.

There are two instances of Technical Scaffolding (TS) at the end of Block 1 of Excerpt 2 (see Table 5-7) where they are seen using calculators to support their calculations of the angles and forces. A further single instance occurs at the end of Block 2 of Excerpt 2 (see Table 5-8).

A different use of scaffolding by the students is found in Block 4 of Excerpt 2 (see Table 5-20) where Student A supports a verbal question about the nature of compression by ‘squeezing hands together’, an instance of Conceptual Scaffolding (CS). Later in the same excerpt, a different student (Student D) also uses his hand to demonstrate ‘the intended range of movement by hand gestures’, again an instance of non-verbal Conceptual Scaffolding (CS). In Block 1 of Excerpt 7 (see Table 5-24), there is another example of non-verbal student conceptual scaffolding when ‘Student A picks up model to demonstrate how it will be supported’; later in the same excerpt Student A also points at the bridge to strengthen their question “*so the centre is here*”. These two instances occur in the course of an interaction with the facilitator where both the facilitator and the students are picking up, or pointing at, the model bridge as they verbalise their debate about the effectiveness of the model.

One final, isolated use of scaffolding by the students is in Block 2 of Excerpt 7 reported in Table 5-25. Here, again, the semiotic resource is non-verbal and an instance of Procedural Scaffolding (PS) described as ‘Student has picked up model and laid it against the edge of the desk’. Again this falls within a sequence where the facilitator is picking up and pointing at the model bridge as he explains the nature of his concerns with their design.

Across these rare instances of student use of scaffolding the common element is the use of non-verbal resources (calculators or the model bridge) to scaffold either their problem solving or verbal statements. In this case such scaffolding strategies adopted by the students can be seen in the context of ‘tool-use’ as discussed in Chapter Four. This theme is returned to in more detail in Chapter Six.

5.3.1.4 Discussion of students' role

The analysis above particularly focuses on the shift of student meaning as they move from considering the theory underpinning the bridge design to actually designing their model bridge. As such it indicates the strengths of taking a multimodal approach which integrates the use of verbal and non-verbal resources in meaning making. While in most excerpts speech is dominant, for those reported in Tables 5-22, 5-23 and 5-24, where the two students are laying out potential designs, the non-verbal element is dominant (i.e. speech is merely vocalising what they are doing with the paddle-pop sticks). Here, an analysis of meaning making that did not include the non-verbal element would be significantly limited in seeking to represent the meaning-making process.

The quantitative analysis in Section 5.3.1.1 does indicate some broad differences in the content of the semiotic resources used as the students shift from theory to practice. The theory excerpts are dominated by Concept-related Talk (CT) but less use of Elaborated Explanation (EE) and Elaborated Telling (ET). In combination this indicates a more passive learning mode and a close focus on the specific task (mostly calculating forces and the design needed to resist those forces). The model building excerpts still see a lot of use of Concept-related Talk (CT) but supplemented by discussion based on Task-related talk (TT) and Tool-Related Talk (TR). There is a greater incidence of Personal Talk (PT), especially in Session 4 (see Section 5.2.6), perhaps reflecting the less formal nature of that session and the extent to which they lost focus on the task or as a means of social collaboration. On the other hand the model building excerpts saw a greater use of both Elaborated Explanation (EE) and Elaborated Telling (ET), reflecting a more active learning mode. The students were seeking to explain to each other and to the facilitator what they were trying to achieve with their model design.

However, as Figure 5-6 indicates, quantitative analysis is useful but has its limits. In this case, a simple counting of the interaction between verbal and non-verbal resources indicates a rough parity of use. However, when four of these excerpts (two concerned with theory, two with model building) are explored in more detail (see Section 5.3.1.2) a richer picture emerges:

1) In one of the theory building excerpts (see Table 5-14), speech is dominant to the extent that the non-verbal elements are simply pointing or recording the information;
2) In the second theory building excerpt (see Table 5-20), speech is again dominant but this time the non-verbal gestures are used to emphasise the spoken meaning (especially about the direction of the forces and the nature of ‘compression’);
3) In the first model building session (see Table 5-22), the non-verbal elements are dominant. Meaning making is driven by the arrangement and re-arrangement of the paddle-pop sticks and speech is used as a ‘filler’ or to verbalise the gestures; and
4) In the second model building session (see Table 5-26), there is more of a balance between the role of verbal and non-verbal elements in meaning making. In this case, speech is dominant (i.e. it is used to set out the meaning intended) but heavily dependent on arranging the model to exemplify what is meant or pointing at the model to indicate where the problems are.

Thus it is not as straightforward as saying that in the theory discussions, verbal resources are dominant and in the model building discussions, the non-verbal resources are dominant. Nonetheless, there is a clear shift. In many theory excerpts, non-verbal resources are used to emphasise the meaning making primarily carried by speech. In some model building excerpts (especially those reported in Section 5.2.6), meaning is primarily carried by the non-verbal resources. In others it is shared, but even here, the meaning of speech is heavily reinforced by the use of gestures and tools (in particular the model bridge). Overall, there may be an equivalent volume of verbal and non-verbal resources deployed, but their respective roles in meaning making shift as the task shifts from theory to practice.

There is a wider issue across these selected excerpts related to the different modes of problem solving adopted by the students as opposed to by the facilitator. This is explored in more detail in Section 5.3.2 and then in Chapter Six, but, as has been noted in the detailed discussions of the transcripts, scaffolding is rarely used by the students themselves and where it is, this tends to be more of the form ‘tool use’ than set out in speech (as explored in Section 5.3.1.3). In terms of problem solving, they are seeking to move from their current knowledge to the next step (whether in terms of theory or the bridge design process). The literature on the psychology of problem solving (Simon, 1978) notes that this step-by-step approach to problem solving is typical of novices who lack the wider understanding with which to frame their cognitive efforts. How the facilitator uses scaffolding, and the variation in this as the PBL class developed is a major focus in the next section.

This analysis starts with a consideration of the shifting use of verbal resources and then considers the relationship between verbal and non-verbal meaning making.

5.3.1.5 Speech

The verbal utterances purely generated by the students (i.e. excluding all comments by the facilitator) are listed (Table 5-30). The categories of metacognition, interpretation and scaffolding are excluded as they are either not represented or occur less than six times across the five PBL sessions (within student speech). Where ‘N/A’ is indicated it shows how many utterances were not coded using for particular conceptual category. In total there are 168 verbal utterances:

Table 5-30: Shifting verbal meaning making from model building to theory (students)

	Focus					
	Model Building		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Total Utterances	78		90		168	
Content						
Concept-Related Talk (CT)	54	69.0	79	87.8	133	79.2
Personal Talk (PT)	6	7.8	1	1.1	7	4.17
Tool-related Talk (TR)	2	2.6	3	3.3	5	2.98
Task-related Talk (TT)	16	21.0	7	7.8	23	13.7
Collaboration	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Acknowledgement (ACK)	-	-	2	2.2	2	1.2
Agreement with Facilitator (AF)	1	1.3	-	-	1	0.6
Conceptual Agreement (CA)	7	9.0	3	3.3	10	6
Conceptual Disagreement (CD)	-	-	1	1.1	1	0.6
Facilitator’s Explanation (FE)	3	3.8	-	-	3	1.8
Facilitator’s Tool-related utterance (FT)	1	1.3	-	-	1	0.6
New Addition (NA)	1	1.3	-	-	1	0.6
Need Clarification (NC)	14	18.0	17	18.9	31	18.5
Questioning Facilitator (QF)	5	6.4	-	-	5	3
Conceptual Questions (SC)	-	-	3	3.3	3	1.8
Self-Directed Learning (SDL)	-	-	2	2.2	2	1.2
Self-answered Questions (SQ)	-	-	1	1.1	1	0.6
Task-related Agreement (TA)	3	3.8	2	2.2	5	3
N/A	43	55.1	59	65.5	102	60.71
Complexity	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Agreement with PBL Member (AM)	10	12.8	6	6.7	16	9.5
Brief Answer (BA)	22	28.2	29	32.2	51	30.4
Seeking Clarification (Clarif)	14	18.0	17	18.9	31	18.5
Elaborated Telling (ET)	32	41.0	36	40.0	66	39.2
N/A	-	-	2	2.2	2	1.2
Knowledge	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Conceptual Knowledge (CK)	12	-	35	61.0	47	28.0
N/A	66	-	55	39.0	121	72.0
Internalisation	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Peer-to-Peer Internalisation (IPP)	20	52.64	33	36.7	53	31.5
Student-to-Facilitator Internalisation (ISF)	2	2.6	1	1.1	3	1.8
N/A	56	71.8	56	62.2	112	66.7

In terms of content, concept-related talk (CT) dominates in both the model building and theory sessions, however, it is less common in the former. Notably personal talk (PT) and task-related talk (TT) are much more common in the model building sessions. In Kress’s (2010) terms, this indicates that such verbal modes are more appropriate. The suggestion is that the nature of that part of the meaning-making process allowed the students more time for personal talk, that such personal talk is a part of the group meaning-making process (as opposed to the individual meaning making that dominated the theoretical discussions) and that discussion of how to complete the task again reflects the more collaborative nature of the model building excerpts. This is summarised in Figure 5-9.

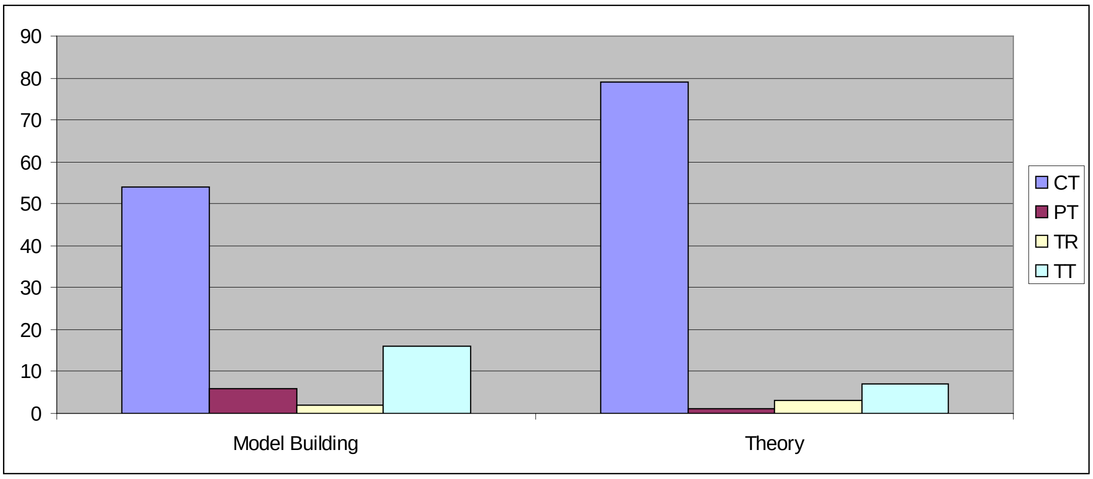


Figure 5-9: Varying content talk (students)

66 of the 168 verbal resources are coded in terms of the degree of collaboration between the students. Regardless of the whether the focus was on theory or model building, the most common single mode was seeking confirmation (NC). However, there are some differences in the use of the other modes of collaboration. Conceptual Agreement (CA) is more common in the model building excerpts as is directly questioning the facilitator (QF). The latter is indicative that it was in the model building excerpts that a dialogue, to some extent, existed between the students and the facilitator, which was largely absent in the more theoretical discussions. Noticeably, the bulk of the instances of QF are to be found in Session 5 where the students are displaying and defending their model. Typical is the sequence of:

Student A: *Well, what I'm thinking we should do*
is instead of here like that…
What if I put it right here? (QF)
Facilitator: *You can't just have it sitting on the frame;*
It's got to be below.
It's a bridge.
It's effectively a platform that you can go across
Student A: *So it can't be like that? (QF)*
What if I like (QF)

All Student A's utterances are coded QF (Questioning Facilitator) from the excerpts reported in Tables 5-25 and 5-26 where the students are seeking to defend their design as well as to seek information on what now needs to be done to improve on their model. In this case QF can be seen as a semiotic mode they use when they are either confident in their work, are seeking to defend that work or are presenting their ideas for validation and consideration. This is only found almost at the end of the PBL class, perhaps indicating their shift from passive learners to having their own conceptualisation of the nature of the problem.

The overall shifts in the semiotic modes of collaboration are shown below (for clarity the Not Applicable (N/A) are excluded):

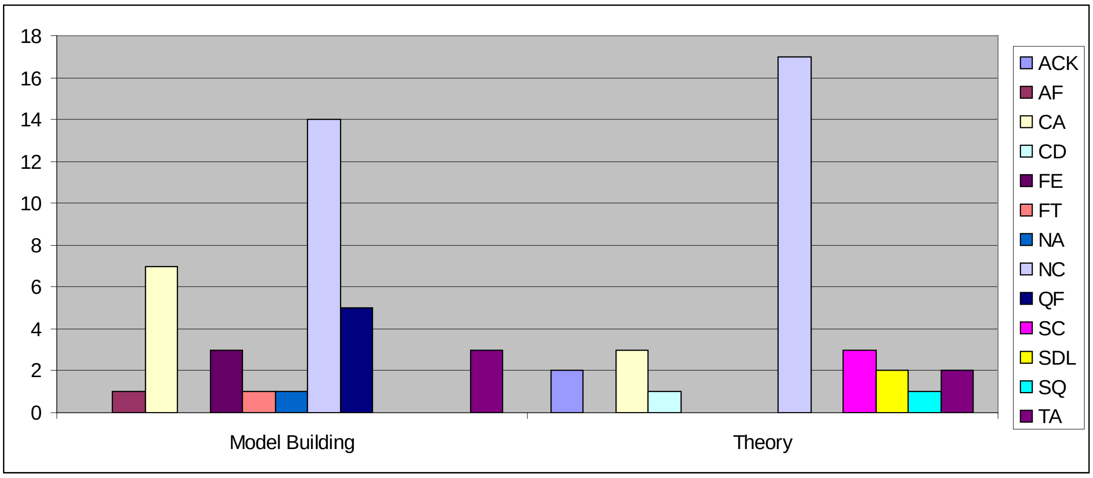


Figure 5-10: Modes of students' collaboration (verbal)

From Table 5-30 there is no evidence that the level or style of complexity of the verbal semiotic resources varied between model building and theory excerpts. The students used whichever approach seemed to be appropriate but there was no evidence that the semiotic complexity of their verbal utterances altered.

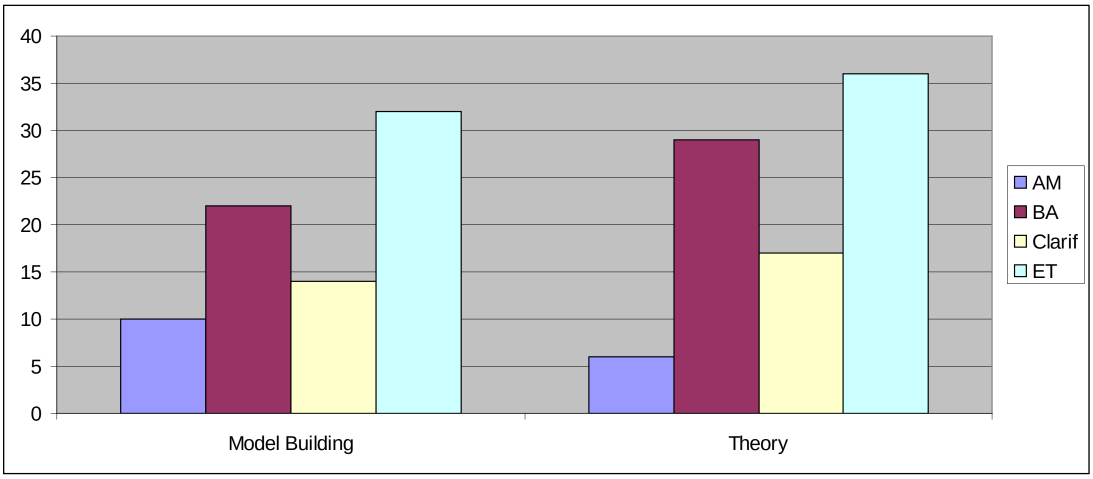


Figure 5-11: Complexity of verbal utterances (students)

In terms of knowledge, the only type of semiotic resource used was classified as Conceptual Knowledge (CK). This was far more common in the theory-focussed excerpts and mirrors the use of Concept-related Talk (CT) in such instances. The use is grouped into particular aspects of their discussions (i.e. the use of CK is in a small number of concentrated blocks), for example (from Table 5-7):

Student A: *So this is 45 –*
Student A: *if this is 15 degrees,*
Student A: *that's 45, 180, minus 45.*
Student B: *135…*
Student A: *Divided by 2, is 67.5*
Student B: *because they're different angles.*
Student B: *I don't know why that doesn't work,*
Student B: *like the cos thing,*
Student B: *because in theory that should*
Student B: *I don't see why it doesn't.*
Student B: *It just doesn't.*
Student A: *If all 10k newtons was on the resultant in FA…*

This is a continuous dialogue as the two students discuss their calculations about the forces that will be applied to the bridge. This implies that Conceptual Knowledge (CK) is only used in very particular situations, mainly where they are actively problem solving and have some understanding of the immediate task.

Internalisation is the final semiotic process that is widely used in student speech. This aspect (i.e. internalisation) was developed by the researcher and added to Hmelo-Silver's (2008) categorisations and, in practice, reflects student interaction with the facilitator.

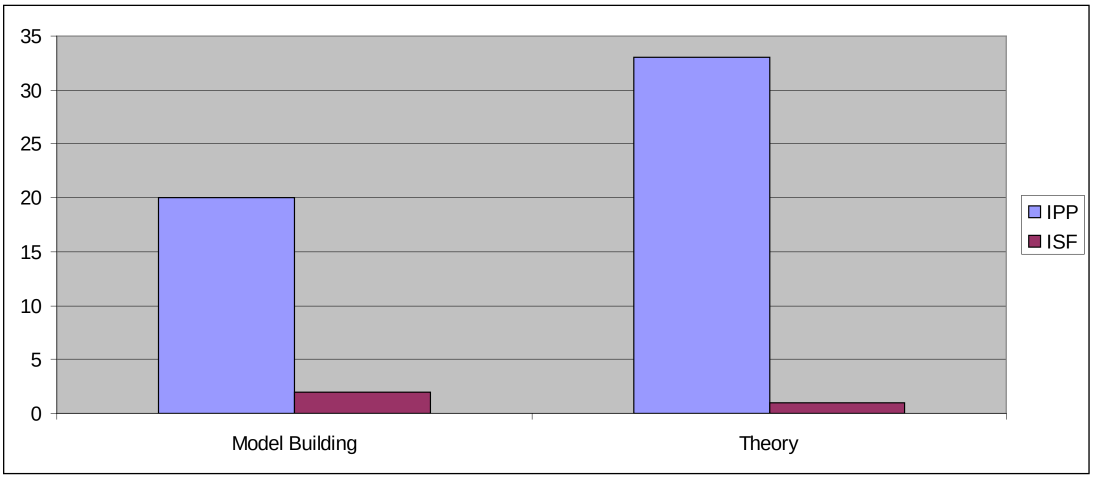


Figure 5-12: Students' internalisation (verbal only)

Peer-peer internalisation (IPP) clearly dominates over instances of internalisation in dialogue with the facilitator (ISF). This supports the argument in Chapters Four and Five (and summarised below) that the facilitator has not tended to adopt an interactive meaning-making mode in these PBL classes. His role has shifted from information provider, to one of evaluation, with considerable use of questions, but as such he has not adopted a role of shared meaning making with the student group (Choo, 2012).

5.3.1.6 Use of non-verbal resources by the students

Table 5-31 repeats Table 5-30, but listing only the non-verbal utterances generated by the students, excluding all comments by the facilitator. Again, 'N/A' shows how many utterances were not coded using that particular conceptual structure.

However, in creating Tables 5-30 and 5-31 there were several practical difficulties. One, discussed above, e.g. in Sections 3.1 and 3.2.1, the use of a single camera angle means that potentially important non-verbal meaning making may have been missed given the camera focus at that stage. Also, there are a number of sequences (most notably the excerpts drawn from Session 4) where the non-verbal meaning making by the students cannot easily be ascribed to one or the other student. There are instances where more than one student is active (for example, laying out the paddle-pop sticks) at one time. Here the solution has been to code that instance to both students where it is not clear which one was leading the meaning making at that stage.

This produces a total of 85 instances of non-verbal meaning making by the students. Again, the coding Not Applicable (N/A) is used to indicate that a given utterance was not coded in terms of that particular form of semiotic meaning making (so, for example, not every example of the use of non-verbal resources is also an example of scaffolding).

Table 5-31: Shifting non-verbal meaning making (students)

	Focus					
	Model Building		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Total Utterances	37		48		85	
Content						
Concept-related Talk (CT)	20	54.1	32	66.7	52	29.4
Personal Talk (PT)	11	30.0	8	16.7	19	22.3
Tool-related Talk (TR)	-	-	5	10.4	5	5.9
Task-related Talk (TT)	6	16.2	3	6.3	9	10.6
Collaboration	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Acknowledgement (ACK)	2	5.4	-	-	2	2.4
Conceptual Agreement (CA)	13	35.1	13	27.1	26	30.6
Facilitator's Explanation (FE)	1	2.7	-	-	1	1.2
Need Clarification (NC)	1	2.7	1	2.1	2	2.4
Conceptual Questions (SC)	3	8.1	-	-	3	3.5
Self-Directed Learning (SDL)	-	-	1	2.1	1	1.2
Task-related Agreement (TA)	2	5.4	8	16.7	10	11.8
N/A	15	41.0	25	52.1	40	47.0
Complexity	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Agreement with PBL Member (AM)	-	-	3	6.3	3	3.5
Brief Answer (BA)	1	2.7	3	6.3	4	4.7
Seeking Clarification (Clarif)	-	-	2	4.2	2	2.4
Elaborated Telling (ET)	5	13.5	6	12.5	11	12.9
N/A	31	83.8	34	70.8	65	65.9
Knowledge	**Model Building**		**Theory**		**Grand Total**	
Conceptual Knowledge (CK)	1	3.0	9	18.6	10	12.0
N/A	36	97.0	39	81.3	75	88.0
Metacognition	**Model Building**		**Theory**		**Grand Total**	
MSDL	-	-	3	6.3	3	3.5
N/A	37	100.0	45	93.7	82	96.5
Interpretation	**Model Building**		**Theory**		**Grand Total**	
IH	1	2.7	-	-	1	1.2
IL	-	-	1	2.1	1	1.2
N/A	36	97.3	47	97.7	83	97.6
Internalisation	**Model Building**		**Theory**		**Grand Total**	
Peer-to-Peer Internalisation (IPP)	-	-	5	10.0	5	6
N/A	37	100.0	43	90.0	80	94
Scaffolding	**Model Building**		**Theory**		**Grand Total**	
Conceptual Scaffolding (CS)	-	-	4	8.3	4	4.7
Technical Scaffolding (TS)	-	-	5	10.4	5	5.9
N/A	37	100.0	39	81.3	76	89.4

Since there are only two instances of interpretation and six of internalisation, these are excluded from the discussion that follows.

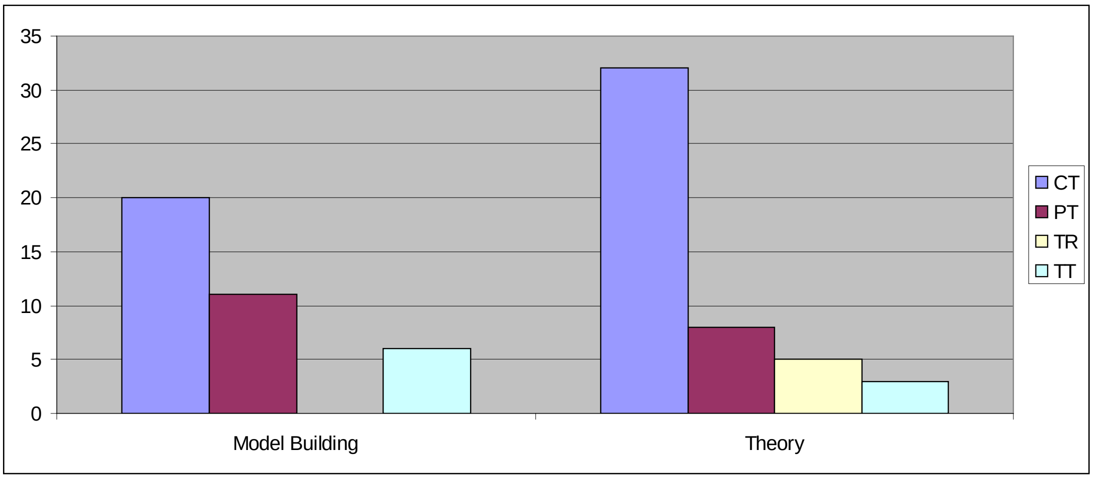


Figure 5-13: Content of non-verbal resources (students)

As discussed earlier in Chapter Five, this confirms that Concept-related (CT) meaning making was dominant across the PBL sessions. However, Concept-related Talk (CT), was especially dominant in the theory-building excerpts and there was more use of Personal Talk (PT) in the model building excerpts. The latter reflects a range of actual gestures and actions. These include nodding to indicate agreement, gestures such as sitting back in the chair or crossing their arms or fiddling with the paddle-pop sticks. In turn, the main use of non-verbal resources in terms of collaboration was to indicate Conceptual Agreement (CA), as:

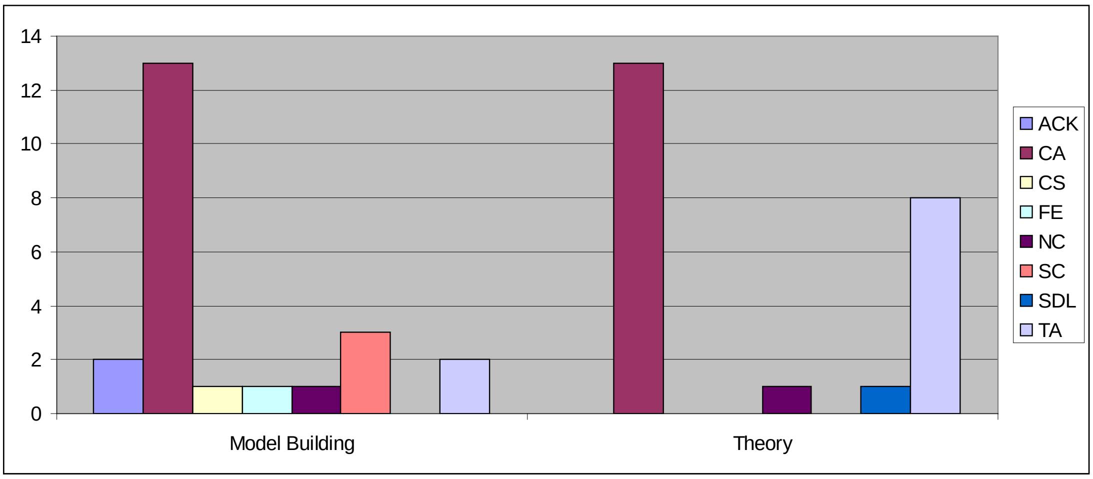


Figure 5-14: Students' collaboration (non-verbal)

Figure 5-14 indicates a very different use of non-verbal resources for collaboration compared to the verbal resources set out in Figure 5-13. At its simplest, it is immediately clear that non-verbal resources were used as the basis for a much reduced range of meaning making in this respect. In addition, there is the clear domination of Conceptual Agreement (CA) (as discussed in relation to Figure 6-8 this can include bodily gestures such as nodding) and some use of task-related agreement (TA) in the theory-dominated sessions.

In terms of complexity, the main difference is the relative complexity of non-verbal meaning making in the model building excerpts.

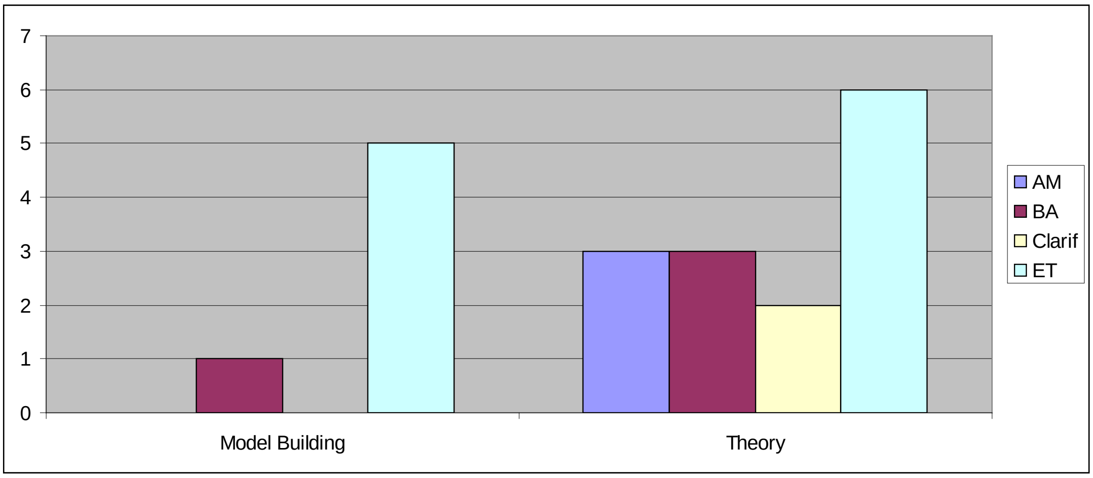


Figure 5-15: Complexity of non-verbal resources (students)

Thus in the model-building excerpts, elaborated telling (ET) dominates. ET is also the most common mode in the theory related excerpts but there is much more use of non-verbal gestures for Agreement with PBL Member (AM) and Clarification (Clarify). However, given the small number of relevant instances (20 in total) such conclusions need to be treated with some caution.

As with speech, knowledge was completed dominated by instances of Conceptual Knowledge (CK). CK occurred almost exclusively in the theory-dominated excerpts. The final category, with any frequency was that of scaffolding. In effect, for the students, this was carried out purely in terms of non-verbal resources.

5.3.2 Differences in meaning making by facilitator

This section looks at the meaning-making process of the facilitator and in particular, the use of scaffolding. As discussed in Chapter Two, this is an important aspect to PBL as it is the means by which students' meaning making is assisted but not led. The first section (Section 5.3.2.1) looks at the meaning making purely from the perspective of the facilitator, and the second (Section 5.3.2.2) looks at the interaction between the facilitator and the students. Finally, Section 5.3.2.3 concentrates purely on the use of scaffolding by the facilitator. The facilitator's interactions with the PBL group can be divided into three categories:

1) Presentation to the entire class (i.e. all the students undertaking this module);
2) Interaction with the PBL student team when the facilitator leads the discussion and where he does almost all the speaking, with the students occasionally asking questions. Typical of this is the excerpt in Table 5-11, where the only student intervention is at the end where one student seeks clarification of the final statement by the facilitator; and
3) Interaction with the PBL student team when the discussion is more evenly divided (in this case, the active role in the discussion is shared between the facilitator and the students).

In addition, as with the analysis of the students' meaning making, the excerpts shown in each table can be categorised as to whether or not the discussion was about the theoretical underpinnings to the bridge model or the practical issues in building the bridge model. These can be summarised as shown in Table 5-30.

Table 5-32: Facilitator-student interaction (summary)

Table	Section	Type	Focus
5-2	5.2.1	Facilitator presentation (whole group)	Theory
5-10	5.2.2	Facilitator-led	Practical
5-11	5.2.3	Facilitator-led	Practical
5-12	5.2.3	Facilitator-led	Practical
5-13	5.2.3	Facilitator-led	Practical
5-16	5.2.4	Interaction	Practical
5-17	5.2.5	Facilitator-led	Theory
5-18	5.2.5	Facilitator-led	Theory
5-19	5.2.5	Interaction	Theory
5-24	5.2.7	Facilitator-led	Practical
5-25	5.2.7	Interaction	Practical
5-26	5.2.7	Facilitator-led	Practical

5.3.2.1 Facilitator's use of semiotic resources

The tables and related discussion in this section just look at the semiotic resources coded as being used by the facilitator. Figure 5-9 shows the spread of the nature and description of verbal semiotic resources used by the facilitator. The difference between the theoretical and practical sessions follows that already identified for the students. Concept-related Talk (CT) dominates his speech, but while in the theory sections this accounts for almost 90%, in the practical sessions there is a greater use of Task-related Talk (TT) and Tool-related Talk (TR).

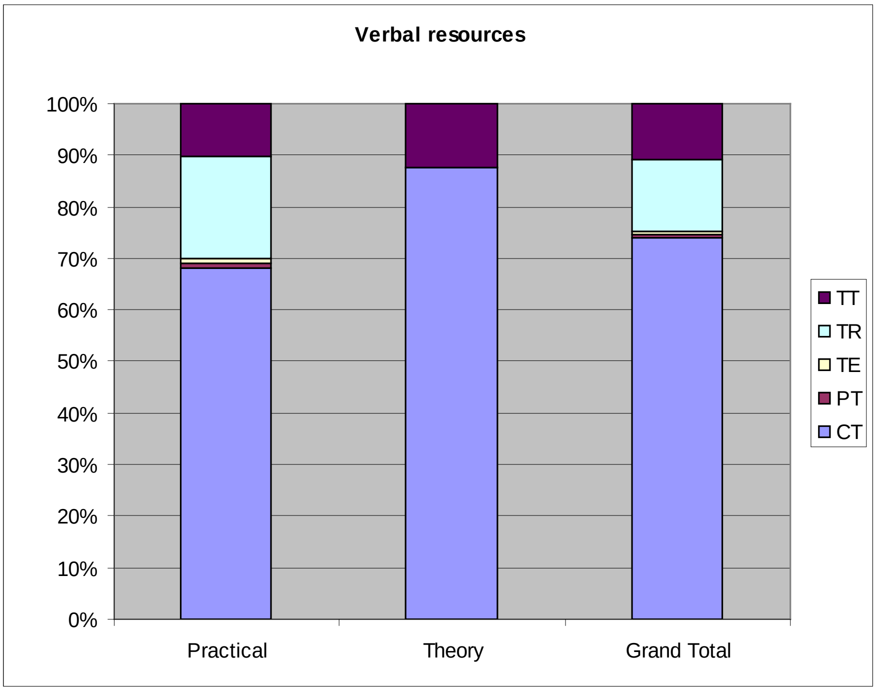


Figure 5-16: Content of facilitator's verbal semiotic resources (N=165)

The use of non-verbal resources follows the pattern set out above with the same greater reliance on context-related meaning making in the theory sessions rather than in the practical sessions. On the other hand, it is also clear that non-verbal resources are more associated with Task-related Talk (TT) and Tool-Related talk (TR) than they are with Concept-related Talk, as shown in Figure 5-17.

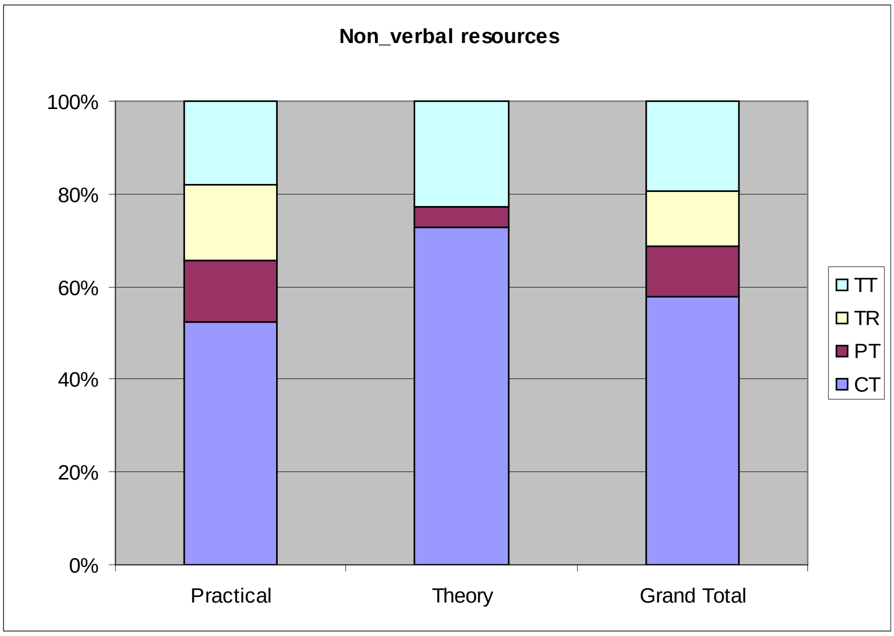


Figure 5-17: Content of facilitator's non-verbal semiotic resources (N=83)

Here, again, Concept-related Talk (CT) dominates but this is less marked in the practical sections where it only accounts for 50% of the non-verbal resources. Instead, the non-verbal resources are used for both Task-related (TT) and Tool-Related meaning making (TR) and substantially for Personal Talk (PT) as there are instances where the facilitator is simply fiddling with the paddle-pop sticks rather than using them for meaning making directly related to the set task.

The nature of the facilitator's meaning making can also be shown in terms of the complexity of his utterances. Even when responding to student questions, there are very few instances of Agreement with PBL Member (AM) or Clarification (clarify) and instead his statements are either Brief Answer (BA) or Elaborated Telling (ET). He is taking on the role of information provider across these PBL sessions (and in this there is relatively little difference between the practical and theory blocks) as shown in Figure 5-18.

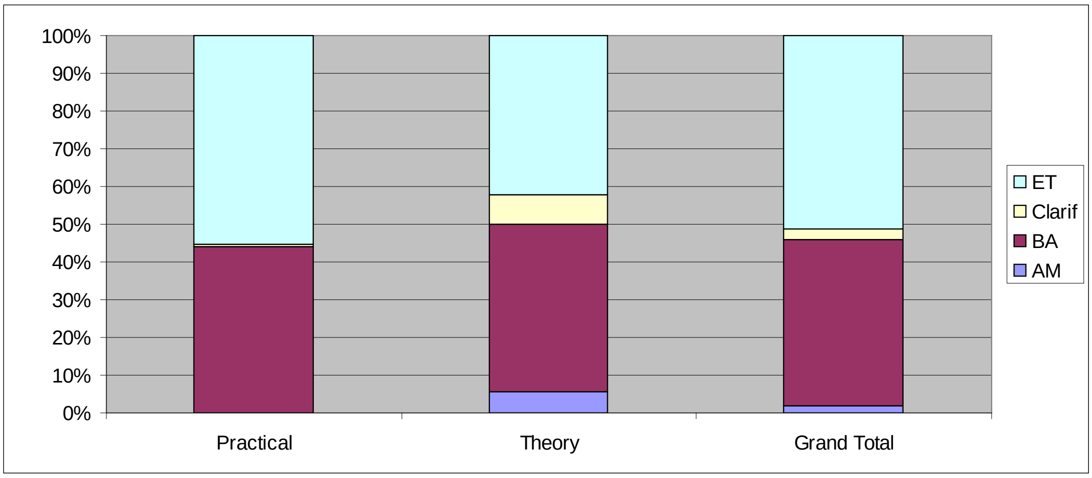


Figure 5-18: Complexity of facilitator's speech (N=168)

5.3.2.1.1 Verbal resources

Table 5-33 is derived on the same basis as Table 5-30 in that it covers all the recorded verbal utterances by the facilitator in all the excerpts reported in Chapter Five.

Table 5-33: Verbal semiotic modes (facilitator)

	Focus					
	Model Building		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Total Utterances	115		51		166	
Content						
Concept-Related talk (CT)	78	67.8	44	68.3	122	73.5
Personal Talk (PT)	1	0.87	-	-	1	0.6
Talk Elaborated (TE)	1	0.87	-	-	1	0.6
Tool-related Talk (TR)	23	20.0	-	-	23	13.9
Task-related Talk (TT)	11	9.6	7	13.7	18	10.8
Collaboration	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Facilitator's Explanation (FE)	71	61.7	32	62.7	103	62.0
Facilitator Monitoring FM	3	2.6	-	-	3	1.8
Facilitator's Tool-related utterances (FT)	20	17.4	1	2.0	21	12.7
Questions provoking Long Examples (LE)	-	-	2	4.0	2	1.2
Modifications of Ideas (ModI)	-	-	1	2.0	1	0.6
Need clarification (NC)	1	0.87	3	6.0	4	2.4
Conceptual Questions (SC)	-	-	1	2.0	1	0.6
Task-related Agreement (TA)	-	-	4	8.0	4	2.4
Task –related Disagreement (TD)	1	0.87	-	-	1	0.6
N/A	19	16.5	7	13.7	26	15.7
Complexity	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Agreement with PBL Member (AM)	-	-	4	8.0	4	2.4
Brief Answer (BA)	50	43.5	23	45.1	73	44.0
Seeking Clarification (Clarif)	1	0.87	4	8.0	5	3.0
Elaborated Telling (ET)	63	54.8	19	37.1	82	49.4
N/A	1	0.87	1	2.0	2	1.2
Knowledge	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Conceptual Knowledge (CK)	16	13.9	17	33.3	33	20.0
N/A	99	86.1	34	66.7	133	80.0
Metacognition	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Group Monitoring (GM)	8	7.0	11	21.6	19	11.4
Theory-driven Planning (ThP)	-	-	1	2.0	1	0.6
N/A	107	93.0	39	76.4	146	88.0
Interpretation	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
High Level Interpretation (IH)	36	31.3	8	15.7	44	26.5
Low Level Interpretation (IL)	39	33.9	21	41.2	60	36.14
Long Analogue (LA)	1	0.87	-	-	1	0.6
N/A	39	33.9	22	43.1	61	36.7
Internalisation	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Facilitator-to-Student Internalisation (IFS)	11	10.0	10	19.6	45	27.0
N/A	104	90.0	41	80.4	121	73.0
Scaffolding	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Conceptual Scaffolding (CS)	17	15.0	-	-	17	8.9
Metacognitive Scaffolding (MS)	4	3.0	2	4.0	6	3.2
N/A	94	82.0	39	81.3	76	89.4

In terms of the content, when the facilitator is discussing the underlying theory he makes use of Concept related talk (CT) and, much less frequently, task-related talk (TT). On the other hand within the excerpts discussing the model, while concept related talk (CT) remains dominant, there is substantial use of both tool-related (TR) and task-related talk (TT). This reflects the shifting focus with the excerpts that are related to designing the model bridge creating a need to discuss how to carry this out as well as setting out the rules for this task. This division can be set out graphically as:

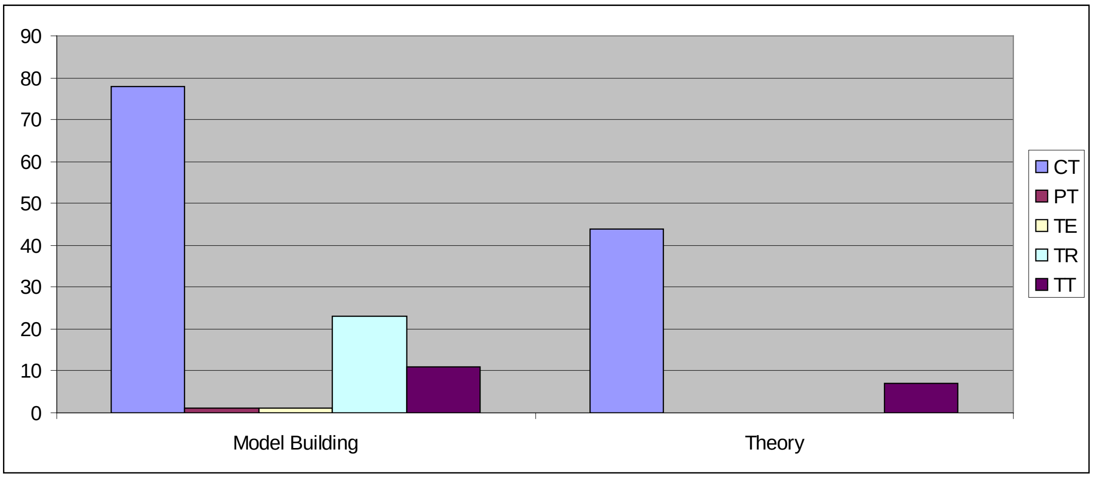


Figure 5-19: Use of content (facilitator)

Unlike the students, Table 5-33 indicates he makes much more use of collaborative semiotic modes in his speech. This reflects his role as both an information provider and in leading their meaning making, so that very few of his verbal utterances lack an interactive element. The most frequent use is Facilitator's Explanation (FE) with this particularly frequently used when discussing the theoretical underpinnings while when the focus is on the model-building he makes substantial use of 'Facilitator's explaining Tool-related utterances' (FT). In this instance, this provides both evidence that the semiotic use is being modified according to purpose (from concepts to tools) and that the facilitator is making use of a semiotic mode (collaboration) that the students access relatively rarely.

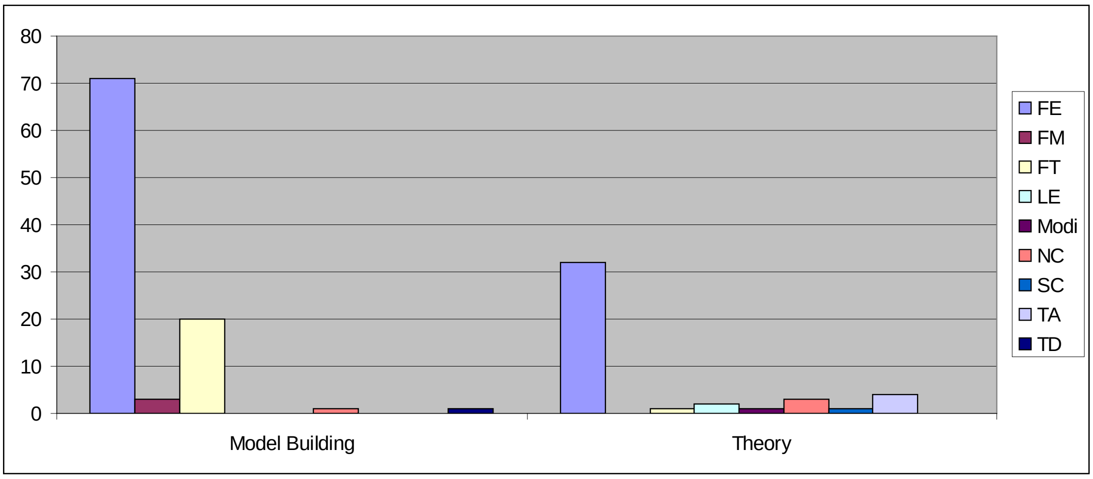


Figure 5-20: Use of collaborative speech (facilitator)

In terms of complexity the facilitator makes substantial use of both Brief Answers (BA) and Elaborated Telling (ET). What stands out is the very rare use of Agreement with PBL Member (AM), which may indicate the relative power relationship between the facilitator and the students, at least in terms of possession of knowledge relevant to this PBL task. Effectively, the facilitator almost always answers by adding new information and very rarely by simply agreeing with what is said. On the other hand, the students make significant use of both Seeking Clarification (Clarif) and Agreement with PBL Member (AM) in their responses.

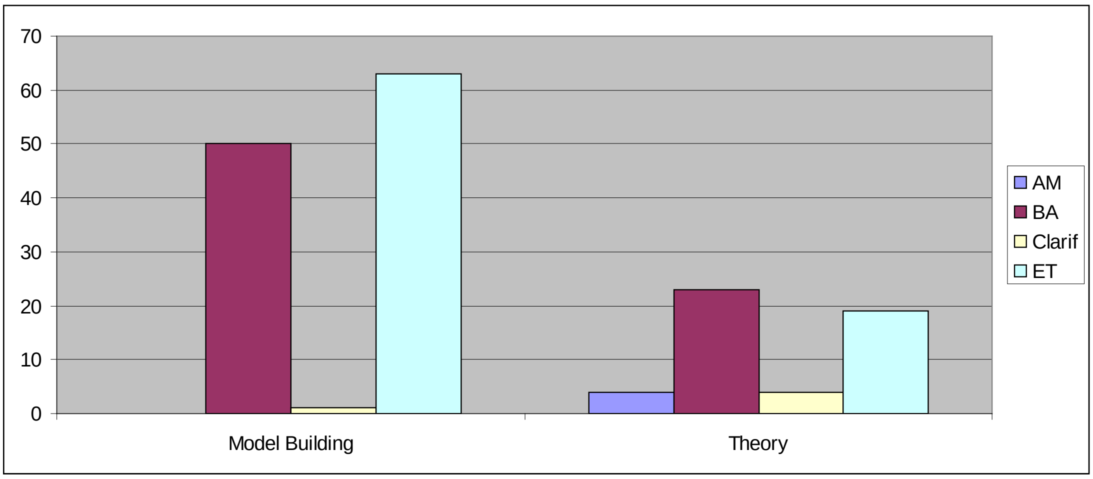


Figure 5-21: Use of complexity (facilitator)

In terms of knowledge, like the students the facilitator only makes use of Conceptual Knowledge (CK) and with the instances of this evenly divided across the excerpts. Internalisation offers no valuable information except to confirm that this shows the consistent flow from Facilitator-to-Students Internalisation (IFS).

However, interpretation offers further semiotic evidence that the facilitator's knowledge of the PBL task is much richer than that of the students. In this sense he makes a substantial use of 'High Level Interpretation' (IH) utterances, which are defined in Chapter Three as "inference or conclusion drawn from direct interpretation of any PBL event". This mode is used particularly frequently in the model-building excerpts, again reflecting his role of leading the students to make their own interpretations of their statements and ideas.

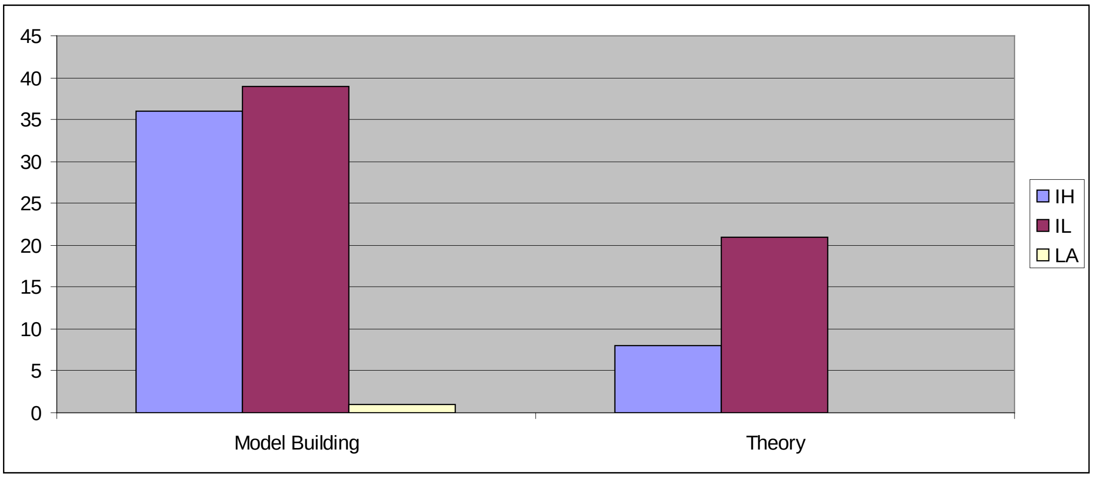


Figure 5-22: Use of interpretation (facilitator)

Similar to the students the facilitator makes relatively limited use of metacognitive speech and almost always in the format of Group Monitoring (GM). Of the 19 relevant instances, the majority are in the theory focussed excerpts, perhaps indicating a greater degree of need to monitor student understanding of that critical stage in the PBL task.

The facilitator's use of scaffolding has already been substantially discussed. Here it is useful to restate that he does so substantially using both verbal (as indicated in Table 5-33) and non-verbal (as discussed in the next section) resources. This is indicative of his central function within the PBL task environment.

Overall the facilitator's use of verbal semiotic resources can be usefully compared (a) to that of the students, and (b) to the particular focus, in order to understand how he makes use of different semiotic speech modes at different stages. Compared to the students, he:

- Makes more use of collaborative speech;
- Very rarely uses simple agreement;
- Makes substantial use of complex interpretation; and
- Makes substantial use of scaffolding.

All these indicate that the facilitator is taking a different role in the PBL task to the students. This addresses the question explored in Chapter Four as to whether the facilitator should, in activity theory terms, be seen as part of the student group or the wider community. While he interacts substantively with the students, his semiotic speech patterns indicate he is carrying out a very different role to that of members of the student group. In addition, it is clear there is a power relationship and distinction of roles from the students. He uses directive speech, sets the tone of the conversations and introduces new material. When speaking as a facilitator, his utterances almost always add new information (rather than just agreement), usually designed to assist with their learning (both collaboration and scaffolding), and are used to assist them in thinking about the consequences rather than just supplying information that they may have requested.

5.3.2.1..2 Non-verbal resources

Table 5-34 mirrors Table 5-32 in that it summarises all the instances of the use of non-verbal resources by the facilitator in the excerpts selected in Chapter Five. Table 5-34 is constructed on the same basis as Table 5-32 in that Not Applicable (N/A) indicates a particular non-verbal resource that was not described in terms of that particular semiotic use (so again, not every non-verbal resource is an example of scaffolding). The result is there are very few such resources coded in terms of knowledge, metacognition, interpretation or internalisation. As such these categories are then excluded from the detailed analysis. Overall there were 55 instances where the facilitator made use of non-verbal resources.

Table 5-34: Use of non-verbal resources (facilitator)

	Focus					
	Model Building		Theory		Grand Total	
	No.	%	No.	%	No.	%
Total Utterances	41		14		55	
Content						
Concept-Related talk (CT)	25	60.9	13	92.9	38	69.1
Personal Talk (PT)	1	2.4	-	-	1	1.8
Tool-related Talk (TR)	10	24.4	-	-	10	18.2
Task-related Talk (TT)	5	12.2	1	7.14	6	10.9
Collaboration	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Conceptual Agreement (CA)	-	-	3	21.4	3	5.5
Facilitator Explanation (FE)	8	19.5	8	57.1	16	29.0
Facilitator's Tool-related Utterances (FT)	6	14.6	-	-	6	10.9
Questioning Facilitator (QF)	-	-	1	7.14	1	1.8
Conceptual Questions (SC)	1	2.4	-	-	1	1.8
Feature Specification (SF)	1	2.4	-	-	1	1.8
Task-related Agreement (TA)	-	-	1	7.14	1	1.8
Task-related Disagreement (TD)	2	4.9	-	-	2	3.6
N/A	23	56	1	7.14	11	20.0
Complexity	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Agreement with PBL Member (AM)	-	-	1	7.14	1	1.8
Brief Answer (BA)	1	2.4	1	7.14	2	3.6
Elaborated Telling (ET)	6	14.6	5	35.7	11	20.0
N/A	34	83	7	50.0	41	74.5
Knowledge	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Conceptual Knowledge (CK)	-	-	3	21.4	3	5.5
N/A	41	100	11		52	94.5
Metacognition	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Group Monitoring (GM)	1	2.4	2	14.3	3	5.5
N/A	40	97.6	12	85.7	52	94.5
Interpretation	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
High Level Interpretation (IH)	4	9.8	1	7.14	5	9.1
Low Level Interpretation (IL)	1	2.4	1	7.14	2	3.6
N/A	36	87.8	12	85.7	48	78.3
Internalisation	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Facilitator-to-Student Internalisation (IFS)	-	-	1	7.14	1	1.8
N/A	41	100	13	92.8	54	98.2
Scaffolding	**Model Building**		**Theory**		**Grand Total**	
	No.	%	No.	%	No.	%
Conceptual Scaffolding (CS)	20	49.0	3	21.4	23	42.0
Metacognitive Scaffolding (MS)	4	9.8	1	7.14	5	9.1
Procedural Scaffolding (PS)	3	7.3	-	-	3	5.5
Technical Scaffolding (TS)	9	21.9	4	28.6	13	23.6
N/A	5	12.0	6	42.9	11	24.0

The information above has been extensively analysed already in this chapter, so this section will restate the main findings and consider how these relate to the facilitator's use of verbal resources. The reliance on Concept-related Talk (CT) in the theory focussed excerpts has already been discussed as is the use of both Tool-related Talk (TR) and Task-related Talk (TT) resources when the focus is on the model building task. As with his use of verbal resources, compared to the students, he makes constant use of different forms of collaboration in his meaning making. He very rarely interacts without this being an important part of his use of semiotic resources. Again, as with speech, he makes limited use of the simpler forms of agreement through giving Brief Answer (BA) and Agreement with PBL Member (AM) and instead tends to use Elaborated Telling (ET) when providing explanations. Thus both verbally and non-verbally, he tends to answer student questions not by simple agreement but by providing additional information. His use of scaffolding has already been substantively discussed, but Table 5-34 emphasises how frequently he does so using non-verbal resources (over 50% of the instances are also examples of scaffolding). In general this supports the argument that his approach to meaning making varies from that of the students and that he is active in seeking to elaborate, explain and provide the students with the information they need for the task.

5.3.2.2 Interaction between facilitator and students

Section 5.3.2.1 has concentrated purely on the semiotic resources used by the facilitator. This section elaborates on that discussion to consider whether the variations in his use are matched in turn by variations of the classification of the semiotic resources used by the students. Even from Table 5-30 it is clear that the facilitator plays a very active role in the meaning making that takes place in the twelve blocks where he is seen interacting (in one way or another) with the student group. Table 5-31 shows the relative volume of use by the facilitator and the students.

Table 5-35: Spread of semiotic resources between facilitator and student

Participant	Interaction (No.)	Facilitator-led Excerpts (No.)	Facilitator presentation (whole group) (No.)	Grand Total (No.)
Facilitator	30	114	18	162
Student	29	13	-	42
Grand Total	59	127	18	204

In the excerpts where he is present, the facilitator is dominating the meaning making (both verbally and non-verbally) with almost 80% of the semiotic resources overall. Here the focus is on who dominates the meaning making, not how that meaning making is constructed, so the focus is on who is using semiotic resources regardless of whether they are verbal or non-verbal.

However, in the excerpts described as interactive (i.e. where the students do more than ask the occasional direct question) it appears as if the level of interaction is more even. If the distinction between blocks where the focus is on the theory behind the bridge design as opposed to the practical issue of constructing a model is drawn, then we see the pattern as shown in Table 5-36.

Table 5-36: Type of interaction and purpose of session

Type of Session		Practical (No.)	Theory (No.)	Grand Total (No.)
Interaction	Facilitator	26	4	30
	Student	17	12	29
Interaction Total		43	16	59
Facilitator-led	Facilitator	86	28	114
	Student	11	2	13
Facilitator-led Total		97	30	127
Facilitator Presentation (whole group)	Facilitator	-	18	18
Grand Total		140	64	204

Table 5-36 sub-divides Table 5-35 by showing the difference between the type of session, dominance and the purpose. There is only one session with a focus on the theory behind the design that the students dominate (see Table 5-19), where the students initiate a discussion about the direction and type of forces they are trying to calculate. Table 5-36 can in turn be broken down, shown in Table 5-37.

Table 5-37: Student-facilitator interaction by excerpt

Type of Session	Table	Facilitator (No.)	Student (No.)	Grand Total (No.)
Interaction	5-16	12	12	24
	5-19	4	12	16
	5-25	14	5	19
Interaction Total		30	29	59
Facilitator-led	5-10	6	1	7
	5-11	10	1	11
	5-12	11	-	11
	5-13	15	3	18
	5-17	13	2	15
	5-18	15	-	15
	5-24	22	3	25
	5-26	22	3	25
Facilitator-led excerpts Total		114	13	127
Grand Total		144	41	186

Table 5-37 expands Table 5-35 and it becomes clear there is considerable variation even within the different modes of ‘interaction’ and ‘facilitator-led’. One instance of interaction (see Table 5-16) sees an even activity rate by the student(s) and the facilitator and another (see Table 5-19) is dominated by the students. On the other hand, two of the 'facilitator-led' blocks (Tables 5-12 and 5-18) see no semiotic moment (i.e. verbal utterances and non-verbal actions student utterance) and overall the students generate less than 10% of the semiotic resources. The balance of this section explores the reasons for these apparent shifts and the way in which tables that are related in time (e.g. Tables 5-24, 5-25 and 5-26) vary considerably in their deployment of semiotic resources.

These three tables are drawn from the final video recording (Session 5) and observe the facilitator's interaction with the PBL students as he reviews the bridge model they constructed after the conclusion of Session 4 (see Section 5.2.6). In the excerpt reported in Table 5-24 the facilitator starts with the directive statements about what is required with "*any modifications that have to be done should be done now … If the bridge is off centre at all it will not be supported by the joints*", with this sequence ending in a closed question "*will it?*". He continues to speak until he asks a further question, "*What's the total torque?*", with this eliciting both a verbal and non-verbal response from Student A. He then rejects this answer, "*That's going to have no support*", and develops this analysis over the next 30 seconds until one of the students interrupts, looking for Clarification (Clarif), "*So the centre is here*", and the facilitator uses this to emphasise the point he was making, "*Right here is typical of the sort of issue you see*".

In this excerpt, the facilitator completely dominates the discussion, setting out the focus and adding clarification as the students answer his closed questions. He is actively guiding their meaning making towards a desired answer.

The excerpt in Table 5-25 follows directly on from this with the facilitator continuing to use both verbal and non-verbal resources as he emphasises his concerns. The first intervention by Student A is again in response to a direct, closed, question: "*How many popsicle sticks did you use in total?*". At this point the nature of the discussion shifts to a more interactive style, with first Student A indicating what he thinks he should do, "*Well, what I'm thinking we should do*", as he develops a solution, both verbally and non-verbally. The facilitator then ends this discussion by saying, "*You can't just have it sitting on the frame … it's got to be below … It's a bridge*". Student A then seeks to argue with *"what if I put it right here"* to which the facilitator replies, “*No, no….I think if you read the instructions it would become clear*”.

Again this excerpt shows the facilitator leading the meaning making. He starts with a closed question, then discusses Students A’s ideas with him, but then shifts to a direct statement of the required design. When Student A expresses disagreement with this, he closes the discussion by telling them they have not read the instructions for the task.

The excerpt in Table 5-26 follows from this, with the facilitator again leading the meaning-making process. He commences by explaining what would need to be done to address his concerns and how they should modify the design. Student A briefly interrupts, only for the facilitator effectively to ignore the idea with, “*It would be very tight, what we call a force fit. in this situation you only need to be a fraction of a millimetre over*”. After this, he dominates the session as he carries on explaining what is wrong and what potential solutions exist. The only remaining instance of student interaction is near the end when one indicates agreement with a non-verbal gesture.

The extent to which the facilitator leads meaning making is clear at other stages. His use of scaffolding to do this is explored in detail in Section 5.3.2.3 but one clear example is found in the excerpt reported in Table 5-19. This excerpt was dominated by the students. On closer inspection, in the first 50 seconds (at Timer 11.19-12.02) there is a discussion between Students A and D, ending with Student D asking the facilitator, “*The X one is in tension?*”, at which point the facilitator commences by taking them through the interaction of the two forces, “*So just look at the force at D there*”, “*have a look at the force in D*” and “*because D must be opposite to the force at A*”, before pointing to the image on the whiteboard.

5.3.2.3 Scaffolding by facilitator

As discussed briefly in the detailed analysis of the excerpts in each table, unlike the students the facilitator makes regular use of scaffolding. This is an important feature of the PBL process and a key role for the facilitator. Overall the facilitator uses 88 instances of scaffolding (45 in the practically focussed excerpts and 43 in the theory excerpts). Of these, 60 were verbal and 28 made use of non-verbal resources (gestures, diagrams or the manipulation of the paddle-pop sticks). The spread of scaffolding employed by verbal resources is shown in Figure 5-12.

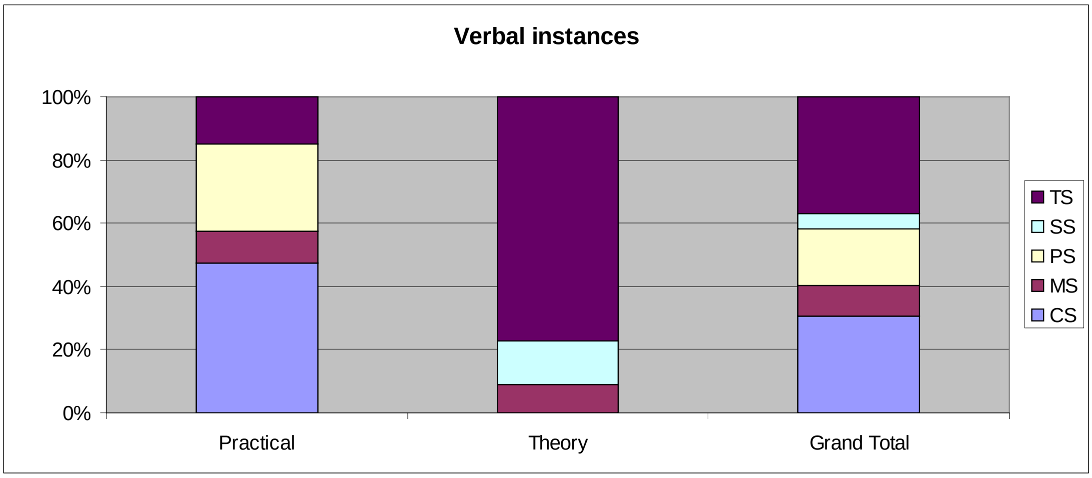


Figure 5-23: Verbal instances of scaffolding by facilitator (N=62)

Figure 5-23 indicates substantial variety in the type of verbal scaffolding used by the facilitator. In the practical sessions, around 50% were Conceptual Scaffolding (CS) where the facilitator supports the student(s) in choosing the information they need or in identifying the most significant information. Most of the other utterances are of the form Procedural Scaffolding (PS), where the facilitator supports the student(s) by providing other examples and information that will support their problem solving. In the practical sessions there is also limited use of Metacognitive Scaffolding (MS), where the facilitator uses scaffolding to assist the students in choosing between options and approaches or by reframing the problem so as to identify new options.

In the theory excerpts, scaffolding was prevalent to the same extent but takes on a very different form. Here the dominant form of scaffolding is Technical Scaffolding (TS) where the facilitator supports the student(s) by providing the technical information they need to perform the task. Beyond this there are instances of both Strategic Scaffolding (SS) and Metacognitive scaffolding (MS) where he seeks to place concepts in a wider context. Overall, Figure 5-12 provides strong evidence that the form of scaffolding adopted by the facilitator varies substantially according to the type of information being presented to the students as he makes use of a range of approaches to scaffolding.

A comparison of the non-verbal instances of scaffolding shows that the difference between the type of session is still important but it is much less significant than it is for verbal instances of scaffolding.

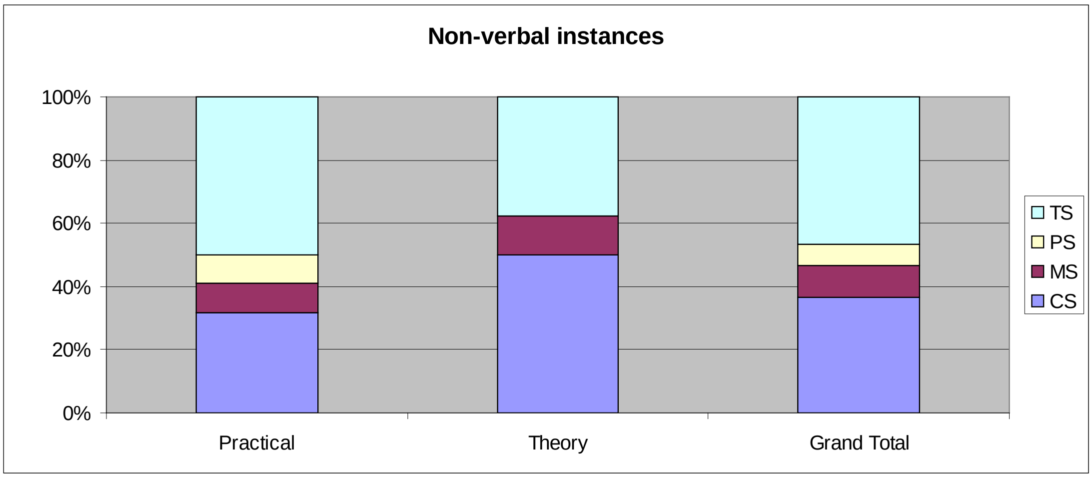


Figure 5-24: Non-verbal instances of scaffolding by facilitator (N=30)

In the practical excerpts, Conceptual Scaffolding (CS) and Technical Scaffolding (TS) are each used in about 40% of scaffolding resources. In the theory excerpts, Conceptual Scaffolding (TS) dominates with 50% of the instances and Conceptual Scaffolding (CS) accounts for another 40% of scaffolding resources. Again, as with speech, there is intermittent use of Meta-cognitive Scaffolding (MS) which accounts for the balance of the scaffolding resources. This indicates that non-verbally, Conceptual and Technical scaffolding (CS and TS) are dominant, reflecting the use of diagrams, alignment of the paddle-pop sticks and gestures to inform the students' problem solving. The relationship between the type of scaffolding and the mode of delivery (verbal or non-verbal) is shown in Figure 5-25.

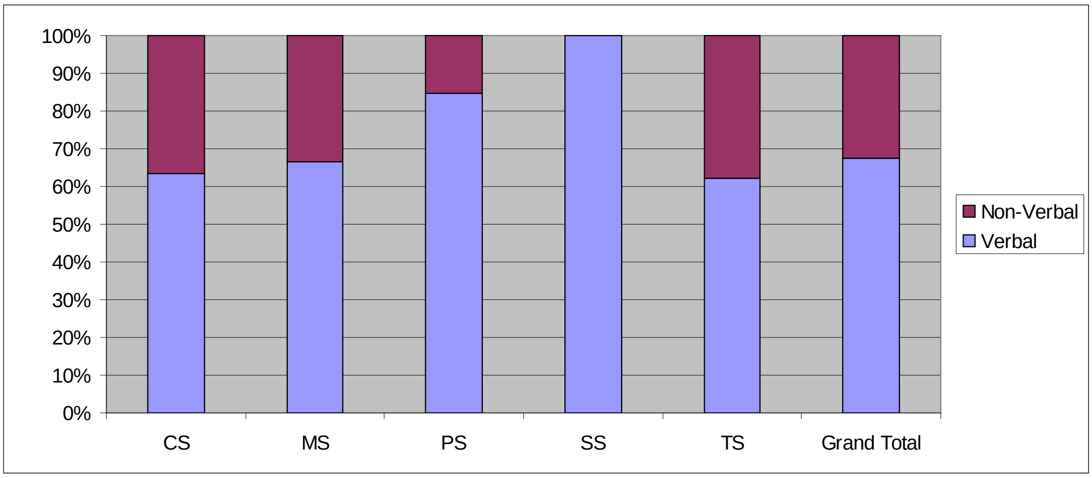


Figure 5-25: Relationship between type of scaffolding by facilitator and mode of delivery (N=88)

Figure 5-14 shows the relationship between the type of scaffolding approach and the mode of its delivery. Overall, 32% of scaffolding resources were non-verbal. Here it is clear that Strategic Scaffolding (SS), where the student(s) are encouraged to think about different approaches, is only delivered verbally. However, with regards to both Technical Scaffolding (TS) and Conceptual Scaffolding (CS) there is a bias towards using non-verbal rather than verbal resources.

As in Section 5.3.1, this essentially quantitative analysis is indicative of some broad trends, but needs to be supplemented by an in-depth analysis looking at the detailed use of scaffolding as the meaning-making focus shifts. Sections 5.3.2.3.1, 5.3.2.3.2, 5.3.2.3.3, 5.3.2.3.4 and 5.3.2.3.5 below focus specifically on the use of scaffolding both in terms of form of delivery (i.e. verbal or non-verbal) and purpose (i.e. theory or model building) by the facilitator. Table 5-34 below shows how the tables used in the detailed analysis have been divided in terms of both the focus and the degree of interaction with the student group.

Table 5-38: Division of excerpts in terms of scaffolding

	Focus	
Type of Interaction	**Theory**	**Model Building**
Facilitator Input	Table 5-2	No Examples
Facilitator-dominated	Tables 5-10, 5-17, 5-18	Tables 5-11, 5-12, 5-13, 5-24, 5-26
Interactive	Table 5-19	Tables 5-16, 5-25

This analysis proceeds first by discussing the nature of scaffolding in each of the five combinations above (there is no instance of purely facilitator's input in terms of the model building process) and then contrasts this to find out whether the intensity and role of scaffolding varies. As with Table 5-27, this makes a distinction between those sessions where the facilitator interacts with the students and where he dominates (for example, by speaking for almost all the session).

5.3.2.3.1 Scaffolding during a formal presentation (theory)

The only instance of formal presentation by the facilitator that was selected was at the start of Session 1 (see Section 5.2.1), which captures an instance where the facilitator was verbally presenting key theoretical information and at the same time showing images on one whiteboard and writing on another. The detailed transcript is in Table 5-2.

He starts with an example of Strategic Scaffolding (SS), which is defined in Chapter Three as an attempt to present an alternative so as to assist the students' problem solving. In this case "*there is another way of doing this guys if you*", which is followed by an example of Conceptual Scaffolding (CS) with an image on the whiteboard. The facilitator then elaborates on this image verbally with two successive instances of Technical Scaffolding (TS), which is the presentation of technical information designed to aid the students' thinking, "*where you've got your force in one direction*" and "*if you've got an X-Y plane*", with this in turn supported by writing these concepts on the whiteboard as Conceptual Scaffolding (CS). There is then another sequence of five instances of Technical Scaffolding (TS) as he elaborates, starting with "*add them to get a resultant FRX*" and ending with "*FRY and FRX gives you your overall resultant FR*", a sequence where he presents a substantial amount of technical information designed to allow the students to frame the overall problem.

This sequence of relatively directed scaffolding (i.e. these are the steps you need to take to solve this type of problem) is followed by a return to using Strategic Scaffolding (SS) with "*So there are two ways of solving it*" and "*You do need to know the angles*", with the latter being followed again by information on how to approach this type of problem as a Technical Scaffolding (TS), "*So what I've done is to resolve these forces into an X and Y… X and Y, Y and X components*". This sequence of scaffolding is completed by an example of Meta-cognitive Scaffolding (MS), with the idea of concentrating the students' thinking on the specific problem, "*in order to get the result in force*".

Video-recording at this stage focuses mainly on the actions of the PBL student team, not on the facilitator, who can be described as leading the meaning making at this stage. This explains why non-verbal scaffolding may well have been missed in this part of the analysis, so the discussion above may underestimate the importance of using diagrams and notes on the whiteboard as tools for Conceptual Scaffolding (CS). In general, the usage of a single camera angle proved to mean that non-verbal meaning making (either by the tutor or the students) may have been missed due to camera focus at any particular stage.

In summary, we have an instance here where the facilitator is making a formal presentation on the underlying mathematical concepts to the entire class. If the final instance of Metacognitive Scaffolding (MS) is ignored, then the process of scaffolding can be traced through the interaction of three different approaches. The major shifts in his presentation at the start with "*there is another way…* " and in the middle with "*So there are two ways…* " are marked by a use of Strategic Scaffolding (SS). Here both can be said to be used to attract attention and to inform the students that a different approach is about to be discussed. When he is presenting the information between these breaks, he makes use of Technical Scaffolding (TS) in speech (describing the equations or calculations) and Conceptual Scaffolding (CS) with the non-verbal resources (diagrams, written examples).

5.3.2.3.2 Scaffolding during a facilitator-dominated session (technical focus)

This discussion is drawn from the excerpts in Tables 5-17 and 5-18 in Section 5.2.5 above. This occurred early in the third session when the students were working in their PBL team on the theoretical underpinnings of the bridge design.

Table 5-17 contains a sequence of four instances of Technical Scaffolding (TS) in the middle, running from, "*so you work out the force against the other members*" to "*on that 45 degrees*". Here the facilitator is answering direct student questions about the nature of the force that will be applied to the bridge and the form of scaffolding adopted, as indicated in Section 5.3.2.3.1, is Technical (TS) and mirrors the content of the information he is imparting.

Table 5-18 shows a continuation of this discussion, with the facilitator still relying substantively on Technical Scaffolding (TS) as he explains what the students need to do to resolve the problem, starting with "*what you need to do is to work out a balance*" and ending with "*So it's saying there that FY…*". Here the non-verbal resource (the workings that are already on display on the OHP) also take the form of Technical Scaffolding (TS). However, the sequence of information provision ends with an example of Metacognitive Scaffolding (MS) as he says, "*see what you've done is in the Y direction*", reinforced by him pointing to the OHP screen.

Thus there are similarities with the analysis in Section 5.3.2.3.1 – and it is worth noting that there are only two instances of the students speaking in the excerpts in Tables 5-17 and 5-18 – with meaning making dominated by the facilitator. He makes substantial use of Technical Scaffolding (TS) as he seeks to provide the core knowledge the students need for the task. This is supplemented, where appropriate by Metacognitive Scaffolding (MS) where he seeks to concentrate their attention (of interest this happens in both excerpts reported in Table 5-2 and Table 5-18 at the end) and Strategic Scaffolding (SS) as he shifts to introduce alternative ways of problem solving. The relative reliance on and use of verbal and non-verbal scaffolding is the same as discussed with regards to Figures 5-12 and 5-13 above

5.3.2.3.3 Scaffolding during a facilitator-dominated session (practical focus)

This discussion commences with a further analysis of the transcripts in Tables 5-10 to 5-13 in Section 5.2.3 above, transcripts of events that occurred almost at the end of the first PBL class session. Here the facilitator sits with the student group and discusses how to translate the technical information (such as how to absorb the pressure the bridge will be subjected to) into a practical bridge design. He completely dominates the discussion and there is only one, very brief, student comment in either of the excerpts in Tables 5-10 to 5-13.

The excerpt in Table 5-10 captures a relatively brief interaction where the facilitator sits down with the students to commence a discussion of how to make a transition from the theoretical meaning making that dominated the rest of the first PBL class session to how to apply this to the model building task. In scaffolding terms he commences with a non-verbal instance of Technical Scaffolding (TS) as he indicates the paddle-pop sticks that will be used to build the model. This is followed by three instances of Metacognitive Scaffolding (MS) as he seeks to place the task in context. This starts by a non-verbal gesture where he uses his hands to indicate the type of pressure that will affect the bridge and this is followed by stating, "*What you don't want to have*", as he tries to ensure they understand the stress test that will be applied to their model, "*so think of something strong*". This excerpt is effectively a transition from theory to practice and within it the facilitator is seeking to provide the students with an overall framework for their problem solving, which is reflected in the substantial use of Metacognitive Scaffolding (MS).

The excerpt in Table 5-11 commences with a sequence of Technical Scaffolding (TS) as the facilitator sets out the expectations of the frame of the model bridge from "*the frame has got to span 500 mm*" to "*50 cm and you will need the frame so that it's strong*" as he provides the needed information for the students. He then shifts to two instances of Procedural Scaffolding (PS) as he provides essential background information on the construction and the characteristics of the paddle-pop sticks. This sees "*It's going to be sections of components that are glued together*" followed by "*a paddle-pop stick is generally quite strong*".

In the excerpt in Table 5-12 he returns to a reliance on Technical Scaffolding (TS) as he starts with "*So you've got your frame to consider*" and then discusses the various components of the bridge, supplemented by deploying the paddle-pop sticks in the desired pattern. Indeed, there are four instances were Technical Scaffolding (TS) is a product of the non-verbal rather than verbal resources as he uses the sticks to indicate shapes, what a 30 degrees angle is and what length they need to aim for to ensure a robust design.

The excerpt in Table 5-13 completes this sequence of meaning making with the facilitator explaining how the paddle-pop sticks can be used to build the frame. He commences with an instance of Procedural Scaffolding (PS), "*You can do anything with a paddle-pop stick*", to indicate that this part of the discussion will be different to that reported in Table 5-12. This is developed later as he discusses the importance of creating effective joints with some Conceptual Scaffolding (CS), first verbally with "*the joints have to be strong*" and then non-verbally as he demonstrates this with the paddle-pop sticks. This is then followed by a sequence of non-verbal Technical Scaffolding (TS) as he demonstrates the required angles and then the type of gaps that should be left between the bridge struts.

A further instance of facilitator dominated practical discussion is in the excerpts displayed in Tables 5-24 and 5-26. Both of these are derived from the final PBL class session (see Section 5.2.7) when the students are discussing the bridge design they constructed after their problem solving discussion reported in Section 5.2.6.

The excerpt in Table 5-24 commences with the facilitator reviewing the bridge design. He starts with an instance of Procedural Scaffolding (PS) as he seeks to remind the students of the context of their task with "*Any modifications that have to be done should be done now*", followed by more Procedural Scaffolding (PS) as he first picks up the model and then asks, "*OK so how are you going to fit this into the unit?*". So the information is designed to ensure the students take account of the wider task rules and the question is designed to ensure that they think about how their model will be used. The last question is followed by a shift to Conceptual Scaffolding (CS) as he tries to ensure the students understand the reasons for his concern with "*What's the total torque?*", followed by "*That's going to have no support*". The rest of Table 5-24 reports a sequence of Conceptual Scaffolding (CS), delivered both verbally and non-verbally by pointing to aspects of the model as he explains the flaws in the design.

In the excerpt in Table 5-26, the discussion has returned to the issue of the model bridge design and in particular how the frame will be supported when it is subject to the stress test. Here the facilitator starts with a series of Conceptual Scaffolding (CS) as he makes practical suggestions with "*I would definitely try to straighten up the corners*" to "*and would try to give some stability to the frame*", concluding with "*so it doesn't deform in this direction…*", with this final statement supported by placing a paddle-pop stick on the frame to indicate what he means. He then shifts to indicating how the students can improve on their design with several instances of Procedural Scaffolding (PS) with "*So what your going to do is bind the frame in*" and "*You could do away with these central beams*" with, again, the latter point emphasised by pointing at the model.

There are both similarities and differences in the use of scaffolding to Sections 5.3.2.3.1 and 5.3.2.3.2. It is noteworthy that Technical Scaffolding (TS) remains his principal strategy as he is providing information the students will need to complete the task. However, when the discussion is primarily framed in terms of the underlying theory the Technical Scaffolding (TS) is mostly delivered verbally, in contrast, and in particular in Table 5-12, the Technical Scaffolding (TS) is mostly non-verbal as the paddle-pop sticks are used to give a visual picture of the design constraints (and indeed what type of design shape the students need to achieve). As discussed above, the contrast between this information, the students' meaning making in Session 4 (see Section 5.2.4) and the actual design they bring to the final session (see Section 5.2.5) is clear. Their final design seems to take little account of either the facilitator provided information or their own exploratory problem solving.

One further issue that occurs on a number of occasions is the use of scaffolding to signal a shift in focus as the facilitator seeks to ensure the students are prepared to follow the new material he will present. He uses scaffolding to indicate a new area of discussion and to encourage the students to expect such a shift in focus.

In both Tables 5-24 and 5-26, the facilitator shifts between Procedural Scaffolding (PS) and Conceptual Scaffolding (CS). Given the focus (design, not theory) there are no instances of Technical Scaffolding (TS). Procedural Scaffolding (PS) is used either when he is setting out the constraints of the task (when they need to be finished, how the bridge will be tested) or if he wants the students to think more broadly. In contrast, Conceptual Scaffolding (CS) is used when he is discussing precise aspects of the design with the idea of presenting the students with the information they need for their problem solving.

5.3.2.3.4 Scaffolding during an interactive session (technical focus)

As discussed in Section 5.3, for the most part meaning making when the focus is on the technical underpinnings is largely dominated by the facilitator's inputs. One exception to this is provided by the transcripts presented in Table 5-19 (see Section 5.2.5). It is worth noting that this instance follows directly from the material analysed in Section 5.3.2.3.2 above and effectively completes that discussion of the technical underpinnings of the bridge design. The majority of the reported discussion is a conversation between two of the students as they work out what type of forces are involved and use the information displayed on the whiteboard.

In the excerpt presented in Table 5-19, the facilitator is silent almost to the end when he intervenes to guide the student discussion. This intervention is marked by three instances of Technical Scaffolding (TS), from "*So just look at the force at D* *there*” to “*have a look at the force in D*” and ending with “*because D must be opposite to the force at A*” as he points to the relevant example on the whiteboard.

In this case, there is no difference between how the facilitator uses scaffolding according to whether it is a session he dominates or one where he interacts with the students. This provides some evidence that it is the focus (in this case, theory) that informs his choice of scaffolding, not the mode and level of interaction with the students.

5.3.2.3.5 Scaffolding during an interactive session (practical focus)

Again, there are relatively few blocks that can be described as properly interactive but excerpts shown in Tables 5-16 (see Section 5.2.4) and 5-25 (see Section 5.2.7) offer examples of this.

Table 5-16 covers a discussion towards the end of the second PBL class session as the students explain how they are approaching the bridge design. The discussion starts with the students explaining their approach and the facilitator listening. However, the facilitator then intervenes with the statement “*There’s some major problems there*” as he indicates his concerns. This is supported by a non-verbal instance of Technical Scaffolding (TS) where he sketches out a design that shows what is missing. He then explains some of his concerns as he develops his sketch. In this sequence, the scaffolding is non-verbal as he seeks to provide information on the flaw in their design.

He then offers two instances of Conceptual Scaffolding (CS) with “*And this span is 5…*” and “*So effectively you’re going to have the force applied in the centre…*”, and follows this attempt to direct their thinking by a shift to Metacognitive Scaffolding (MS) as he encourages them to think about the tools and the overall design with “*So you really need to sort of think about paddle-pop stick*” and “*even the strengthening situation that you can do here to make that very strong*”. Here the sequence of scaffolding is designed to ensure they understand the nature of his concern with this, followed by providing Technical and Conceptual Scaffolding (TS, CS) to support their problem solving. Finally he shifts to trying to present the wider concepts, again with the goal of encouraging the students to reflect on the tools and the nature of the task.

The other excerpt where the discussion is both interactive and focussed on the model is found in Table 5-25 from the final PBL class session (see Section 5.2.7). The wider context is the facilitator seeking to ensure the students understand his concerns about the model they have constructed. He starts with a sequence of Conceptual Scaffolding (CS), "*You have the load*", emphasised by a non-verbal gesture. In the discussion that follows, it appears as if the students do not understand what he is saying and thus he later shifts to Procedural Scaffolding (PS) with "*You can't just have it sitting on the frame*" when discussing how the bridge will be supported when it is tested. One of the students persists in asking if their original idea is valid, leading to the facilitator again using Procedural Scaffolding (PS), this time rather abruptly with "*I think if you read the instructions it would become clear*" and, as discussed in Section 5.2.7, he then turns his back to the students who carry on looking at their model.

The facilitator is using Procedural Scaffolding (PS) in Table 5-25 in much the same way as he uses Metacognitive Scaffolding (MS) in Table 5-16. He uses this particular strategy when he wants the students to reflect less on a specific point in the task development and more about the wider rules and context for the meaning-making activity.

5.3.2.4 Discussion of facilitator's role

5.3.2.4.1 Interaction

Both the discussion of the quantitative and the qualitative analysis make it clear that the facilitator dominates the active meaning making when he is present. The excerpt in Table 5-2 is different from all the other selected excerpts in that it captures a formal presentation to the entire PBL class. However, Table 5-33 indicates there are 11 other excerpts where he is present with the student group. As was discussed in Section 5.3.2.2, even when a simple counting indicates some degree of interaction, in reality he is very active in guiding meaning making. The sequence from the final PBL class session sees him trying to lead the students to an understanding of the required model design, while the interactions with the students are mostly very brief, and effectively ignored. The reason may be the nature of the task. At this stage the PBL students needed to have prepared a bridge for the evaluation test and so he is modifying the meaning-making process inherent in PBL to reflect the limited time left and the precise requirements of the academic class. If so, that is an example of how external rules and constraints limit how meaning making can be undertaken.

One question this raises, is the extent that the facilitator is working within the traditional model of PBL, as opposed to this being a more conventional engineering problem solving class. In some respects, his approach fits with PBL, in particular the substantial usage of scaffolding (Section 5.3.2.3 above). As discussed in Chapters Two and Three this is typical of the student centred model in PBL, where additional information is provided to assist the students in their own meaning making rather than to offer them a direct solution. On the other hand, there is ample evidence that he dominates many of the sessions where he interacts with the students (Table 5-33) to the extent that many excerpts see little or no active student engagement. Finally, especially in the discussions from session five (Section 5.2.7) he is also very task focussed, and aware of both the time scale and the need for the students to meet the assessment rules for this particular module. The extent that this module should be characterised as PBL or a typical engineering design project is returned to in Chapter Seven after comparing the data from the multimodal analysis with the findings from Chapter Four (especially Section 4.5.3).

5.3.2.4.2 Scaffolding

The discussion of the quantitative analysis indicated that there were differences in the use of scaffolding when discussing theory as opposed to the bridge design. This is supported to some extent in the detailed qualitative analysis, mainly in the use of Technical Scaffolding (TS) when presenting theoretical issues and Conceptual Scaffolding (CS) when discussing the model design process. However, the discussion in Section 5.3.2.3 is somewhat of a hybrid between theory and practice. While the discussion is about the design of the model bridge, it is actually as much about how to transfer the theoretical knowledge to the domain of engineering design. In consequence the transition from theory to practice is marked by a use of Technical Scaffolding (TS) as the facilitator explains how the theory of load bearing needs to be taken into account in the actual bridge design.

As with the discussion of the nature of their interaction it is clear that the facilitator tends to dominate the meaning-making process when he is present. In particular he sometimes uses scaffolding to indicate when he is introducing a new concept, almost as a means to signal this and draw their attention. The other use he makes, in particular of Metacognitive Scaffolding (MS) and Procedural Scaffolding (PS), is to frame the meaning-making process. He uses these strategies, as suggested in the discussion in Section 5.3.2.3.5, as a means to frame that process with the specific task constraints imposed by the assessment of the bridge building task.

5.4 Summary

This section follows the structure of the brief summary at the end of Chapter Four. It very quickly sketches out how the material in this chapter relates to the four specific research questions. In turn, Chapter Six will develop this material and combine the findings of Chapters Four and Five with the implications of the literature review in Chapter Two.

5.4.1 Importance of context

One key reason for conducting an analysis in terms of activity theory in Chapter Four was to explore the importance of the wider context on the meaning making that took place. That led to the conclusion that there were two sets of rules in use, the rules needed to build any model bridge and the rules that applied to this particular PBL task (around assessment, timeline and the resources available).

This chapter has explored the issue of context in a different manner, mostly in terms of the use of scaffolding in the PBL meaning-making process. In the PBL literature (Hmelo-Silver et al., 2007), scaffolding is key to supporting and guiding the student learning experience, or the students will become disorientated (Tan, 2004). Context can now also be seen not just as the rules and environment that frame the task, but also the information presented that guides and supports the student learning process.

As will be explored in detail in Chapter Six, context can now be seen as a combination of the underlying nature of the task (i.e. the process of building any efficient model bridge) and of the rules set for this task (i.e. the nature of the end test, the timeline, how the assessment has been constructed and the resource limitations), to which should be added the support created during the meaning-making process by the facilitator’s use of scaffolding.

5.4.2 Students’ meaning making

Chapter Four identified how students’ meaning making varied in terms of group involvement. It was noted that in particular during the sessions that focussed on the theoretical underpinnings of the task, there was a tendency towards individual working. Across all the video-recorded PBL sessions, there were very few instances of all of the group being involved in problem solving and instead the group aspect to meaning making involved discussions between shifting sub-groups of the five students.

Section 5.3.1 summarises the various ways in which students’ meaning making varies according to the shifting focus (basically either the theoretical underpinnings to the bridge design or the process of constructing a model). The theoretical sessions see an overwhelming use of Concept-related Talk (CT) and even the non-verbal aspect of meaning making is dominated by Concept-related Talk (CT) use (Figures 5-4 and 5-5). However, the model-making excerpts saw more use of Elaborated Explanation (EE), indicating a more active role in the meaning-making process by the students (see Section 5.3.1.3). For most of the theory-based excerpts, speech is the dominant mode for meaning making, with gesture and tools used in a secondary manner. However, for the model-building excerpts, the situation is more mixed. In some (such as shown in Table 5-22) the non-verbal semiotic resources are dominant in the meaning-making process, with speech used in a secondary, supportive, manner. In others (such as shown in Table 5-26) speech is dominant, but the non-verbal element is critical to building up meaning.

Overall, Chapter Five indicates that students’ meaning making changes according to the focus. When this is on theory, the students tend to use Concept-related Talk (CT), and speech tends to dominate the meaning-making process. When they are focussed on model building, there is a greater use of elongated periods of speech (indicating more active meaning making) and non-verbal resources are either critical or important in the meaning-making process.

5.4.3 Facilitator's role in meaning-making process

In Chapter Five, the facilitator's role has been studied in several ways. It is clear that when he is speaking (either to the entire class or with the PBL group being studied), he tends to dominate the discussion with relatively limited use of Acknowledgement (Ack) and Brief Answers (BA) in his speech patterns. As with the students, his use of verbal resources varies between when the excerpt is focussed on theory or model building (see Figure 5-9). In the former, as do the students, he favours Concept-related Talk (CT) and he makes more use of Tool-related Talk (TR). Again, as with the students, a similar pattern recurs in terms of the use of non-verbal resources with Concept-related Talk (CT) being the most frequent, if no longer so dominant (see Figure 5-10).

According to the PBL literature, one major role of the facilitator is scaffolding to provide a context and a structure to the students' meaning making. As discussed with regard to Figure 5-13, there is a clear divide between the type of scaffolding he used in the theoretical excerpts (where he relied on technical scaffolding) and in the practical excerpts (where he relied on conceptual scaffolding). As with the students' meaning making, there are excerpts when scaffolding is carried out in terms of verbal utterances (most commonly in the theoretical excerpts) while in others it either relies on non-verbal resources, or these are critical to understanding what is meant. As with the students, both in terms of the deployment of semiotic resources and of how he uses scaffolding, the facilitator shows a clear difference in his approach to meaning making between the theoretical and the practical excerpts.

5.4.4 An analysis of task performance

Chapter Four indicated that the facilitator expressed strong reservations about the final bridge model the students brought to Session 5, specifically as discussed in Section 5.2.7. However, again, this chapter has identified excerpts where the students express their own doubts about the task and a lack of understanding, either of the task environment (see Section 5.5.1) or how to solve the problem they have been set.

Chapter Six
Discussion

6.1 Introduction

This chapter brings together the empirical results reported in Chapters Four and Five, with the theoretical review in Chapter Two, to address the four key research aims and associated questions set out in Chapter One. For convenience, these are again restated as:

1) Understand the role of context in the PBL task, specifically, how far can the actions of both the students and the tutor be understood in terms of external constraints rather than their own preferred problem-solving/ meaning-making approach?
2) Understand the role of the students in the meaning-making process, specifically, how do they draw on different semiotic resources or use them differently as the task evolves and their understanding shifts?;
3) Understand the role of the tutor/facilitator in the meaning-making process, specifically, does his use of semiotic resources vary as the task evolves and, if so, how does this affect their interaction with the students and use of scaffolding?; and
4) Evaluate the overall performance of the student group in terms of task performance and the students' construction of meaning.

PBL is a student-centred learning pedagogy where the key feature is that the students deal with an ill-structured problem in a group context. They are expected not just to apply existing knowledge to the problem, but to acquire additional knowledge in a group context as they undertake the problem-solving task. To support them in this, they are conventionally supplied with additional materials they can access and a facilitator who works with the group. A key role for this person is to engage in scaffolding, where they guide and direct the students' meaning making but do not provide direct information.

Chapter Two also reviewed the literature on multimodality as a concept and noted (see Table 2-1), that while the concept of the influence of the wider environment on meaning making (resemiosis) was acknowledged to be important, this was rarely clearly handled in multimodal studies. To address this gap, following Jewitt, use was also made of activity theory (Jewitt, 2006) to allow a systematic investigation of the importance of context in framing the PBL meaning-making process. Activity theory was also used to review and report on the entirety of the video recordings (resulting in

425 pages of transcript) and, from this, to select seven separate excerpts (spread across the five video-recorded classes) that exemplified key stages in the development of the class or typified particular modes of interaction

These excerpts were analysed in detail using a multimodal approach and the results are reported in Chapter Five. In particular that analysis focussed on the shifts in terms of the use of semiotic resources (by both students and the facilitator) as the focus of their meaning making shifted.

The balance of this chapter offers an overview of the findings reported in Chapters Four and Five and brings them together to address the four detailed questions. It does this by reviewing the findings in terms of:

- The impact of context on the meaning-making process;
- How the students construct meaning;
- How the facilitator interacted and assisted with this meaning-making process; and
- Whether it is feasible to come to a judgement as to the outcome in terms of the students' task performance.

6.2 Review of research questions

6.2.1 Contexts for meaning making

A key issue in all social constructivist models of meaning making is that human activity can only be understood in context (Bannister & Fransella, 1986; Cromby & Nightingale, 1999; Hendry et al., 1999; Poyas & Eilam, 2011; Stojcevski & Du, 2008). This context influences how a given situation is understood and what language exists with which to describe it (Blunden, 2011). Activity theory stresses the importance of the way in which the available tools, as well as the wider social environment, influence how a given task is understood (Engeström, 1987; Leontev, 1978, 1981). Thus, before the meaning-making approach of either the students or the facilitator can be examined, it is first necessary to explore the framework that provides the context for the class.

The analysis has highlighted how complex and multifaceted context is in the PBL classroom. Indeed there is evidence of three distinct contextual dimensions that impact on and inform the meaning-making process: (a) the underlying *theoretical* *context* of physics and mathematics that underpins this and similar problem-solving tasks; (b) the *methodological context* in which the rules and constraints are set for this particular problem-solving task; and, (c) the *procedural context* provided and evolving as the students carry out the task. The first two of these were primarily analysed in Chapter Four using activity theory, the final dimension was evident in Chapter Five and mostly falls under the concept of scaffolding (and, as such, is the focus of Section 6.2.3 below). However, these contexts will be discussed here further in relation to the process of resemiosis.

6.2.1.1 Theoretical Context

The first step in exploring how context informs the meaning-making process is to consider what could be described as constituting the theoretical underpinnings integral to the process of building a model bridge, such as the need for the bridge to absorb certain forces. Chapter Four has indicated that some of this context is provided by other classes the students have studied and which underpin the process of resemiosis (the impact of the wider context on the specific context) as, for example "*What you've got is a whole lot of material, because this really is superimposed on EM1032, which was the previous introduction to design. So what we've made this as a PBL subject*" (PBL facilitator, Session 2, 26.15).

In turn, this broader theoretical context leads to re-semioticisation of meaning in different ways, for example, as in Session 1 with "*So the first thing that I want you to think about is how you're actually going to get a strong structure. Think back to that wire frame job*" (facilitator, Session 1, 37.12). At several stages the facilitator emphasises the importance of a strong frame, built in a particular way using engineering design principles, another example from Session 2 being "*The frame should be very strong, with a combined surface area, that's got very good sort of joints*" (39.30).

In general, the long presentation by the facilitator at the start of the first session and again in Session 3 can be seen as both reflecting and contributing to this overall theoretical context. Although some of that information is specific to this task, the majority is concerned with the more general theoretical underpinnings. Wider academic knowledge within an engineering degree provides the theoretical context and is applied to the practical task of designing a model bridge.

6.2.1.2 Methodological Context

The second contextual dimension is methodological. It forms the major contextual frame and relates to the application of the theoretical domain and knowledge to this PBL task, with a focus on the additional rules created around how this task is to be approached. These rules are variously around the testing process, the resources available, and the timeline.

A critical early statement of the task constraints is provided by the facilitator with:

> *What you're going to do is to build a bridge or a tower out of these paddle-pop sticks. You're only allowed to use the paddle-pop sticks or the glue. So the first thing that I want you to think about is how you're actually going to get a strong structure. Think back to that wire frame job.* (Facilitator's input, Session 1, 35.59)

In turn they are told how long the bridge will need to be (500mm) and that they have 275 paddle-pop sticks to work with and a finite amount of glue. They are warned that the bridge will be weighed to ensure it meets these requirements. In addition to the overall task, they are also given specific targets such as "*So what I want to see next week from you – don't go using the paddle-pop sticks and sort of ruining them before you know precisely what you're going to do*" (Facilitator's input, Session 1, 41.35). The student group is told they are expected to conduct some of the task outside the class with "*Guys, you need to finish this work on your own time*" (Facilitator's input, Session 1, Timer 21.56) and later on again by stating that part of the work is '*your homework*'. All these methodological prescriptions link to the underpinning principles of PBL methodology and directly impact on and create a context influencing how the students make meaning.

However, this also (as discussed in Section 2.2.2) raises the question of the difference between PBL and the general engineering pedagogic tool of project-based learning. Group work, a relatively open ended project and students working with little or no direct supervision does not mean a given module can be automatically characterised as PBL. One tension is that, given the context of a university degree course, no module can be truly open-ended or reliant on student-centred learning. PBL acknowledges this by creating the role of the tutor/facilitator and the importance of scaffolding to guide meaning making. Equally, the PBL literature (especially Section 2.2.2.2) acknowledges that the facilitator faces a challenge in balancing the expectations of PBL with the constraints of an academic programme of study. In this thesis, the focus is on the ways in which student problem solving has varied according to the task and situation, but the issue of the nature of the entire session is a theme returned to in this Chapter and in Chapter Seven.

6.2.1.3 Procedural Context

The final contextual dimension impacting on meaning making and problem solving is procedural, and frames the students' actual processes and actions by dictating what they need to do next, or information provided to structure and assist their activities. For example, late in Session 1 the facilitator tells the students "*The preliminary report is next week and then we'll see some sketches*". This statement is followed by admonition not to commence actually gluing together the paddle-pop sticks. However, the facilitator is not the only person creating a procedural context to cope with the development of the task as the students too make plans such as "*My plan on the holidays is to go through all those questions and finish everything, and get it back up to normal*" (Session 2, 5.57). A later example of this is Session 4 (23.13) "*Unless, do you want to do the report and I'll see if I can do this, try and do the whole thing. And you be the one to do the report. No, I don't mind doing it, it's not that – because I hate report writing. … Yeah I've got no problem with doing the bridge if you're cool doing the report.*" This is followed by agreeing a timeline (30.54) of "*Yeah for sure, because I've got tonight. I'll work on it tonight and if I don't get it finished tonight, I'll definitely have it finished Tuesday night. And then I might start gluing a couple of these together*".

In addition, ongoing procedural context is provided by the facilitator as he seeks to guide their meaning making. This also falls into the category of scaffolding and, as such, is discussed in Section 6.2.3 below as it fits into a wider discussion of the role of the facilitator.

The multimodal construction of these contexts shows that Activity Theory is not adequate enough to explain the role of context or how it is built. Multimodal analysis has been critical in understanding how the social context is built and how the different participants engage in the process of this construction.

6.2.1.4 Are contexts shared?

One related theme, discussed in Chapters Four and Five, is the extent to which there is agreement about the context, and, in particular, about the rules between the student group and the facilitator. The role of the facilitator in setting out the rules was discussed in detail in Chapter Four and summarised above. The formal rules that create the methodological context are a mixture of those that are implicit within the PBL pedagogic model (the concept of a facilitator who guides meaning making using scaffolding), those specific to this task (timeline, resources, how the model will be tested) and those that form the procedural dimension of the context that seek to guide the students procedurally through the task.

What is not so clear is what rules the students are using or accept, although their interactions and observation suggest divergence in how the contexts are read and responded within. In part, this lack of clarity is the consequence of there being no interviews, meaning that the evidence base lies in what was observed, rather than any data on personal cognition. However, even with this limitation some conclusions can be drawn:

First, the students quite often query or seek clarification of the rules and the timeline for the task (this may reflect a search for clarity, forgetfulness or indicate a lack of acceptance of the framework set out).

Second, there are clear instances where the students explicitly state they lack clear information or would prefer to not be engaged in the classic PBL task structure (an example is found in Session 2: "*The teachers, they haven't taught us anything but she just expects us to know all this crap. What does this… mean*"). Similarly, there is the statement set out in Table 5-15 "*I want questions and answers*", which again can be read as indicating a desire for information that will ease the process of task completion. The final examples are covered in Table 5-23 where the students lose focus on the model building task and by both speech and gesture indicate frustration or confusion with the task.

These instances are not definitive, but taken together with the discussion about the students' preferred learning approach (discussed below), it does indicate that the students know the rules for a PBL-style task environment and methodological context, but have reservations about the application. There are two sets of rules in operation, those of the academic process and those preferred by the students. This theme is explored in the balance of this chapter and, in particular, in terms of the differences of the meaning-making approach both within the student group and between the students and the facilitator.

In activity theory terms this indicates that in some respects the focus and meaning of the task are agreed and in others there is disagreement (or at least a lack of shared agreement). The classic activity theory diagram can be used to set out the various categories from the perspective of the facilitator (in black) and the students (in red), as in Figure 6-1.

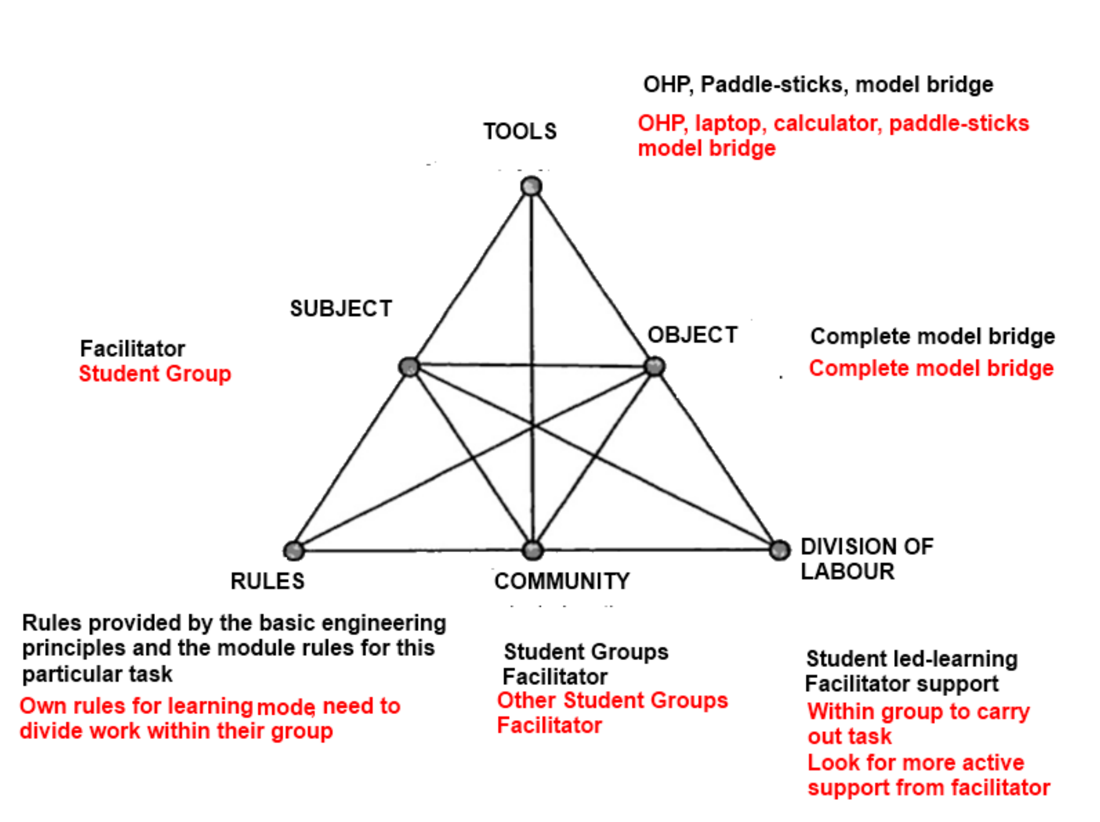


Figure 6-1: Student-facilitator task understanding

6.2.1.5 Summary

The context within which this problem-solving task takes place can be said to constitute three dimensions. The first is the theoretical context of designing a bridge (i.e. any bridge) and incorporates concepts from physics, mathematics and engineering design in terms of the ability to bear a given weight. The second is the methodological context provided by the rules that surround the building of this particular model bridge within the PBL methodological and pedagogical framework. These are variously the resources available, how the knowledge and learning is expected to be generated and will be tested and the timeline that the students have. The third is the procedural context provided by the shifting set of goals (i.e. requirements that the students need to meet before the next class) or guidance (this is mostly captured in the discussion about scaffolding below) provided. In combination, these different contextual dimensions form the context within which the meaning making by both the students and the facilitator need to be understood. In particular, any evaluation of student performance (see Section 6.2.4) can only be made in the context of this particular PBL learning experience and must consider how through processes of re-semioticisation the students engage in meaning making to generate the learning outcomes.

6.2.2 Students' meaning making

The student meaning-making process is the core aspect of any PBL task. Ideally this should be student-led, based on group interaction and lead to a successful solution to the task as set (Choo, 2012; Gijbels et al., 2005; Hmelo-Silver 2004; Pennell & Miles, 2009; Savin-Baden, 2004). On the other hand, Chapter Two pointed to two common problems with PBL: that students often do not engage in group problem solving (Remedios et al., 2008a, 2008b) and the frustration often reported by students at being expected to undertake a task when they know their facilitators already have all the necessary information (Pennell & Miles 2009; Tan, 2004). There is evidence in this research that both these issues affected this particular PBL group. This summary is divided into a number of themes that explore different aspects of the student meaning-making process in order to answer the second of the research questions. The main themes are:

- Response to the PBL expectations;
- The learning environment;
- The linkage between scaffolding and tool use by the students;
- Different modes of meaning making among the students.

6.2.2.1 Student response to the expectations of PBL

The discussion of the PBL process in Chapter Two identified a number of problems that are often reported. These are: (a) silent students (Remedios et al., 2008a); (b) student frustration with the self-directed learning model (Tan, 2004); and, (c) the difficulty of fitting in the relatively open-ended task with other demands on their time (Ramsden & Brown, 2008). There is evidence presented in both Chapter Four and Chapter Five that these problems influenced student performance in this instance.

Chapter Four has discussed how the student group relied on individual working or sub-group interaction as their primary meaning-making strategies. In that discussion it was indicated that one student (Student E) was often working on his own, using a laptop when the others were working with pen and paper and he was rarely being involved even when more than two of the other students were discussing their progress or interacting with the facilitator. This relative silence by some of the students can be confirmed by counting speech events in the excerpts reported in Chapter Five. For this purpose the interactions that took place in Session 4 are excluded as only two of the students were present. Otherwise, the number of speech events per student (excluding non-verbal interactions) were:

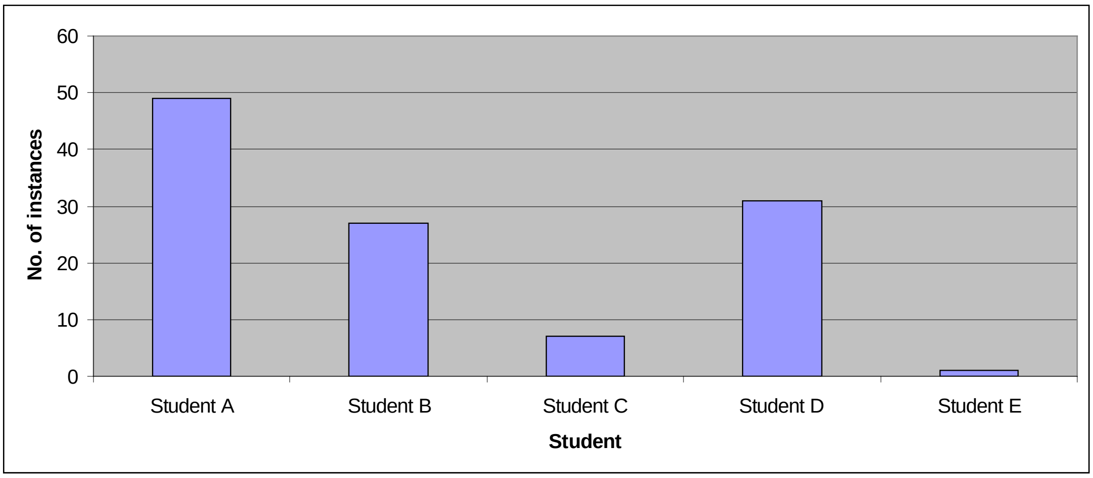


Figure 6-2: Level of individual students' interactions (verbal)

In this case, Figure 6-2 provides evidence that the active (and shared) student meaning was mainly carried out by three of the group of five, with one (Student E) making a single statement and another (Student C) making seven statements. The extent that some students are 'silent' becomes even more obvious if only those excerpts coded as 'student dominated' (i.e. where the facilitator takes no part) are taken into account (again this excludes Session 4 as that only includes two of the students).

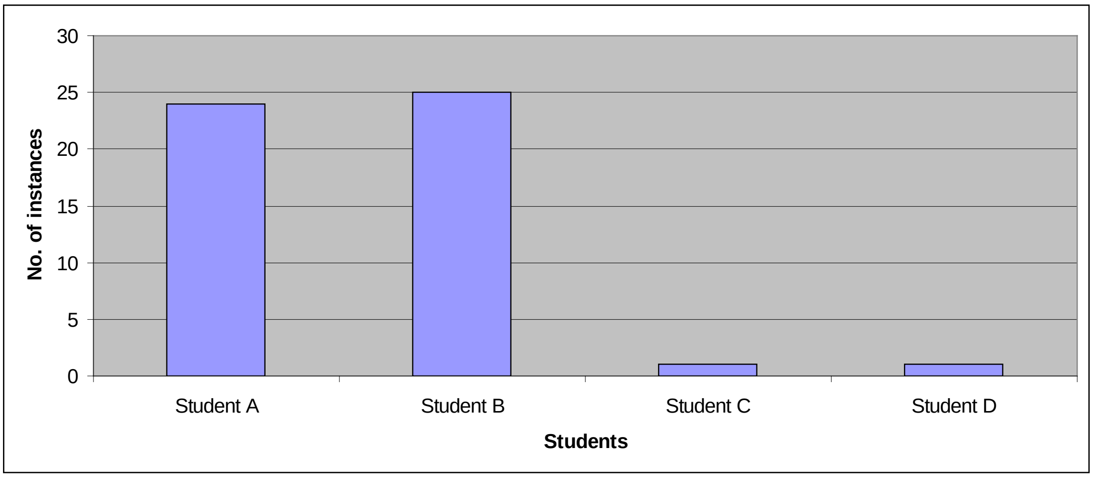


Figure 6-3: Students' verbal interactions when excerpt is 'student dominated'

Note: There are no instances for Student E.

Figure 6-3 shows only two of the students are active in the verbal meaning making when the student group is working on its own. Two of the others (Student C and Student D) are mostly silent and one, Student E, makes no comments at all. This also indicates very different levels of activity for students B and D depending on whether or not the facilitator is present. Student B makes two utterances when the facilitator is present and 25 when he is absent (out of a total of 27). By contrast, Student D makes 30 utterances when the facilitator is present and only one when he is absent. Student A seems to be equally active in both instances.

When the instances of active meaning making using non-verbal resources is analysed a similar pattern emerges to that shown in Figure 6-2 above (see Figure 6-4):

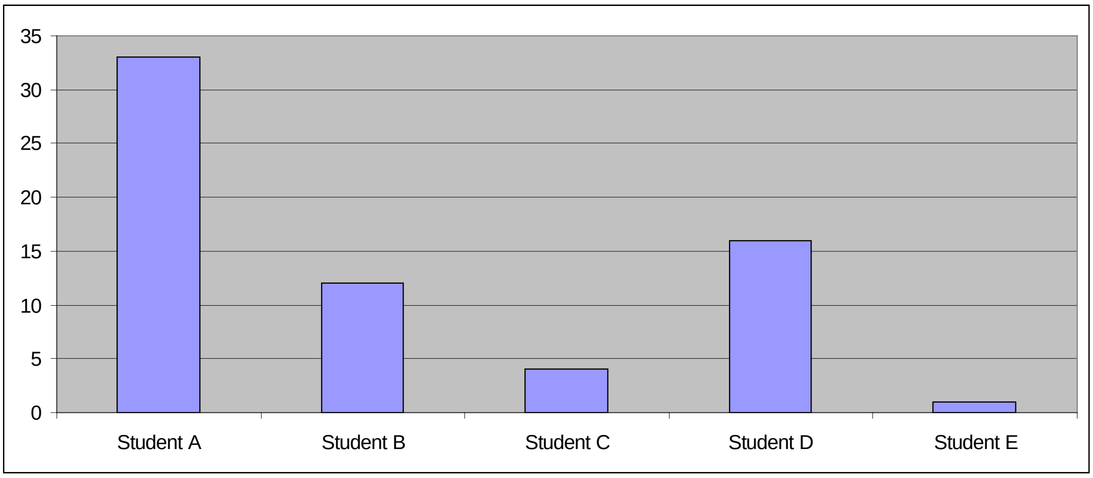


Figure 6-4: Students' interactions (non-verbal resources)

Again, Session 4 is excluded from this figure as only two of the students were present at that stage. It is clear that Student A was the most active both verbally and non-verbally (accounting for 33 out of the 66 instances) and that Student E worked on his own and engaged in an extremely limited manner with the rest of the student group non-verbally as well as verbally. However, since he used his laptop to search for possible bridge designs, he nevertheless participated in the learning process, even though with a very low level of engagement. This supports what other studies found. For example, Jun's study (2012) found that silence is a communicative approach, and a method of engagement. Remedios, Clarke & Hawthorne (2008b) affirm that silence should not be considered as a lack of learning. As a result, it can be concluded that while students work non-verbally, they engage in the PBL process. Student E was silent because he "to digest other students' information or search information" (Jin, 2012, p. 183). Indeed, as mentioned, in Section 2.6, the different deployments and exploitations of semiotic resources by the students lead to the conclusion that learning approaches vary among these students. By acknowledgement multimodality a variety of learning approaches can be discerned as students engage differentially with the various signs and symbols, combine them and develop their own interpretations. Furthermore, this observation affirms the relationship between the theory of multimodality and social constructivist approaches (Fairhurst & Grant, 2010). From the perspective of PBL, this affirms that PBL enhances the students' learning preferences (Felder & Silverman, 1988).

Overall on the basis of the data about contributions to interactions, it is reasonable to conclude that this PBL task was affected by the problem of silent students. Chapter Four, in particular Figure 4-15 shows how much of the time the students spent on individual working rather than group interaction. If time spent listening to, or working with the facilitator, is excluded then 50% of Session 1, 45% of Session 2 and 75% of Session 3 can be seen as in-group meaning making by the students with no external involvement. As discussed, Session 4 is unusual in that just two of the students were present and Session 5 is dominated by a review of the model bridge already partially built. Very little time, only 15% of the whole, can best be characterised as "all group discussion" where the entire student group is actively engaged in meaning making.

There is an element of these differences that appear to relate to the focus. When the students are addressing the theoretical underpinnings to the task, they tend to work on their own with intermittent (usually one-on-one) interaction. However, when, as is Session 5, they are focussed on the model building task, there is a greater degree of sub-group (i.e. not all the student) collaboration in problem solving. The extent that this can be linked to the environment (in this case the learning norms within Engineering) is discussed in the next section.

There is intermittent evidence of student frustration with the task and the information they have to hand. Examples include from Session 2: "*The teachers, they haven't taught us anything but she just expects us to know all this crap. What does this… mean*". The excerpt in Table 5-15 contains another short interaction (between Students A and B) where the students express a need for more information

Student A: "*It's too hard…. I want questions and solutions*" (he is laughing and pointing at the information on the OHP slide)

Student B: "*That's what I asked too*".

Related to this is seeking repetition of information already presented. This encompasses the length of time available, what tasks need to be ready and for when, the number of paddle-pop sticks they have to work with.

There is less evidence that being expected to work outside the formal class times was a problem or that the students found the PBL task interfering with their other studies. There are a few instances where the students seek clarification of the rules, in the sense of what is to be seen as ‘homework’. The excerpt in Table 5-23 reports an exchange between two of the students who are discussing how to combine completing the PBL task with the other demands their academic studies are placing on them.

6.2.2.2 Learning environment

Section 6.2.1 has examined the impact of the contexts in creating the rules for the particular task. These are sub-divided into theoretical, methodological, and procedural contexts. From the discussion in Section 6.2.2.1, it appears as if there is another aspect to understanding the learning environment: achieving an understanding of students’ preferred learning approach/es. Ascribing cultures to entire academic communities is difficult and prone to the creation of stereotypes and generalisations. There is some, very intermittent research into how the culture of higher education affects overall behaviour (Dill, 1982). Engineering, as a discipline, can be described as a hybrid in that concepts of project work and design are core to its ethos (Dym, Agogino, Eris, Frey, & Leifer, 2005). In this aspect, it is well suited to the use of PBL as one means to encourage a group problem-solving approach among students as well as the skills of project planning (Mills & Treagust, 2003; Stojcevski & Du, 2008). On the other hand, engineering is a discipline founded in mathematics and the physical sciences (Winkelman, 2009), which can be characterised as dominated by individual learning. Finally the assessment model in use (in particular how marks are divided between individual and group performance) can have a strong impact on student learning (Savin-Baden, 2004).

A final aspect to the question of the apparent disengagement from the PBL learning model is the question of student preference. Some students learn better than others working on their own or in a group environment (Biggs & Tang, 2011). In this instance, from the available evidence, it is not possible to go beyond suggesting that the apparent preference of some of the student group for individualised learning can be linked to culture of learning (either subject-based or personal), and reflect their own preferred learning approach. However, the issue of preferred learning approaches is part of the environment that needs to be taken into account when discussing task performance, and in that sense, is as important as the imposed rules and internally created work divisions as a means to understand observed behaviour.

There appear to be, in fact, four different learning approaches evident within the group of five students. These preferred approaches are evident in the level of the students' engagement across different modalities and in different forms of group formation and interaction. One approach is evidenced by Student A. He is best characterised as a *fully multimodally engaged learner*. He engaged in the PBL task actively both verbally and non-verbally (see Figures 6-2, 6-3 and 6-4). He was a very confident learner and deployed non-verbal resources the most amongst his PBL peers. This strong engagement rendered Student A the student who had the deepest comprehension for PBL task (Graaff & Kolmos, 2003; Shinde & Kolmos, 2011). The second approach is evidenced by Student B, who I have chosen to classify as an engaged peer learner. This is because he engaged, but far more when the PBL team worked independently from the facilitator than when the facilitator was present with the team. He also engaged non-verbally. Students C and E are the least engaged students verbally and non-verbally. However, Student C is a bit more active than Student E. This is particularly obvious through the use of non-verbal semiotic resources. Both Students C and E can best be characterised though as *passive* or 'silent' *learners*, and whilst they participated in the group, the extent to which they contributed to interactive meaning making and learning must be questioned. Student D, is an interesting contrast to Student B, in particular and is best understood as a *facilitator-focused learner*. This nomenclature is proposed because he engaged verbally with the PBL team primarily when the facilitator was present and virtually not at all when the facilitator was absent. It appears as if it was important for him for the facilitator to observe his participation – you may even say he was an 'exhibitionist'. However, it is important to note that he was a considerable contributor to the meaning making non-verbally, being the second highest among the students in his non-verbal turns.

This further analysis has highlighted some distinctive and markedly different learning approaches and modalities of meaning-making contributions across the student group. Furthermore, multimodal analysis has been critical to uncovering some key differences in students' participation in PBL discussion and hence in the meaning-making process.

6.2.2.3 Student use of scaffolding and tools

The role of scaffolding by the facilitator is a major concept within the pedagogy of PBL (Choo, 2012; Greening, 1998; Hmelo-Silver et al., 2007). However, consideration of the use of scaffolding by the students indicated that (see Section 5.3.1.3) scaffolding by them was evident, albeit on isolated occasions. In Section 4.3.4, it was noted in activity theory terms what tools were accessed and how they were deployed. What marked out the student use of scaffolding was the reliance on tools rather than speech. In some instances, scaffolding was the use of a tool (such as a calculator) to assist in carrying out a task. In others, the model bridge was used as the means to carry meaning and to assist someone else (usually the facilitator) to understand what they were seeking to achieve. However, when this information is combined with a multimodal analysis, it is possible to start to answer the question of why certain tools are used in particular ways.

It was suggested in Section 5.3.2.3 that the much more substantial use of scaffolding by the facilitator was linked to his different understanding of the problem space compared to the students. Simon (1978) made a now classic distinction between problem solving when someone faces a new situation (iterative, built up step by step from known information) and when someone has a degree of domain expertise and is able to take an overview, act holistically and is aware of how different aspects fit together. Section 5.3.2.4 hypothesised that this explained the greater use of scaffolding by the facilitator. Not only is this his role in the situation, but he possesses a degree of technical knowledge that allows him to guide others from their current comprehension of a problem to a richer understanding. In turn, it was argued that the students lacked this overview and were thus unable to get the maximum benefit of scaffolding, even when engaged in discussions amongst themselves.

However, what appears to be the case is that when the students do use scaffolding they do so using non-verbal tools. If the instances of using a calculator (Tables 5-7 and 5-8) are discounted then the majority of instances are related to the use of the model to indicate what they are seeking to achieve. From the available information, it is not possible to go beyond noting this reliance on tools for scaffolding and, tentatively, suggesting this may be linked to their limited ability to vocalise in contrast with their capacity to use gesture or objects to indicate their understanding of the problem. The exploitation of scaffolding in the form of non-verbal resources may also indicate the PBL students' lack of some knowledge of the PBL task, entitling them to scaffold each other non-verbally. For example, as discussed in Section 5.3.1.3, when Student A 'squeezes his hands together' to show to the nature of compression to Student D, this could reveal that Student A does not know the technical term (i.e. compression) or that he expects that his peer (Student D) will not understand him verbally. This means that using non-verbal scaffolding strategies may reflect the students' level of knowledge and capacity to semioticise this verbally and/or assumptions about non-verbal scaffolding being more accessible to their other group members.

6.2.2.4 Different modes of meaning among the students

A significant theme that was explored in Chapter Five in particular was the use of different semiotic resources by the students as they shift the focus of their meaning making. In this respect Kress (2010) has developed the concept of affordance as the means to capture just what types of meaning can be sustained by a given mode. This takes into account the potential that a particular semiotic mode can be used for a range of meaning-making tasks but that, in turn, some modes are more suited to particular tasks (Kress, 2010). In this sense, affordance is a product of the meaning attributed to a mode, of our social understanding of what can be done say with gesture as opposed to writing. There is a linkage here to Leontev's (1978) argument that social norms constrain how a particular work task is described and indeed how it is to be carried out. In Leontev's theory this is a two way process in that new forms of work organisation, in turn, influence the social norms that are used to described such tasks.

The basic part of this argument in this thesis was presented in Section 5.3.1 where it was argued that:

- The students use different semiotic resources when dealing with the theoretical concepts as opposed to the problem of building a model bridge. The former is dominated by concept-related talk and the latter by elaborated explanation as they engage in more open discussion;
- The dominant mode (Iedema, 2003) between verbal and non-verbal semiotics varies also. In the theoretical sessions, speech tends to dominate, but in some instances non-verbal gestures and tools are essential to support the meaning making. In the practical sessions either there is a balance in the importance of the two modes or in some instances (such as Table 5-22) the non-verbal mode is dominant and speech used simply to vocalise the meaning that is being constructed using gesture and the tools;

In addition, as discussed in Chapter Four and above, the students make more use of group (either the whole group or sub-group) discussion when focussed on the model building rather than on the underlying theory. In combination this points to an important difference in the meaning-making process as the nature of the task shifts. There are exceptions, but, broadly, when carrying out the calculations, meaning making by the students can be characterised as individual and any shared meaning making dominated by speech. When the focus is on the model construction, there is more group meaning making, greater use of non-verbal semiotic resources and their interaction is marked by longer elaborations. This could indicate that they have greater confidence, and feel they have a better understanding of the practical task, than the underlying theoretical principles. However, given the facilitator's response to their final design (Session 5), this optimism may well have been misplaced.

This leaves the conclusion that there are patterns to the modes that students choose to use for different meaning-making tasks. Broadly the students make greater use of non-verbal modes when dealing with the model building aspects of the task. The model building aspects are marked by more elaborated explanations (EE) and the theoretical aspects by concept-related talk (CT). For example, some of the choice of modes by the individuals may reflect their own beliefs as to how to take such a task forward. These beliefs may prioritise individual over group work, regardless of the notional learning approach preferred within PBL. This may explain why in the theory-focussed excerpts the students tend to prefer individual working and tend to rely on particular semiotic modes. The balance between verbal and non-verbal resources and the different semiotic modes adopted is now explored.

The ideal analysis would be to compare how different students used semiotic resources as the focus (theory or model building) and degree of interaction (in-group or with the facilitator present) varied. However, as discussed in Section 6.2.2.1, two of the students can be described as ‘silent’ making very few contributions. The other three are not consistent with their contributions varying substantially across the four PBL sessions where all five students were present. Nonetheless, it is possible to analyse the implication of the shifting semiotic modes (and the varying use of verbal and non-verbal communication) as the meaning-making process of the student group develops.

Both Chapter Four and Chapter Five noted differences in how the students engage in meaning making as they shift from a focus on the theoretical aspects of the task to the process of designing and building their bridge model. In this context, there is a reliance on individual working, verbal meaning making and concept-related talk (CT) when they are engaged in the theoretical aspects. To some extent, this is reversed (see, for example, Figure 5-4) when they are engaged in model building. If so, this can be developed using Kress’s (2010) concept of affordance to consider why some resources might be more useful in one role than the other.

As discussed in Chapter Five, the shift between verbal and non-verbal modes can be analysed using quantitative approaches. Such an approach, as shown in Figure 5-8 (Chapter 5), implies that verbal and non-verbal resources are used equally, regardless of the focus on theory or meaning making. However, in the longer discussion of the individual excerpts, three different forms of interaction between verbal and non-verbal meaning making emerged, that is 3 distinct modes of multimodal meaning making:

1) *Verbal-dominant*, but re-semiotised non-verbally:

   Instances where the verbal element carried the main meaning-making role and the non-verbal aspect was secondary;

2) *Non-verbal-dominant,* but re-semiotised verbally:

   Instances where the non-verbal element carried the main meaning-making role and the verbal aspect was secondary; and

3) *Intermodal* – meaning making is truly multimodal:

Instances where both verbal and non-verbal modes were essential and mutually interdependent in the construction and interpretation of meaning.

As well as these three multimodal modes, there are two modes that do not involve multimodality, *Verbal* only and *Non-verbal* only

An example of the first mode is the discussion transcribed in Table 5-14 and partially reported in Section 6.2.2.4.1 above. As the students verbalise their understanding of the forces, they also scribble notes and use a calculator. The meaning making is essentially verbal, but supported by the use of non-verbal tools. On the other hand the excerpt reported in Table 5-28 is an instance of where the meaning making is by gesture (pointing with the paddle-pop sticks) and speech is used to record what is being developed non-verbally. Finally the excerpt reported in Table 5-29, is an instance where both speech and non-verbal resources hold equal status and are interdependent in the meaning making in that, if you only accessed one or the other, the intended meaning would be impossible to discern.

These modes of interaction between verbal and non-verbal resources can be applied to the students' meaning making as reported in the excerpts in Chapter Five. The listing below covers all the tables in Chapter Five with the exception of those that cover the first excerpt (see Section 5.2.1) as that is principally about the facilitator's presentation, and any other tables that report excerpts where the students are silent.

Table 6-1: Different forms of interaction between verbal and non-verbal in students' meaning making

Table #	Focus	Description	Summary
5-7	Theory	Non-verbal is dominant as meaning making is carried out using calculators and hand written calculations	Non-verbal
5-8	Theory	Verbal is dominant but non-verbal is important as a means to write down and capture their deliberations	Verbal
5-9	Theory	Verbal is again dominant, but tool use (especially calculators) is a vital part of their meaning-making process	Verbal
5-13	Model	Mostly facilitator dominated, brief student questions and verbal is dominant	Verbal
5-14	Theory	Verbal is dominant (this is the excerpt discussed above) but non-verbal is important as a means to support and capture their deliberations	Verbal-dominated
5-15	Theory	Both are important, the students are verbalising their understanding but point at the OHP and indicate their frustration with non-verbal gestures	intermodal
5-16	Model	The students discuss their sketches with the facilitator, mostly by verbal statements, he in return mostly uses a sketch he is making for his contribution to the meaning making. This excerpt can be described as balanced.	intermodal
5-17	Theory	The students briefly ask the facilitator questions and support this by pointing to the images in the whiteboard. Again this can be described as balanced.	intermodal
5-19	Theory	A discussion of the forces that will apply to the bridge. Verbal dominates but non-verbal (gestures and tool use) are important in supporting their meaning making	Verbal-dominated
5-20	Theory	A discussion of the forces that will apply to the bridge. Verbal dominates but non-verbal (gestures and tool use) are important in supporting their meaning making	Verbal-dominated
5-21	Model	Two students are constructing a potential layout. The deployment of the paddle-pop sticks is key to meaning making with speech used to vocalise what is being done.	Non-verbal dominated
5-22	Model	Two students are constructing a potential layout. The deployment of the paddle-pop sticks is key to meaning making with speech used to vocalise what is being done.	Non-verbal dominated
5-23	Model	This is similar to the two excerpts above except that the students lose their focus and the discussion is about other work demands. As such the verbal element is dominant but non-verbal gestures are important in meaning making.	Non-verbal dominated
5-24	Model	The facilitator is reviewing their model, student active meaning making is limited but is a balanced combination of speech and gesture (pointing at their model) as they seek to elaborate their logic behind their design.	Non-verbal dominated
5-25	Model	This is similar to the above, the students respond briefly to the facilitator and use a balance of verbal and non-verbal resources to do so	Verbal-dominated
5-26	Model	This too follows a similar pattern as the students respond briefly to the facilitator and use a balance of verbal and non-verbal resources to do so	Verbal-dominated

Table 6-1 supports the argument that both verbal and non-verbal resources are important in meaning making across the entire PBL class. However, the two resources do play shifting roles with instances where one is dominant (even if the other is then important) to instances where they are equally important and interdependent. Perhaps the simplest test of this assertion is the extent to which an observer could understand the meaning making either by simply seeing a transcript of the speech or of viewing a video recording with no sound. The relative importance of both verbal and non-verbal resources in the students' meaning making justifies the decision (Chapter Three) to employ Jewitt's (2006) methodology. The use of different resources is reinforced by the discussion of the different ways in which the facilitator undertakes meaning making.

The final column in Table 6-3 seeks to summarise form of multimodal meaning making across the excerpts based on their focus on theory vice versa model. It suggests a possible axis where at the extremes only one mode is employed, and with points between reflecting the three distinct forms of multimodal meaning making. The potential scale is set out below and the differential importance of the modes in terms of model building and theory are mapped onto it:

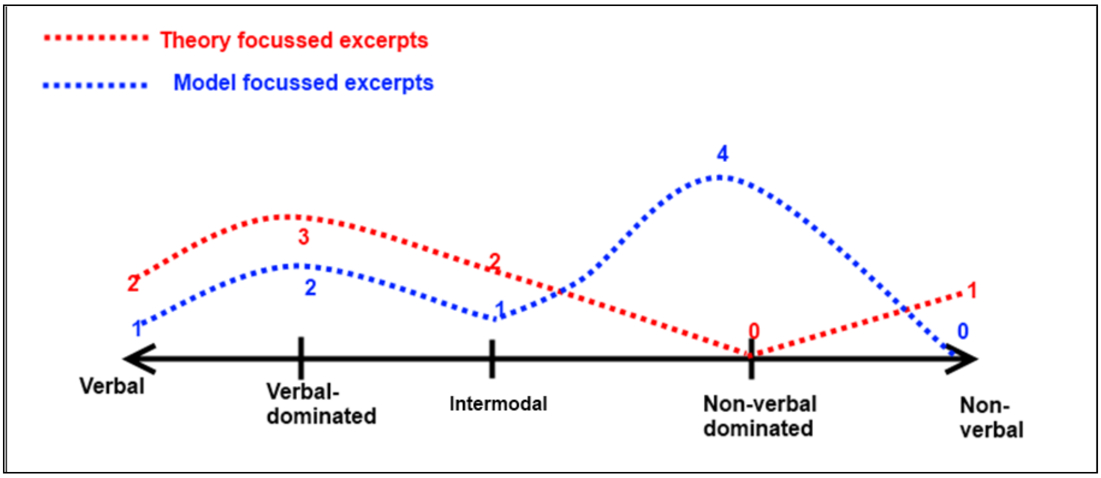


Figure 6-5: Shift of dominant mode in students' meaning making from theory to model building

Practically this may imply that the nature of the task is influencing both the semiotic resources available and, more importantly, those accessed by the students. When the task is essentially one of calculation, they are using verbal resources primarily in their meaning and supporting this verbal meaning making by tool use and making calculations and sketches on paper. On the other hand, especially once they commence trying to build a bridge model, the richness of the available non-verbal resources, and the non-verbal nature of the task, shifts their meaning making to either a reliance on the non-verbal or a mode where non-verbal and verbal resources carry equal weight and meaning is constructed intermodally. Thus in Figure 6-5, 50% of the excerpts where the focus is on the model are on the non-verbal side of the scale, on the other hand when the focus is on the underlying theory all but one excerpt lies on the scale from purely verbal to intermodal (with its associated balanced between the two modes).

In turn this indicates that very few instances of meaning making can be understood purely in terms of either speech or the use of non-verbal semiotic resources. In some instances, speech is used by the students to vocalise what is being done with the paddle-pop sticks (this in particular applies to the excerpts from Session 4). In other instances, speech is supplemented by pointing (even if just at the display on the OHP) as a means to reinforce and clarify intersemiotically exactly what is the focus of the meaning making.

6.2.3 Facilitator's role

In the wider PBL literature, the facilitator's role is one of guiding the student discussion and, in particular, of assisting their meaning making by use of scaffolding (Choo, 2012; Greening, 1998; Hmelo-Silver et al., 2007; Stålbrandt, 2007). However, some supporters of PBL suggest that in a technical subject, such as engineering, there is a need to go beyond this restricted role and instead to actively present additional information (Berger, 2005; Mills & Treagust, 2003; Perrenet et al., 2000; Yeo & Tan, 2011) as the nature of the discipline makes a pure student-centred meaning-making process inappropriate.

In the literature, the supporting role is described variously as that of a facilitator, a tutor (Greening, 1998) or even as a teacher (Spronken-Smith and Harland, 2009). In part this may reflect the evolution of this role from that of facilitator of group problem solving (common in the early medical models) to being a subject specialist who will assist problem solving through means of scaffolding (Dolmans et al., 2002). The role observed in this thesis fits the latter conceptualisation of the academic as subject specialist seeking to lead students' meaning making and, indeed, as reported in Chapter Four, there are two instances where the presentation is akin to that of a formal lecture rather than the interactive student-led learning model promoted in the PBL literature. Nonetheless, for reasons of consistency, the role is described as that of facilitator in Chapters Four and Five.

The approach to supporting PBL from the perspective of a subject expert has been adopted in this class. There are two long presentations by the facilitator to the entire class of 10 minutes in Session 1 and over 14 minutes in Session 3 (see Table 4-6) and overall (if Session 4 is ignored) the facilitator interacts with the student group for around 40% of the entire video-recorded sessions. Overall, as discussed in Section 5.3.2.2, the facilitator tends to dominate those sessions where he interacts with the students. In these interactions he dominates the active meaning making and, as explored in 6.2.1 seeks to frame their problem solving. Some of this is simply the provision of task specific information, but in other cases it forms an evaluation of their progress. Thus in Session 2, on reviewing their sketches, he states "*There's some major problems there. This sort of scene here is a major problem. … . Well the problem there is here, and you're going to have a problem there on the truss*" (Facilitator's input, Session 2, 35.19). Here (see Table 5-16) his meaning making is a combination of speech and a sketch that he develops to show the students what type of bridge design they actually need. By Session 5, on reviewing their partially conducted model, this has become "*Well I'd lift that out and sort of throw it into the rubbish, that's what I'd be doing*" (Facilitator's input, Session 5, 29.30).

6.2.3.1 Scaffolding

In the literature on PBL, scaffolding has become the key skill and function of the facilitator (Chng, Yew & Schmidt, 2011). The goal is to provide the students with enough information to ensure that their problem solving is directed rather than the potentially unguided problem solving that novices might otherwise indulge in (Simon, 1978). Scaffolding, in theory, is about guiding students' meaning making so that in answering the questions, or following the suggestions, they develop their own insights (Stålbrandt, 2007). Choo (2012) notes that an important element to scaffolding is the effective formulation of questions so the students are still active in the meaning making, but, nonetheless, are provided with clues to help them effectively direct this meaning making.

Section 5.3.2.3 contains a substantial summary of the use of scaffolding by the facilitator so the goal here is not to repeat that discussion, but instead to consider the reasons for the variations noted in the excerpts and the way these may be explained in terms of the task rules, rather than an abstract concept of the facilitator's role. Chapter Four stressed the importance of the task environment in understanding the observed meaning making and in setting the rules for this PBL task. The facilitator's role can be said to consist of three aspects:

1) Provision of technical information (the two long presentations where he sets out key theoretical concepts to the entire class). This role was contributed to the *theoretical context* (see Section 6.2.1.1),
2) Provision of task rules (the frequent discussions with the student group under observation to inform them of the requirements in terms of the resources available, how the bridge will be tested and the timelines involved). This role provided the *methodological context* (see Section 6.2.1.2) and
3) Scaffolding and supporting the students' meaning making (again numerous discussions with the student group as he seeks to lead and assist their problem solving). This role contributed to providing the *procedural context* (see Section 6.2.1.3).

One issue in this case is that the second and third roles to some extent come into conflict. In his role as facilitator he is expected to guide the student learning, but ensure that the problem-solving process remains student-centred. In his role as a member of the academic staff he has a responsibility to ensure their activities remain directed towards the constraints of this particular element in their overall academic programme. Those constraints include what resources they have to hand, how the model will be tested and when it will be tested. This creates the observed tension between his role as a manager of an academic process (see Section 5.3.2.2) and the role of a facilitator using scaffolding to guide student learning (see Section 5.3.2.3).

In particular, as discussed in Section 5.3.2.2, there are a number of instances where his interventions are very directive as to the nature of the flaws in their problem-solving approach. Sometimes this is, as in the excerpt reported in Table 5-24 ("*any modifications that have to be done should be done now … If the bridge is off centre at all it will not be supported by the joints*") which can be described as a simple statement of what is wrong, especially as it is followed by essentially rhetorical question (“*will it?”*). With the excerpt reported in Table 5-25 this has become “*You can’t just have it sitting on the frame … it’s got to be below … It’s a bridge*” with this followed by simply stating “*No, no….I think if you read the instructions it would become clear*”.

These instances are not failings in terms of scaffolding, but are indicative that the purely student-led model of learning conceptualised within the PBL literature is, in reality, compromised by the practical realities of such tasks in an academic setting. As explored in Chapter Four and Section 6.2.1 above, the theoretical context of a task has a significant influence on the conduct of the task and has a great influence on the way multimodal semiotic resources are employed (see Section 6.2.14). An important insight from the analysis is that the scaffolding strategies adopted by the facilitator shift with the shift of contexts. Scaffolding is critical in keeping the PBL students on track with their PBL task and encourages them to properly exploit the resources (McKenzie, 2000).

6.2.3.2 Semiotic resources used in meaning making by facilitator

This section reflects on the varying semiotic resources used by the facilitator and the way in which these alter according to the focus or purpose at each stage. This follows Section 6.2.2.4.1 in starting with an analysis of the verbal resources in use.

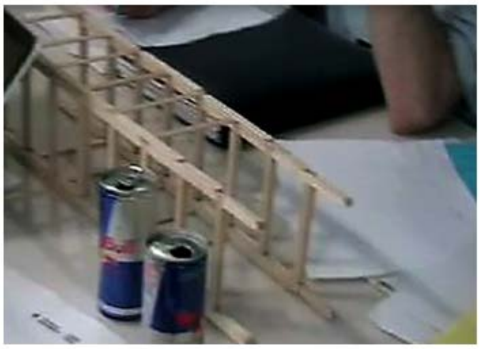
The varying use of verbal and non-verbal resources by the facilitator has been substantively discussed in Chapter Five. In particular, it was noted in respect of Figures 5-12 and 5-13 how his approach to scaffolding varied with Strategic Scaffolding (SS) only being used as a verbal resource while both Technical Scaffolding (TS) and Conceptual Scaffolding (CS) were more often delivered using non-verbal resources. As argued in Section 5.3.2.4.2, there is clear evidence he uses different approaches to scaffolding as the PBL task evolves. He frequently uses scaffolding not just to aid students’ meaning making, but also as a verbal clue to the students that he has shifted the discussion to a new concept. Table 6-5 shows just how often he uses non-verbal semiotic tools in order to scaffold their understanding.

6.2.4 Task performance

The final goal in this research was to provide an evaluation of the outcome, rather than just the process, of the PBL task. As discussed in Section 6.2.2, there is intermittent evidence that the students are not sure as to what is required of them. Some of this is related to querying information already provided, but there are very specific instances where the students express their frustration, for example, at the start of Session 2 with "*The teachers, they haven't taught us anything but she just expects us to know all this crap. What does this… mean*". Session 4 in particular provides evidence that the students are not effectively linking all the available information together. In the course of that video recording there is limited reference to the theoretical questions that dominated the earlier sessions but they are seen referring to the sketches they have made. This can be seen in the transition between three images. The first occurs at Timer 39.24 in Session 2 and shows a diagram sketched by the facilitator. The second image is from Timer 3.04 in Session 4 and shows the students laying out the paddle-pop sticks (at this stage the design relates to the earlier sketches) and the third image from the final session shows the model produced by the students.

Session 2 - tutor input and diagram

Session 4 - student experiment with design layout



Session 5 - bridge model built between sessions 4 and 5

Figure 6-6: Development of model bridge

The facilitator's response to the model produced for Session 5 is clear and exemplified in the discussion in Section 5.2.7 where he ends by expressing his frustration that the students have not followed the task rules as set out, with a discussion ending with him saying "*No, no…. I think if you read the instructions it would become clear*" (Facilitator, Session 5, Timer 24.57) and this is followed by him partially turning away for the students.

Secondly, in consequence, as is argued in Section 5.2.4.3, the students are not connecting the theoretical information with their sketched designs for the model nor are they linking either theory or outline diagrams to the final bridge model they produce. Their meaning making does not seem to build on the theoretical foundations, their sketches or their experimental layout of bridge designs. Instead the final design appears to bear little resemblance to those earlier steps.

However, the nature of the evidence gathered (the five video recordings) in the sessions means it is not possible to come to a final judgement as to whether or not the final bridge design met the task requirements. The final discussion in Session 5 (i.e. after the discussion reported in the excerpt in Table 5-26) indicates that the students and the facilitator carried on discussing the design and methods to address any weaknesses in the model they had constructed between Sessions 4 and 5. The final set of comments by the facilitator (Timer 29.17 to 31.41), indicate the provision of new information and the creation of a new set of rules for the students to take forward:

- *So you have a different kind of frame, but the same kind of pattern. I like that pattern because you have your framing in the area where you are going to have the applied force here*
- *And it's going to be distributed out…. But you need to take a second look at the corners… I would laminate the corners up… How many paddle-pop sticks would be right here?*
- *So I would laminate the corners so they are strong.. Maybe use a bit more of a tie down.. I don't want any distortion. As soon as you have distortion.. as soon as the load starts to distort any weakens, you will have a problem. You need lots of these joints..*
- *I'd be laminating the bottom with paddle-pop sticks … similar to this*
- *Yeah, try to emulate that frame…. But maybe strengthen the mid section*
- *The midsection and the ends.*
- *So that looks good…*

- *All right, so you guys are well on your way then. As for the report, you do a generic sort of report for the team but you got to have different drawings and different test results. They go into your separate reports and you submit that with your portfolio.*
- *Next week, next Monday. You got exams and that so you don't want to be messing around with it too much. It's just really a compilation of everything you have done, including this.*

With this, the students commence work studying a diagram the facilitator had sketched out and left behind. Overall, while the discussion of the excerpts reported in Chapter Five indicates that the initial design did not meet the task requirements, these final comments indicate that the facilitator and the students had agreed to a solution that might address those weaknesses. This shows, as mentioned in Section 6.2.3.1, that the facilitator's scaffolding directs the PBL students to move to the next step of their task. However, the students' solution to the problem was unsuccessful. This may depend on the fact that the link between theoretical bases and practical (model design) was missing. The PBL students did not apply the theories to that model. Furthermore, this failing could come about as a result of most of the time spent in theoretical sessions having been exploited individually. One possible reason for the students' limited engagement in group meaning making is that this may reflect either their personal beliefs about an appropriate approach to learning or their internalisation of the learning norms for their subject community (so again, the actions of the students can be seen as internalising a particular model of what it means to be a student).

6.3 Implications

6.3.1 Student meaning making

As analysed in Chapters Four and Five, and above, the student approach to meaning making in this task shows some interesting characteristics. These can be summarised as:

- The shift in the use of semiotic resources when the focus is on the theoretical task as opposed to when they are constructing the model bridge;
- In particular, in this respect, the evidence that the mathematical work carried out in the first two sessions was not referred to in the fourth session when two of the students are testing out model designs. This stage, in particular, is largely about practical experimentation and there is substantive use of non-verbal resources in their meaning making;
- There is little evidence (see the discussion in Chapter Four) of all group active meaning making. As discussed in Section 6.2.2.2, only two of the students can be described as active and one is all but silent throughout the entire exercise.

Whether, this is an example of the 'silent student' problem referred to in the PBL literature or simply that some of the students are not convinced of the merits of group learning, it is clear that this student group does not co-operate effectively in terms of meaning making or task performance.

6.3.2 The facilitator

As discussed in Section 6.2.3, in some respects the tutor performs the role expected of a facilitator in a PBL class. There is ample evidence of scaffolding as an important tool to guide student meaning making but on the other hand he is often more concerned with the task, and meeting the academic requirements, than with encouraging student learning. As noted, in particular in session five, there are several instances where, being aware of the timescale and test requirements, he adopts a very directive approach. In effect, there is strong evidence that he makes meeting the task a priority over independent student learning. What is possible, but there is no means to test the assertion, is that his relative dominance (see Section 5.3.2.2) when he is with the student group may be one reason why they are, as a whole, relatively silent, and why some only seem to make comments when he is present.

6.3.3 Contributions

The contribution of this thesis is returned to in Chapter Seven, but it can be argued it crosses a number of domains:

- One key contribution is in terms of methodology. It supports Jewitt (2008) in arguing for using a mix of Activity Theory and Multimodality in this sort of enquiry. Not only do they complement each other as research tools, but they support each other in terms of analysis. Although they share an acknowledgement of the importance of context, this is much clearer in practice using Activity Theory. On the other hand, Multimodality, brings in the capacity to look at the essential details of meaning making and how this shifts as the task changes shape;
- A second key contribution is to an understanding of student learning and how this adapts. Not only do the students employ different semiotic tools at different stages, but they adopt a different approach when interacting with the facilitator than when they are working by themselves;
- From this, there are implications for both PBL and engineering education. In terms of PBL, this analysis has identified a number of common problems documented in the literature, especially student disengagement and student frustration, without uncovering much evidence for the benefits. The research design did not include summary interviews or the ability to reflect on the

outcomes at a later stage, so may have impacted on the capacity to gather such evidence. In terms of engineering education, the analysis and findings support the view that student centred learning (whether or not this is explicitly PBL), needs considerable care. There are tensions between independence of learning and the need to have the requisite subject-specific knowledge, between the desire to allow student meaning making and the constraints of the academic course and between the need for the supervisor to enable open-ended learning and to ensure that the module fits within the wider bounds of the academic degree.

Chapter Seven
Conclusions

7.1 Introduction

The overview of the findings reported in Chapter Six enables a move towards considering the main findings from this study and these will be summarised in the following sections.

One strength of the approach adopted to this research has been the extension of Jewitt's (2006) methodological approach of combining activity theory with multi-modality. Besides the main advantages stated by Jewitt, "to give due attention to the socially situated character of meaning making" (2006, p.16), this research has benefited from this combination in two other ways. First, activity theory has allowed an overview, adding a breadth that is sometimes lacking when a multimodal analysis concentrates on the specific details of speech and the use of other semiotic resources. In addition, in its focus exclusively on a PBL context, it has been valuable in high-lighting some of the challenges and dilemmas in generating the expected learning outcomes through the PBL methodology, especially with novice PBL students in a complex conceptual discipline, such as engineering.

7.1.1 Context

Activity theory argues that context is important not just for understanding a given task, but also that the socially constructed context creates rules for the conduct of a task and gives a particular meaning to the process of carrying out the task. In this instance, all these dynamics can be seen to be at play.

In consequence, context is built up from a number of different sources:

1) The basic theoretical underpinnings are taken from concepts embedded in engineering and physics (*theoretical context*);
2) The academic programme the students are undertaking sets out the context of the PBL task in terms of the resources, timeline and bridge testing parameters *(methodological context*);

3) The *procedural context* provided evolves as the students carry out the task. Actual processes and actions constructed dictate what they need to do next, and information provided assists them in structuring their activities.

Overall, these form the context of the task, reflecting the knowledge and perceptions of the actors observed and the specific task they were seeking to carry out.

7.1.2 Students

Section 6.2.2 has indicated that some of the observed behaviour by the students fits the wider research into PBL as a pedagogic tool. In particular, group learning is relatively rare and the issue of 'silent' students is observed. In addition to this, two of the students seem to behave very differently when the facilitator is present to when the discussion is within the student group. One (Student D) only speaks when the facilitator has joined the group and another (Student B) speaks far more often when the facilitator is absent. In addition, although not explored directly in this study, it appears that the rules the students have for the role and contribution of a member of academic staff are different to the 'rules' set out in the academic PBL literature.

There is evidence that the students used verbal and non-verbal resources for different aspects of meaning making. As an example, Section 6.2.2.3 indicates that when they engage in scaffolding this is invariably not just non-verbal, but almost always linked to tool use. It can be suggested that this may reflect their lack of knowledge about the task and that they can most easily express their reasons and forward plans using objects rather than speech. For most instances, although both verbal and non-verbal modes are important in meaning making there is clear evidence that in most stages one or the other is dominant (Iedema, 2003). In addition, there is evidence they use different semiotic modes as they vary meaning making, supporting Gibson's (1977) concept of affordance.

7.1.3 Facilitator

The facilitator's role is reviewed in detail in Section 6.2.3 where it is noted that he adopts an approach that is a hybrid of the traditional PBL facilitator and of an academic aware that the student design has to meet some very specific requirements. What stands out is that he uses very different semiotic resources to the students as he carries out his role. This resolves the dilemma discussed in Chapter Four as to whether, in activity theory terms, he should be seen as part of the subject (the active work group) or the community (other individuals with whom the work group interacts). He adopts a very different range of semiotic resources and, in consequence, a role outside that of the student group. As summarised in Section 6.2.3.2.1, his use of semiotic meaning means he:

- Usually is seeking to collaborate with the students (i.e. he is not making meaning just for himself but to guide their learning);
- He rarely simply agrees with a statement by one of the students (this can be either a statement of relative power or that, in most instances, he is seeking to elaborate on their question and help them develop their understanding). The latter interpretation is supported by his frequent use of complex interpretation in his speech; and
- He makes substantial use of scaffolding, drawing on both verbal and non-verbal resources, as he seeks to guide and indirectly lead the students' meaning making.

On balance, this could be argued to reflect the role expected of a facilitator in a PBL context. However, there are instances where he offers very direct evaluation of the student performance and he frequently restates the rules for the task to ensure the students are focussed on what matters in this particular context. This shift of mode of interaction does create some tension with the concept of student-led learning that is, at least in theory, central to PBL.

7.2 Contribution of this research

A key contribution of this research is the linkage of a multimodal investigation with the concepts of activity theory (Jewitt, 2006). The advantage of this is twofold. One is that activity theory allows a focus on the context within which the meaning making takes place. In this case any understanding of how effective the student performance was is meaningless except in the terms of how this PBL class was constrained – in terms of time, resources and the planned test. Second, a common problem with multimodal research (except when done purely by counting instances) is the difficulty of analysing long excerpts of meaning making. In this case, the overview provided by the analysis reported in Chapter Four in turn enabled the selection of seven excerpts that reflected both the development of the PBL task and offered a spread of types of problem-solving behaviour. These varied between excerpts where the focus was on the theoretical underpinnings and those where the focus was on the model design. The overview also captured a spread of the various forms of facilitator-student interaction that characterised this PBL class.

The excerpts were not, as such, selected at random but rather to be typical of the range of meaning making. In turn, each was short enough to be analysed in close detail, but provided sufficient data for comparisons to be able to be made between the style of meaning making and the shifting importance of verbal and non-verbal resources in meaning making.

This combination of research tools has allowed the development of an argument that:

- Meaning making can only be understood in the context of the task, and that, in this case, the context was a product of the academic subject (engineering), the rules set for this PBL experience and also sub-goals introduced at various stages by the facilitator; and
- There is a difference in the meaning making adopted according to the focus. Both the students and the facilitator use different semiotic tools when dealing with the underlying theory as opposed to the model building stages.

In combination this suggests that not only is meaning making related to the rules set for the task, but also varies according to the focus. This is supported by the general findings in terms of activity theory that argue that task performance is both done in a different way and carries a different meaning according to the situation and the tools available.

In general, this research can be said to expand on two previous lines of study of PBL. Jewitt’s (2006) approach has been adapted to use activity theory, not just as a tool for overview and to provide context but to use that overview, in turn, to select specific excerpts for detailed multimodal analysis. The excerpts analysed in Chapter Five are a non-random sample drawn from the video-recorded sessions to provide an overview of the evolution of the meaning-making task. In addition, Hmelo-Silver et al. (2004, 2007) was drawn on to provide the concepts of internalisation and the focus on scaffolding. In turn, this methodology was expanded from a focus just on speech to capture the use of non-verbal resources too.

As a result of this approach and the accompanying integration of multimodality and activity theory it was possible to draw some conclusions in two areas. First, about there being four distinctive and diverse student approaches to engagement in problem-based learning across a group of only five students. Secondly, five primary modes of engagement semiotically were identified, three of which were classified as multimodal, and there were evident differences in preferences for these modes dependent on whether the focus of the meaning making was theory or its application to model building.

7.3 Limitations of this research

There are two general limitations of the research design that became apparent during the analysis process.

One limitation of the research stems from the use of a single researcher and a single video-camera. For example, when the facilitator is engaged in the presentations to the entire class (there is a detailed analysis of one of these excerpts in Section 5.2.1), it appears that his dominant mode of communication is speech (see Table 5-2). However, this may be the consequence of using a single camera as the researcher was faced with the dilemma of whether to focus on recording the meaning-making actions of the students (writing notes, making calculations) or that of the facilitator (Pea & Hay, 2003). In this case, it is clear from the recorded speech that he is referring to examples on the OHP or writing on the whiteboard, but, in terms of what is recorded and able to be analysed in detail, it appears as if it is a speech-dominated period of discourse. Fortunately, there are relatively few instances in the five classes when the meaning-making process is split in this way, but there are other instances when the need to concentrate on the active meaning making (i.e. those students who were speaking at any one time), perhaps has led to a loss of information as to the activities of the less active students who were not captured in the video record.

The second limitation is that the nature of data gathered limited the capacity to come to a clear understanding of the student performance from a cognitive perspective on this particular PBL task. The final session recorded (Session 5) has evidence that the facilitator is deeply concerned at the model the students have produced (and indeed it is possible to compare that model to both the material provided in the early sessions and even the experimental layouts produced by the students in Session 4). Some other research designs that look at the multimodal nature of student learning supplement the recorded information with interviews (Airey & Linder, 2009; Moreno & Mayer, 2007). Such additional information would have been valuable in this instance to explore several issues:

- Did the students feel prepared for the task (there are isolated instances where they indicate a lack of understanding about the theoretical underpinnings and about the task requirements)?
- Did the students believe they had carried out the task as required (in particular to explore the difference between the layouts tested in Session 4 and the actual model presented in Session 5)?
- Did the facilitator have confidence in the student performance on the task, and was this expected? There is evidence in his long presentation in Session 3 that other student groups have performed much more successfully.
- Was he aware of the directive nature of his interventions with the students, and again, was this by design or in response to their difficulties with the task)?
- Interview data with both the facilitator and the students could have helped address the problem of having no access to individual cognitions or representations of actions. As discussed in Section 6.2.2, this would have been beneficial in understanding the reasoning given by the students for their observed actions.

None of these gaps are essential to the fundamental goal of this research of using multimodal methods to explore students' meaning making in a problem-based learning context, but such interviews would have provided an insight into some parts of that process and to explore why it appeared that the students had produced a model bridge that would fail the set test, and appeared to have failed to apply theory adequately in their design. In summary, the lack of interviews can be said to reflect a gap in terms of analysis of individual cognitions. There are a number of instances (highlighted in Section 6.2) where the reason why an action was undertaken or for a mode of interaction can only be assumed. The external observation model adopted in this research provides rich insights into what happened and how it happened. The consequential gap is a lack of knowledge as to how the participants believe it happened and why or an insight into their logic for their own actions.

7.4 Next steps

This thesis has taken two existing methodological frameworks, elaborated on both (by adding new categories and extending the focus to include non-verbal semiotics) to explore the process of students' meaning making in the context of a PBL class. In doing so, as discussed in Section 7.3, a number of refinements have now been identified (in particular, around capturing the cognitive and self-explanatory nature of meaning making) that could be usefully integrated into the research design. The research (see Section 7.1) has also confirmed some findings often associated with PBL and has indicated a number of new insights, such as the linkage between tool use and scaffolding for the students, contextual dimensions, and student learning approaches. In addition, as discussed in Chapter Six the data indicates a number of patterns between the selection of semiotic modes and the focus of meaning making. When the research is based on a single series of observations it is impossible and inappropriate to generalise from these findings. What was observed was unique to this student group carrying out this particular PBL task.

Nevertheless, there are a number of potential research strands that emerge from this research. One is to evaluate whether adding more data gathering approaches (additional camera/s and, most likely, some form of post-event interviews) really would yield valuable additional data. The main issue for further research though is to explore whether the differing uses of semiotic modes are to be found in other instances. Such an investigation could be designed to replicate this study in other broadly comparable PBL tasks and/or with differently constituted group/s - does a similar type of task yield broadly similar findings? To what extent do differently constituted groups generate different approaches to interaction and meaning making? How do learners in PBL evolve in their group learning and meaning making as they gain experience in working with PBL methodology? All such further research would allow a deeper understanding not just of how the use of semiotic tools varies according to the task situation, but also would also start to explore how these variations arise, and how to optimally employ multimodality to enhance learning.

Furthermore, it is recommended that research be carried out on how the different PBL phases (Graaff & Kolmos, 2003) are impacted by the different contexts the PBL process goes through, and how they are influenced by the different multimodal semiotic processes (i.e. intersemiosis and resemiosis). Such investigation will provide further insights for PBL educationalists and methodologists in order to help students maximize their benefits from PBL as a teaching method that promotes life-long and professionally applicable learning. Indeed, this also will enhance PBL facilitators in formulating problems to be applicable and workable for students.

The element of students' conflict in PBL class contexts and how this can be utilised maximally to promote learning is another important area for further research. Particularly, there is scope to investigate this from the angle of how the meaning-making semiotic processes influence such conflicts and how conflict and disagreement affect students' learning process and styles of engagement in problem solving (Shinde and Kolmos, 2011).

One more recommendation for other studies is to investigate how the semiotic resources chosen by facilitators can strengthen the element of students' motivation in PBL. Based on this research, semiotic resources play a significant role in increasing students' motivation to learn through PBL tasks (Graaff & Kolmos, 2003).

7.5 Final words

Some important conclusions can be drawn from this research;

- That the meaning making being studied can only be understood in the context of the rules set for the particular task;
- The PBL context involves multiple and intersecting contextual dimensions which interchangeably affect and are affected by semiotic processes such as resemiosis, and multimodal resources play a critical role in constructing these contexts. In particular, in the PBL context, interacting with the requirements of an academic programme of study, it is important to frame the actions of both the facilitator and the students.
- That the facilitator makes use of different semiotic modes than the students, confirming the impression reported in Chapter Four that he is not part of the Subject (in activity theory terms), but instead part of the Community;
- That both students and the facilitator adopt different semiotic modes as the focus of their problem solving shifts over time and as the task develops.

This confirms the assumption in the introduction that students' meaning making in a PBL context is a combination of their (relatively limited) prior knowledge, information that is accessed (or provided) as the task progresses, the tools available and the rules (constraints) imposed by the academic environment. However, as explored in this instance there is a tension between the student-led meaning-making model that, theoretically, is the core of PBL and the practical need to ensure the students make progress towards a defined end point (how and when their model will be tested). This suggests that the facilitator is not just assisting their problem solving, through scaffolding, but is using rules and direct interventions to lead them to a desired conclusion.

Both the students and the facilitators draw on a wide range of semiotic modes and a variety of resources in their meaning making. Thus, the paddle sticks are notionally available to build the bridge, however they are used to point, to fiddle with, to explain concepts as well as being incorporated into the design. In summary, this provides support for Kress's (2009) assertion that learning can be seen as an inherently multimodal activity.

The exploration of the meaning making process has been enriched by the reliance on both activity theory and multimodality. Activity theory can help us provide an overview of the meaning-making process in a holistic manner and thus proves useful for an understanding of the context and rules, while the concept of multimodality is invaluable to an understanding of how both the facilitator and the students undertake the meaning-making task using different semiotic modes as the task evolves.

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Appendices

Appendix 1: Multimodal transcription – Example Session 1[3]

Kevin's Team Session 1														
	Subjects													
		Facilitator		**Student A**		**Student B**		**Student C**		**Student D**		**Student E**		**General**
		Multimodal Semiotic Resources												
Still Images	**Min**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	
0.12  0.30 	**0-1**				Pen, pad. Writing with right hand, head rests on left arm		Pen, pad calculator, writing		Pen, pad calculator		Pen, pad. Writing		Pad, textbook Turning textbook pages.	A, B, C, D, and E are all working individually to solve the physical question on the sheet distributed by the facilitator
0.20 					Pen, pad calculator writing		Pen, pad. Writing with right hand,		Pen, pad calculator		Pen, pad, Writing		Browsing a textbook and looking specifically to some diagrams showing some forces and their measurements. Pad, textbook.	
0.35 					Pen, pad calculator, writing		Pen, pad. Writing with right hand,		Writing and using his calculator. Pen, pad calculator					
0.41					Pen, calculator, pad. Looking at what B is gesturing to.		Head rests on hand. Uses other hand to point (pen in hand) to A's pad.							A and B are discussing something related to the question

[3] See the CD-ROM for the full multimodal transcriptions of all five Sessions.

Kevin's Team Session 1														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	**Min**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	
														
0.52 				It tells you on that line there.	A is pointing at the diagram on B's sheet using his pen. He is also using his calculator and he is writing on the sheet to solve the question		Looking at page. Sheets							
0.54 						yeah, yeah, yeah right, yeah	Shaking his head and continuing on solving the problem, writing on his sheet. Pen, calculator, pad.							
1.08 	**1-1**									Yeah, I think I know where I'm going with this now. Then I'll have to figure out the extract-ion and then you add them together	Student D is talking to Student C while he is pointing at his notebooks.			

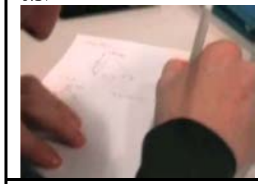
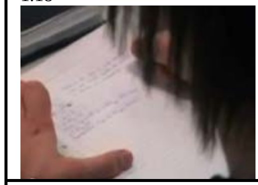
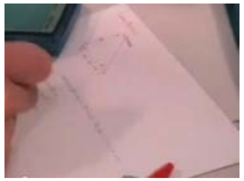
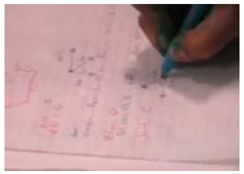
Appendix 2: Multimodal transcription – Example Session 2

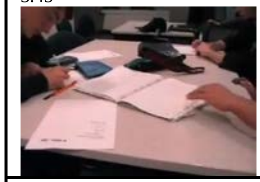
Kevin's Team Session 2													
		Subjects											
		Facilitator		**Student A**		**Student B**		**Student C**		**Student D**		**Student E**	
		Multimodal Semiotic Resources											
Still Images	**Min**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**
0.04 	**0**			I reckon that's going to be stronger because it's…	points at sketch with pen				Holding Pen between his hand				
0.14 				That will be stronger than that one, but I don't know whether that bit's stronger than (…)					Holding Pen between his hands				
0.14 								Yeah because if you twist it, it will (…)	Gesticulates, pen in hand				
0.18 								But this will probably still be stronger.	points at sketch with pen				
								This one yeah, because I've tried it. I did it, I didn't paste it or anything and I tried to bend it in the middle and it's pretty strong.					
								The only thing that I thought could happen was…					

Kevin's Team Session 2													
		Subjects											
		Facilitator		Student A		Student B		Student C		Student D		Student E	
		Multimodal Semiotic Resources											
Still Images	**Min**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**
0.43 				Say this is the bottom level, there's a stick here, then you want to link them up so they're on the same levels.	draws on piece of paper using pencil								
1.02 	1							Yeah, that will be stronger than just all three, so that will be stronger than that.	points at sketch with pen				
1.20 				I think these are pretty cheap, I might do like three or four designs. Remember the first (…)	wiggles pencil								
								Oh yeah, like with the wire thing.					
1.24  1.30 				Yeah, exactly and then you test out which one's the strongest and then you go with it.	picks up papers and puts them down, taps table with pencil								
								Did you hand it in?					

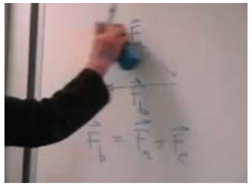
Kevin’s Team Session 2													
		Subjects											
		Facilitator		**Student A**		**Student B**		**Student C**		**Student D**		**Student E**	
		Multimodal Semiotic Resources											
Still Images	**Min**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**	**Speech**	**Gestures, postures and materials**
1.59 	**2**			Yeah, you get till about half 12 to hand it in.	fiddles with pen Pen, on a paper								
2.00 				Very strong fix (…)	reading from sheet								
2.37 				So I was thinking before was to lay it out from the ground, but it’s going to take about 90 sticks.	points at sketch with pencil								
								90?					
2.42 				Yeah, it’s not going - because it has to be 250 x 250, so we won’t have enough.	points at sketch with pencil								
2.45 					rubs eye								

Appendix 3: Multimodal transcription – Example Session 3

Kevin's Team Session 3														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	Min	Speech	Gestures Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures Postures and Materials	Speech	Gestures Postures and Materials	
0.16  0.37 	1								Writing with pen on notebook		Writing with pen on notebook			[S1, S2 and S3 working. General back-ground talking]
1.18 														
2.38  2.52 							pen and notebook		pen and notebook	There's nothing there, you just made it up. It makes me so angry, so, so – why does it matter which… 7, 7.1 newtons …	pen and notebook			

Kevin’s Team Session 3														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	Min	Speech	Gestures Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures Postures and Materials	Speech	Gestures Postures and Materials	
2.59 														
	3					What did you guys get?								
3.35 										I moved it	moves notebook towards S1			
						You didn't get the Y bit did you?								
										Yeah	Notebook, pen			
						You got the Y bit?								
3.45 							Looking in notebook			Fb cos 35 whatever, Y, Ba...	points in notebook			
4.16 	**4**					Cheers mate, thanks.	moves the notebook back to S2				Accepts notebook			

Kevin's Team Session 3														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	Min	Speech	Gestures Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures Postures and Materials	Speech	Gestures Postures and Materials	
4.28 							Calculator, pen			Is sine for the X direct-ion?				
						Uh?								
4.37 									Looking at St D	Isn't sine used for the X direct-ion or is it cos?	Pen in hand			
						No cos								
4.41 										How come they use sine in the one before Fx?	Looking in notebook and holding the pen			
						Because it is, what shall I say...								
5.06 							fiddles with pen							

Kevin's Team Session 3														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	**Min**	**Speech**	**Gestures Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures Postures and Materials**	**Speech**	**Gestures Postures and Materials**	
5.26 new shot  5.29 		The forces right, because of the vector balance – so what we have is a resolut-ion of this in terms of just theta. So Fb is going to equal Fa and Fb, the actual value of Fb, right is going to equal Fa cos theta.	uses the black-board, and uses board wiper											

Appendix 4: Multimodal transcription – Example Session 4

Kevin's Team Session 4 (Outside of Class Time)														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	Min	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	
0.03 	1									… and at 25 – that's two and a half centimetres, yeah?	Writes with pen, holding paddle pop sticks			
0.07 								Yep.	Draws with pen, holds paddle pop sticks					
0.33 										Then you can add like… 2.5 and 2.5 and get 50…	Writes with pen on a piece of paper			
										Total width is 110	Pen, paper			
								Yeah, so…						
0.35 										Which way is that like down?	Gesticulates using pen to point to the paper			

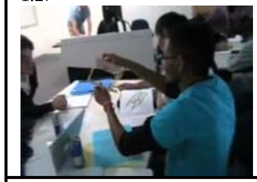
Kevin’s Team Session 4 (Outside of Class Time)														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	Min	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	
0.39 								That’s like, yeah, if you’re looking at it from above, it’s this way. So like down into the pit.	Gesticulates, holds paddle pop sticks, pen					
										Yeah?				
0.45 								This drawing , if you’re looking down into it.	lifts up piece of paper, holds pen and paddle pop sticks					
									Pen, paper, paddle pop sticks	Yeah, into it				
0.51  0.55 									puts pen down and fiddles with paddle pop sticks					

Kevin’s Team Session 4 (Outside of Class Time)														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	**Min**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	
0.59 								Yeah so no row, there’s no row you can see, on the top we don’t need to like cover it over,	Pen, paper, paddle pop sticks					
1.01 	**1**							we just have gaps.	Pen, paper, paddle pop sticks					
										All right, so we’ll do what we did before with the base do you reckon?				
1.08 										Yeah, the ones on the inside and then the outside.	Gesticulates with pen on the notebook			

Kevin’s Team Session 4 (Outside of Class Time)														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	Min	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	
1.15 								Yeah I was thinking it was tighter, but I don’t know how we’re going to connect that to like something like this.	points at paper by pen and holds paddle pop sticks					
										To the bottom side of it?				
1.24 								And I was thinking we’ll still definitely do that, say three like that.	holds paddle pop sticks					
1.24 										Around the edges yeah?	points at paper			

Appendix 5: Multimodal transcription – Example Session 5

Kevin's Team Session 5														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	Min	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	
0.27	**0**	Testing is going to be 1 'til 3... So Thursday, 1PM to 3PM is the test time that has been allocated for us.	Walking around, reading off sheet. Projected solutions (see right)											Screen projection gives two tasks (and solutions?) – a calculation and a force diagram (FBD)
0.37		I will start lecturing at 2:00.		When?										
0.49 					Discussing work with peers				Discussing work with peers					
0.50 						So you got to do that	pointing at the lap top screen by his hand and holding pen							
0.53				Yes, Yes										

Kevin’s Team Session 5														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	Min	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	Speech	Gestures, Postures and Materials	
0.57  		So next, what I have here, is you work out the formula, the G and C, in order to work out the force mixed with BC, the force mixed with BD and the balance of force when mixed with GC.			Discussing work with peer/s		Discussing work with peer/s		Discussing work with peer/s				Discussing work with peer/s, handles model	
1.27 					Discussing work with peer/s		Discussing work with peer/s		Discussing work with peer/s				Discussing work with peer/s, handles model	
1.40				Yes, it's exactly between the two posts?										
1.44 					Touching model model				Discussing work with peer/s, Gestures to model				Discussing work with peer/s	

Kevin's Team Session 5														
	Subjects													
		Facilitator		Student A		Student B		Student C		Student D		Student E		General
		Multimodal Semiotic Resources												
Still Images	**Min**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	**Speech**	**Gestures, Postures and Materials**	
														Female Student: Looking at the equa-tion, what is the, just looking at the truss align-ment?
1.47  1.52		You are looking at a 3-body diagram for this point A.			Discussing work with peer/s, handling model									Female Student: It is only A?
1.54 		Yes because you're finding that ax and ay and dy all interact with each other, so you are finding out the reaction at the pin joints of the force between a and d.							Drawing on pad using pen					
2.19 														

Appendix 6: Coding categories

Category	Abb.	Definition	Example
Acknowledgement of Contribution	Ack	Acknowledgments of others' ideas.	and he's used the cosine, sine and cosine and in order to work out the resultant.
Agreement with Facilitator	AF	When student/s agree(s) with the facilitator.	Student D (replies to the facilitator): Yeah
Agreement with PBL Member	AM	When one student agrees with his peer/s.	Facilitator (replies to a student): Yeah the vectors.
Causal Antecedent	Antec	Questions inviting the responder to give an explanation of the circumstances that led to the present situation and why.	N/A
Affective Scaffolding	AS	When the facilitator supports the student/s or one PBL student supports his peer/s by encouragement and acclaiming their works.	N/A
Brief Answer	BA	Direct answers to general questions without any explanation.	Student A (replies to his peer C): This one yeah
Conceptual Agreement	CA	Agreement on the PBL concepts such as the ways of designing the bridge or the concepts included in the PBL task such as force, truss, frame and so on.	36. Student B (to his peer D): The square root of them both ways.
Conceptual Disagreement	CD	Disagreement over the PBL conceptual framework such as the measurements of the angles, or over the focus of the PBL concepts implied in PBL bridge design task.	Student A (to his peer B): no you can't.
Conceptual Knowledge	CK	Evidence or revelation of knowledge constructed before the PBL bridge design activity.	Student A (to his team): I reckon that's going to be stronger because it's…
Seeking Clarification	Clarif	When PBL student/s inquire(s) about confirmation or evidence for their ideas.	Student A (to his peer D): You didn't get the Y bit did you?
Causal Consequence	Cons	Questions inviting the responder to give an explanation about the consequences of an event.	N/A
Conceptual Scaffolding	CS	When the facilitator supports the student or one PBL student supports his peer to choose the right information he or they need(s) or to decide the most significant information.	Facilitator (to the PBL team): you can make a matrix arrangement,
Concept-related Talk	CT	When the content of the talk is related to the concepts the PBL team use to accomplish the PBL activity (bridge design) such as force, truss, and so on.	Student A (to his peer C): that's two and a half centimetres,
Data-driven Planning	DP	Any evidence showing a plan emerging from the data the PBL team has come up with. The plan for the PBL team is dependent on the information and knowledge the PBL students presently have or have discovered.	N/A
Elaborated Explanation	EE	Answers giving a deep explanation for rationalising one's ideas or showing his knowledge.	Facilitator (to the team): And that's the sort of one that you want to plan for.
Enablement	Enab	Questions inviting the responder to give an explanation about any PBL task actions but not for the circumstances that led to the current situation or for the consequences of event.	N/A
Elaborated Telling	ET	Answers giving an explanation and/or justification.	Facilitator (to the PBL team): So Fb is going to equal Fa and Fb,
Expectational	Expec	Questions inviting the responder to expect or make a prediction.	N/A

Category	Abb.	Definition	Example
Facilitator 's Explanation	FE	When the facilitator explains some PBL activity concepts to the students.	Facilitator (to the PBL team): because of the vector balance
Facilitator 's Monitoring	FM	When the facilitator asks questions, or makes hints to monitoring the PBL team development.	Facilitator (to the PBL team): There's a couple of bridges there
Facilitator explaining Tool-related Utterances	FT	When the facilitator explains and talks about the tools the PBL team is using such as Paddle Pop sticks, glue, the report, bridge model and so on.	Facilitator (to the PBL team): right it's actually buckled,
Group Dynamics	GD	Questions that produce more negotiation or discussion.	Student A (to his peer B): Or you would get 8,669...
Group Monitoring	GM	Evidence or revelation showing that the PBL team students are inspecting or working over their collective advancement such as what the PBL team needs to do.	Facilitator: I recommend everybody to buy the (Hugo) Statics book
Grounded Belief	GrB	When the facilitator or one PBL team student shows his evidence in a highly developed and reasoning-centred way.	N/A
Facilitator-to-Student Internalisation	IFS	Internalisation evidence emerging from the facilitator as a result of the interaction and discussion between the PBL team and the facilitator. It is a reaction to the PBL students' input.	Facilitator: The only way you're going to get a strong sort of bond,
High level Interpretation	IH	Inference or conclusion drawn from direct interpretation of any PBL event.	Facilitator: And that's the sort of one that you want to plan for.
Low Level Interpretation	IL	Direct interpretation of particular PBL events such as a diagram, the bridge design and so on.	Facilitator: So what you have in here is a truss arrangement
Individual Monitoring	IM	Evidence or revelation showing that the PBL team member is inspecting or working over his personal advancement or his individual contribution to the whole PBL team.	Facilitator: so you need to know your sine and cosine rules
Peer-to-Peer Internalisation	IPP	Internalisation evidence emerging as a result of the PBL team students' interaction without the facilitator.	Student D (to his peer C): Tomorrow,
Student-to-Facilitator Internalisation	ISF	Internalisation evidence emerging from PBL students as a result of the interaction and discussion between the PBL team and the facilitator. It is a reaction to the facilitator's input.	Student A (to the facilitator): And then the next one is going to overlap them
Local Analogue	LA	Showing any way of contrasting between the activity constitutes, the PBL bridge designs, or methods within the bounds of the PBL task they are working on.	N/A
Comparison	LC	Questions inviting the responder to compare or to contrast between two or more PBL events such bridge designs.	N/A
Definition	LD	Questions for asking about a definition or meaning of a concept.	N/A
Example	LE	Questions inviting the responder to give an example or to remember an example of a PBL event.	N/A
Interpretation	LI	Questions inviting the responder to infer or conclude from a PBL event.	Student A (to his peer C): What did you end up?
Judgement	LJ	Questions inviting the responder to give an opinion, advice, a plan or a belief.	N/A
Metacognitive	Meta	The ideas relating to the learning process.	N/A
Metacognitive Questions	MetaQ	Questions relating to knowledge and thoughts the PBL team has regarding any PBL event.	N/A

Category	Abb.	Definition	Example
Metacognitive Scaffolding	MS	When the facilitator supports the student/s or one PBL student supports his peer/s to concentrate on the goal of the PBL task or to identify what they know and what to do for the learning process at hand.	Facilitator: In order to get the result in force you need to know the angle too.
Self-Directed Learning	MSDL	What the PBL team need as a group or what one student needs to perform their PBL activity.	Then I found the X from that.
Modification of Ideas	ModI	Talking about the ideas that have been suggested or put forward for discussion before.	For the up and down you'd go
New ideas	N	The ideas that have not been put forward for discussion or suggested before.	Student C (to his peer D): you subtract that one from that one and it gives you negative 7.46.
Need Clarification	NC	Questions asked for more explanation and clarification to be made about a previous statement.	Student B (to his peer A) So you have to subtract the Y you found in the negative direction from the Y that you found in the positive direction.
Prior Experience	PE	Any experience showing that a PBL student has encountered similar engineering design or similar PBL activity.	A (to his peer B): Then I found the S from that
Plan-related Questions	PQ	Questions relating to the future of the PBL team's work plan.	N/A
Personal Experience	PresE	When the facilitator or one PBL team student is showing evidence based on his personal belief without a rational way of thinking.	Student C (to his peer A): It will, but this will probably still be stronger
Procedural Scaffolding	PS	When the facilitator supports the student/s or one PBL student supports his peer/s to evaluate resources and minimises the cognitive burden by discussing around diagrams and sketches of the PBL bridge design.	N/A
Personal Talk	PT	When the content of the talk is NOT related to the PBL activity or the tools used in that activity. For example, the students talk about general social issues.	Student D (to his peer A) : But it's okay, this semester is all right. Keeping up…
Questioning Facilitator	QF	Questions asked by the PBL team for the facilitator to answer.	Student A(to the facilitator): What if I put it up like that?
Quantification	Quant	Questions regulating the quantitative features of the PBL task such as asking about the number of Paddle Pop sticks that should be used for designing the bridge.	Student D (to his peer C): we're not going to use 275
Regional Analogue	RA	Showing any way of contrasting between the activity constitutes, the PBL bridge designs, or methods outside of the PBL task they are presently working on.	N/A
Reflection	Ref	Evidences showing that the PBL team students are mirroring the ideas from earlier bridge designs, possibly built to the present design endeavour, previous solutions to current questions, or any other tasks that are reflected by the students to other previous tasks.	N/a
Request	Requ	Questions requiring any PBL action to be performed by one of the PBL participants or to suggest for some PBL actions to be done.	N/A
Conceptual Question	SC	Questions relating to the concept and the focus of the PBL task such as the physical terms used by the PBL participants.	Student D (to his peer C): Did you get negative 45 for when you calculate?
Disjunctive	SD	Questions that offer two options or two decisions.	N/A
Self-Directed Learning	SDL	Questions relating to defining learning matters and information the PBL team works on.	Student B (to his peer A): okay so this is Y going up and this is Y going down, yeah.

Category	Abb.	Definition	Example
Feature Specification	SF	Questions regulating the qualitative features of the PBL task such as asking about the strength or frame of the bridge.	N/A
Summaries of group Idea	SI	Providing summaries about the PBL team's ideas.	N/A
Self-answered Question	SQ	Question asked and answered by the same person.	Student B answers to the question he asked himself: So then the difference between that and that, -5 for the Y, because this is Y going down.
Strategic Scaffolding	SS	When the facilitator supports the student/s or one PBL student supports his peer/s with more alternatives of the PBL task to be accomplished, for example the facilitator helping the students to think about the different designs of the bridge.	Facilitator: so you could actually stand on a wire frame structure
Verification	SV	Yes/No responses to realistic questions.	Student D (to his peer C): Yes, I got it right for once!
Task-related Agreement	TA	Agreement on the PBL task performance such as the design sketches.	Student D (to his peer C): Yeah, negative 86.
Task-related Disagreement	TD	Disagreement over the PBL bridge design.	Student C (to his peer D): No, because this one is going down this way
Theory-driven Planning	ThP	Any evidences showing a plan emerging from the PBL activity knowledge the students already had such as mathematical and physical rules, and PBL bridge design methods for their future tasks.	Facilitator: There are two ways of solving it
Task-oriented Monitoring	TM	Questions stimulating the PBL team to monitor their development or to plan for their work.	N/A
Tool-Related talk	TR	When the content of the talk is related to the tools used to accomplish the PBL activity (bridge design).	Facilitator: You need to know what your calculator is doing.
Technical Scaffolding	TS	When the facilitator supports the student/s or one PBL student supports his peer/s by using technical information such as *force, truss*, and so on to guide them through performing the PBL task.	Facilitator: you need to know your sine and cosine rules because in terms of the parallelograms that set up the forces,
Task-related Talk	TT	When the content of the talk is related to the PBL activity (bridge design).	Facilitator: keep to those specifications guys
Unjustified Planning	UP	Any evidence showing a plan without demonstrating the rationale behind it or its relation to any prior actions or current actions.	N/A