Chapter 7
Multimodality in Problem-Based Learning (PBL): An Interactional Ethnography

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7.1 Introduction: A 'Next Generation' Research Agenda

Black and William introduced the term 'inside the black box' to research in educational assessment in the late 1990s. This metaphor can be applied to current research in problem-based learning (PBL). This chapter addresses the need to look inside the 'black box' of PBL by exploring two under-researched aspects – independent study and online learning. Using the Interactional Ethnographic (IE) approach to collect and analyse data in context and over time (across contexts), we systematically examined *how* students learn between tutorials to explore how online learning supports independent study in a PBL curriculum.

Despite PBL's 40-year history as an instructional method in undergraduate education, surprisingly few studies have examined and documented the in situ enactment of student learning in PBL contexts from an interactional perspective. While there is a growing body of student evaluation and outcomes data to support the efficacy of PBL programmes, research to date has relied mainly upon student and staff questionnaires and interviews. In dentistry, for example, the majority of studies have focused on problem design, course evaluation, and student achievement or performance. From a methodological perspective, the reliance on self-report data such as student course evaluation questionnaires across clinical education and staff surveys has come under some criticism. Concerns have been expressed regarding the status quo of this research agenda with a recent call to 'look inside PBL programmes', due to a perceived lack of studies into 'the way students experience and understand' PBL courses (Prosser, 2004, p. 204).

Of critical importance is the need to contribute further interactional data and analysis on PBL-in-action to support theory building. This is particularly the case given that the central, constructivist tenet of PBL is its 'process' approach

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to learning. PBL advocates argue that 'learner-centredness' is central to motivating student learning and fostering lifelong learning. However, how this is enacted in the learning process is not clear. Indeed, it is somewhat ironic that research projects designed to investigate a social constructivist instructional method have, in the main, not drawn upon this tradition in conceptualizing a research design.

Since the 1970s there has been a strong interest from educational researchers not only in focusing attention on classroom interaction as the locus of learning, but also on the social and cultural practice that is learning. Methodologically, the orientation to such research has been interpretive from fields such as sociolinguistics (Gumperz & Hymes, 1972), ethnomethodology (Baker, 1997; Freebody, 2003; Sacks, Schegloff, & Jefferson, 1974) and discourse analysis (Green, Dixon, & Zaharlick, 2003; Green & McClelland, 1999; Nuthall, 2000; Smith, 1987). Analysis draws on ethnographic data such as audio and video recordings and their transcriptions (see Appendix B), participant observations, and artefacts in the form of texts and photographs. The impact of these studies on classroom practice has been to raise awareness about patterns of talk and their impact on issues ranging from cognition to social access.

While the majority of studies has been in schools, there is a growing interest in interactional research in higher education with some work in medical education adopting conversational analysis (CA) to explore classroom interactions (Glenn, Koschmann, & Conlee, 1999) and discourse analysis (DA) to examine effective facilitator questioning techniques (Hmelo-Silver & Barrows, 2006, 2008). Given that such methods have provided insights into student cognition and teacher talk at the classroom-level, the use of such approaches to examine talk across time and across contexts (Agar, 2004) should provide a rich database and evidence of learning in higher education, in general, and the enactment of PBL, in particular. The focus of this study is therefore on investigating PBL-as-process in clinical education through detailed analysis of the 'way' students and their tutors construct knowledge and negotiate meaning in situ in a dental PBL curriculum. In the current era of global reform in both higher education and professional education, including clinical education, we envisage that this research agenda holds potential significance for informing the design and development of PBL curricula in this field.

7.2 Background

7.2.1 Multimodal Tools, Independent Study and Blended Learning

Renewed interest in PBL is evident across higher education as institutions seek instructional approaches that meet education reform calls for integrated, learner-centred and outcomes-based systems that support knowledge economies. A concern for many higher education curriculum leaders is how to design

programmes that engage the current generation of technologically connected learners, often referred to as the Net Generation. These learners arrive on campus with various technological skills in particular in utilising networked environments. The most recent wave of undergraduate clinical students are more increasingly engaged in Web 2.0 technologies that are generally synchronous and interactive (Bridges, Botelho, & Tsang, 2010; Bridges, Dyson, & Corbet, 2009).

In considering new text types, literacy theorists have recently been exploring the notion of multimodality where texts are 'constituted by a number of modes of representation' (Kress, 2000, pp. 183–184). The interest in multimodal texts in this study of Net Generation learners arises from attempts to understand how such learners use and create different texts to support their learning. Indeed, proponents argue that the concept of multimodality forces a rethinking of the distinctions usually made between communication and use, and in particular between reading and use as we shift to relying more heavily on the visual, aural and spatial (Kress, 2000, 2010). As a recent research field, its genesis can be traced to literacy theorists grappling with new text forms and how new literacy pedagogies can be developed using 'design' principles (New London Group, 1996). However, no research has examined multimodality in the context of PBL. For the purposes of this study, we focus on two key related notions: (i) modes as the types of print-based and visual texts, sounds, images, movements and gestures that are invoked across one problem cycle; and (ii) their 'modal affordances' (Jewitt, 2008) in examining how such texts mutually support meaning making across the learning experience.

From a higher-education design perspective, the incorporation of blended learning has been posited as the thoughtful fusion of face-to-face and online learning experiences (Garrison & Vaughan, 2008). The challenge for PBL curriculum developers creating online learning experiences is to understand how to structure blended approaches coherently to enhance student learning, thereby avoiding the trap of using technology as a novelty 'add-on'. While undergraduate curricula in dentistry are predominantly delivered in face-to-face modes, there is general consensus that online learning in the field has a growing future (Hillenburg et al., 2006). For PBL curricula, face-to-face facilitation of the PBL process provides important scaffolding for learners engaged in group problem solving. Independent learning is also a key facet as students engage in research between the first and final tutorials. In recognizing the role of self-directed learning (SDL) in PBL curricula, many higher-education institutions have provided infrastructure for online support of independent learning.

Many clinical faculties have employed learning management systems (LMS) embedded with multiple visual and aural texts to support and enhance lecture-based, problem-based and clinical learning. However, no research into real-time learning has explored how blended approaches in PBL support the achievement of learning outcomes. In what follows, we report on a small-scale ethnographic study that explores the role of multimodal texts in a blended PBL environment.

7.2.2 Context of the Study

PBL as both an instructional method and an educational philosophy is well aligned with Hong Kong's current education reform intentions with their focus on nurturing lifelong learners in a growing knowledge economy (Education Commission, 2000). The five-year Hong Kong Bachelor of Dental Surgery (BDS) has been cited as one of only three undergraduate curricula world-wide running a 'pure' PBL curriculum (Winning & Townsend, 2007). Recent studies in the region indicate the success of PBL curricula (either 'pure' or 'hybrid' by design) in comparison with non-PBL curricula, with first-year PBL students in Hong Kong 'more likely to develop generic, as well as subject specific skills' (Downing, 2009). Enactment of PBL in dentistry follows classic models premised on the use of complex, ill-defined, hypothetical problems grounded in real-life contexts to stimulate small group learning with an emphasis on active student engagement (see Fig. 7.1). Hmelo-Silver (2004) summarized the goals of PBL as helping students to develop flexible knowledge; effective problem-solving skills; self-directed learning skills; effective collaboration skills; and intrinsic motivation.

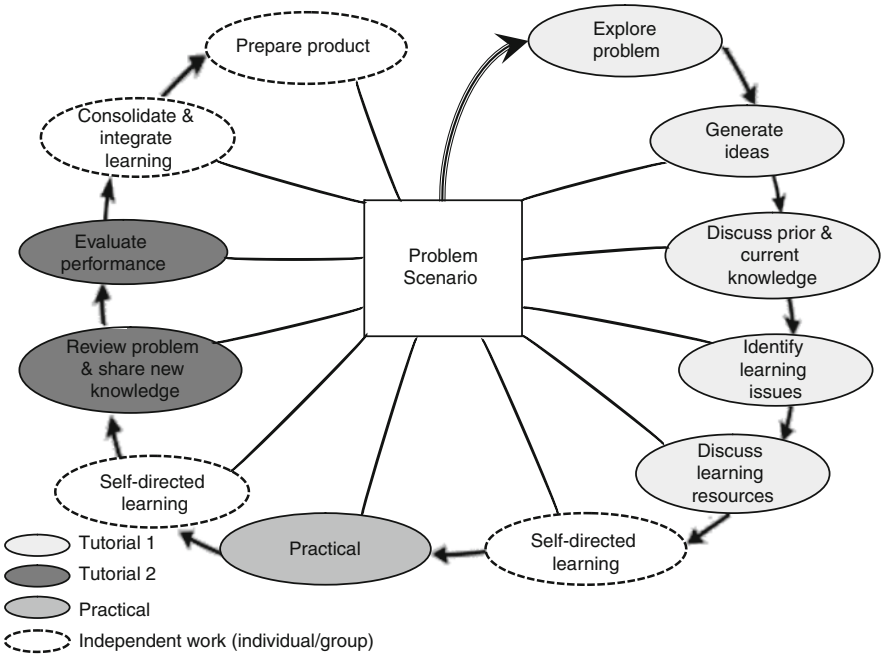

Fig. 7.1 The problem cycle in dental education in Hong Kong

In line with recent recommendations for curriculum design in undergraduate dentistry (Oliver et al., 2008), the PBL problems support vertical and horizontal integration of content across the curriculum (Barrows, 1999; Hmelo-Silver, 2004; McGrath, Comfort, Luo, Samaranayake, & Clark, 2006).

7.3 Theoretical/Conceptual Framework

This study adopts an interactional ethnographic (IE) framework to examine how the use of interactive technologies can support and shape the acquisition of disciplinary knowledge in a small group, problem-based learning (PBL) environment. As noted by Castanheira et al. (2007), the IE approach

> brings together an interdisciplinary set of social, cultural, educational and discourse theories from anthropology, education, linguistics and sociology, creating an orienting framework we use to examine the social construction of life, including identities, across times and events (p. 173).

Through this theoretical framework, the ethnographer studies how the disciplinary content that members of a social group (e.g., a PBL group) propose, recognize and acknowledge leads to the construction of particular knowledge, meanings of actions and patterns of activity. As such, IE has resonance with a social constructivist theory of learning (Palincsar, 1998). The goal of the ethnographer is to gain insider understanding of the processes and practices, norms and expectations, roles and relationships and rights and obligations of the community of practice (e.g., PBL group, a medical education programme). IE provides a systemic and empirical approach to recording, analysing, interpreting and reporting what counts as PBL in dentistry, and how disciplinary knowledge is 'talked into being' across an integrated PBL curriculum. The study therefore traces both collective activity and individuals within the collective across time and events that constitute a PBL problem cycle. This process then makes visible the situated understandings of dentistry as both scientific knowledge and clinical practice as constructed by participants (Castanheira, Crawford, Dixon, & Green, 2000).

Given a structured approach to collection and analysis, an IE logic of inquiry provides frames and iterative processes that support case and cross-case analysis. This approach supports exploration of similarities and differences in what members of a PBL group construct, what they take up and use (or not) from that which is proposed to them, and how their actions, individually and collectively, create a developing web of meanings, understanding and practices needed in subsequent problem-based events (Castanheira et al., 2000; Green & McClelland, 1999).

An IE provides a 'systematic way of studying learning as culturally and socially constructed' (Putney et al., 2000, p. 559) through examining language in use. Since the 'study of dialogue is at the centre of ethnographic work' (ibid., p. 561), the IE's sociolinguistic focus on language in use is particularly relevant. In a PBL curriculum, learning is seen as dialogic with students collaborating as meaning makers and tutors acting as facilitators or guides in the learning process. As Freebody (2003, pp. 90–91) argued, researching educational interaction and communication provides 'the framework through which materials/content can be brought to life and given their preferred interpretations'.

A further utility in adopting an IE approach is that it provides a longitudinal focus on constructed meanings. In educational research, this longitudinal focus can be seen in studies of the 'referential and intertextual nature of classroom life' over time (Green et al., 2003). From this perspective, texts (in all modalities, i.e., talk, print, screen) are seen as 'historically and situationally constructed artefacts' (Dixon, Green, & Brandt, 2005). Analysis focuses on exploring knowledge construction through tracing the way that texts are 'talked (acted) into being collectively and individually' (ibid.). Specifically, by adopting IE, analysis presented in this chapter traces 'how' meaning is negotiated and knowledge is constructed across student learning environments (PBL tutorial classrooms and student computer laboratory) and over time (across one problem cycle) through a focus on analysis of PBL discourse in relation to multimodal texts.

As such, the study has addressed the overarching research question of *how and when multimodal texts support knowledge construction across a problem cycle*.

7.4 Research Design

In this study, discourse analysis focused on naturally occurring talk. IE analysis of 'whole-part-whole' (Putney et al., 2000) focused on the various components of one problem cycle in the second semester of the third year of the curriculum. Interactional data were collected across a 'telling case' (Mitchell, 1984) that was traced in a data trail across contexts and over time. The telling case was a single third-year PBL group ($n = 8$) in an undergraduate dental curriculum as they engaged in learning activities across a problem cycle. The focus PBL problem was selected in consultation with discipline experts. The key criterion for selection was the PBL problem's use of multimodal inquiry (or stimulus) materials. The research focus examined the data trail across PBL learning events and contexts (from T1 to T2 and from tutorial classroom to computer laboratory) and the various discourse members involved.

One discourse member of the PBL group, Student 4 (S4), was selected as an anchor point for tracking across the data collection. Selection of S4 was based on three criteria. First, as a consenting participant, S4 provided data across all naturally occurring talk and screen captures (tutorials 1 and 2 and self-directed learning). Second, S4's activity across three events, and particularly in the second tutorial (T2), indicated consequential progression across a blended learning experience. Third, in analysing the historical relationships of multimodal texts across one problem cycle, S4's activities in T2 provided a key focal point for backward mapping.

This study examined student engagement with a variety of multimodal texts as learning artefacts. These included photographs and radiographs (both hard and digital versions), study casts, online resources and student-devised representations in the form of whiteboard drawings. This approach enabled a systematic and microanalytic analysis of student learning in PBL. Data sources

Table 7.1 Data collection: Focus Problem 3.9

Events	Location	Timing (problem cycle)	Data source	Student identifiers (Year 3)		Length
Tutorial 1 (T1)	Scheduled university tutorial room	Day 1 (AM)	Video + audio	$n = 8$	S1–S8	1:35:50
Self-directed learning (SDL) (1st of 3 sessions)	University student computer laboratory	Day 1 (PM)	Video (whole group) screen capture (Camtasia)	$n = 6$	S1 S4 S7 S8 S9 S10	0:29:57 0:29:37 0:30:52 0:30:57 0:29:52 0:29:20
Tutorial 2 (T2)	Scheduled university tutorial room	Day 9 (PM)		$n = 8$	S1-S8	2:08:01

included naturally occurring classroom and self-study data recorded with video and screen capture across one problem cycle (see Table 7.1). All participants consented to the recordings. Additional sources of ethnographic data included classroom artefacts such as curriculum documents, LMS resources and electronic whiteboard printouts following T1 discussions and products for T2. Audio and video data were transcribed using Transana™. As PBL tutorial groups are routinely rotated to enhance group dynamics and are different to clinical groupings, students were allocated with identifiers so that their talk could be traced across contexts.

Analysis presented in this chapter focuses specifically on two 'black box' areas of PBL as we explored how students engaged with visual representations and online materials to support their learning both within face-to-face tutorials and during SDL between these. Event mapping traced one focal student across real-time learning to explore the overarching research question.

Data were analysed inductively and recursively applying three key analytic constructs used in IE analysis:

1. Historical and over-time relationship between and among texts and contexts developed as forward and backward mapping from a key event.
2. Tracing whole-part, part-whole relationships from descriptions of the actions and discourse of members; and
3. Consequential progression analysis of how knowledge constructed in one context becomes socially and academically consequential to another (Putney et al., 2000).

Data analysis examines these three constructs across the phases of data collection as indicated in Table 7.1. The event map (Fig. 7.2) indicates the timing of the naturally occurring tutorial discussion and real-time online screen capture, including video footage of 'around screen' group activity and discussion.

7.4.1 Construct #1: Historical and Over-Time Relationship Between and Among Texts and Contexts

In examining the historical and over-time relationship between and among texts and contexts, the event map (Fig. 7.2) illustrates the key juncture in the third year of a five-year curriculum when the problem cycle under examination occurred. The event map does not depict the full suite of learning experiences over the third year, such as clinical learning, but rather presents the PBL domain that runs in parallel with clinical and other learning experiences across the year. The specific problem under investigation occurred in the third 'module' (an 8–10 week block) within the second semester. This was the ninth PBL problem encountered in the academic year. The event map (Fig. 7.2) illustrates the historical and over-time relationships between the various multimodal texts. S4's learning activities were identified for forward and backward mapping based on the 'key event' in the second, closing tutorial where she was asked to produce and explain an anatomical drawing.

Figure 7.2 traces the construction of disciplinary knowledge across real-time with particular analysis of one student's talk (S4) in relation to multimodal texts such as visual representations, solid objects and online learning, specifically:

1. Inquiry materials:
   a. in the first tutorial (T1) as hard copies or solid objects;
   b. via the LMS as digital resources for SDL.
2. Online links for research in SDL;
3. Supporting visual representations drawn on the whiteboard in the second tutorial (T2).

Indicated in Fig. 7.2 are the points across the problem cycle when the focus student, S4, engaged with multimodal texts and how the ensuing discussions of these led to hypothesis building in the first tutorial (T1) and synthesis of information for 'problem understanding' (Inman, cited in Butler et al., 2005) in the second tutorial (T2). The event map and the transcribed discussions describe how S4 and her peers seamlessly integrated multiple text types (clinical photographs, radiographs, study casts, online resources) across a learning cycle.

7.4.2 Constructs #2, #3: Consequential Progression Analysis across Whole-Part, Part-Whole Relationships

In what follows, we have identified three key events – T1, SDL and T2 – as 'parts' that we then relate to the 'whole' of a problem cycle. In analysing the relationship between multimodal texts and knowledge construction, the transcribed talk is used to locate *what* is said with respect to these texts and to identify *how* this is consequential to later discussions and learning. By tracing

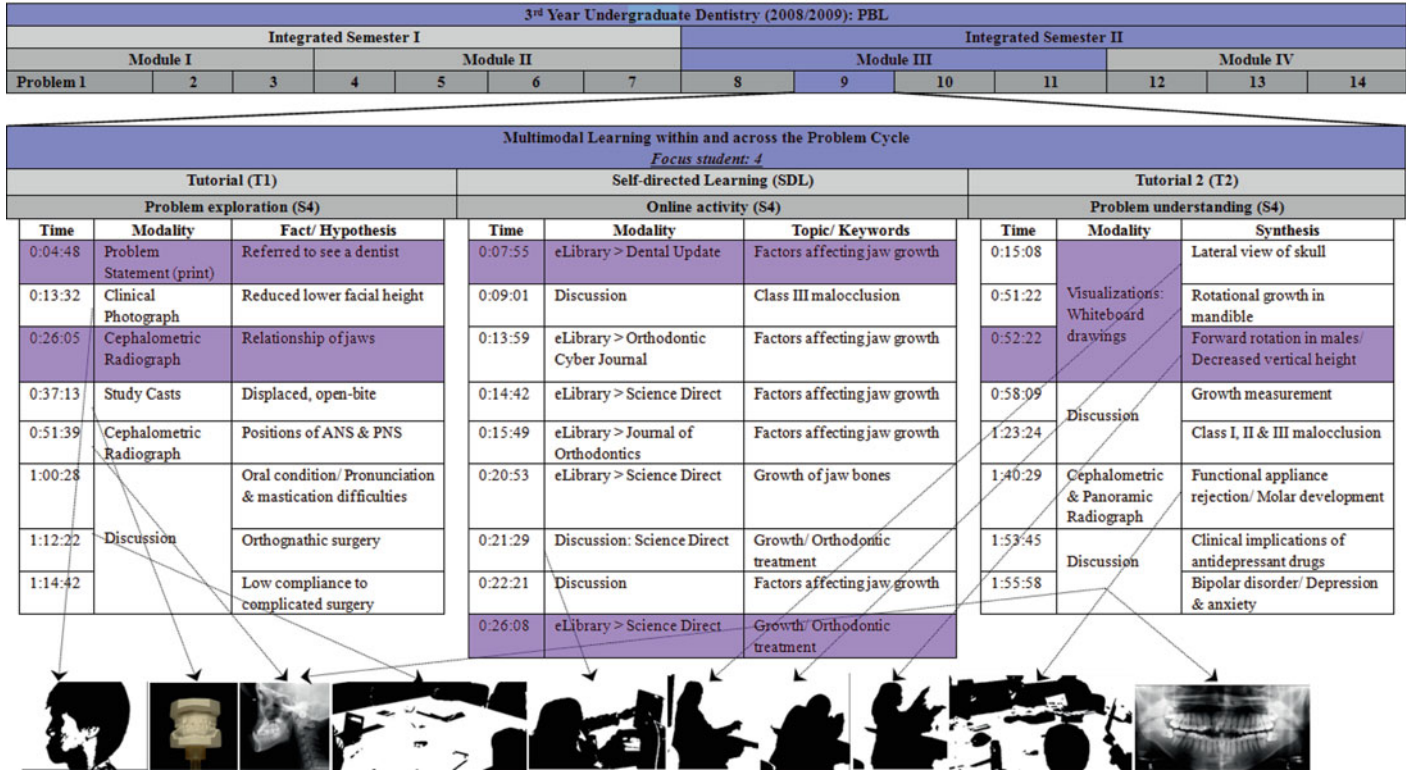

Fig. 7.2 Event map (Third Year PBL): Student 4 (S4) and multimodal texts

whole-part, part-whole relationships from descriptions of the actions and examination of the real-time discourse of members, we can delve more deeply into student learning. In particular, we can explore how the scaffolding inherent in a problem design can support the transition from naive to more sophisticated understandings of the problem and learning issues at hand.

The two constructs of tracing whole-part-whole and consequential progression are therefore examined simultaneously in the analysis that follows, i.e., we trace the learning from key events across the whole problem cycle to gain an understanding of how that which is said, viewed or done in one 'part' is consequential to learning in other 'parts'.

7.4.3 Event 1: The First Tutorial (T1)

As per the literature describing the PBL tutorial process (Barrows, 1985, 1988), the goal of the first tutorial is to arouse learners' curiosity by engaging them in a multidimensional, ill-defined problem. After initially reading the problem statement or 'trigger', one style of problem design, such as the one investigated here, is to incorporate the disclosure of additional information as stimulus or 'inquiry materials', which can refocus and further generate discussion. For clinical education, the introduction of additional inquiry materials such as clinical evidence can provide cognitive scaffolding whilst simultaneously increasing learner motivation.

In the event map above, it is evident that the problem design incorporated multiple visual tools including learning objects in 'hard copy' format i.e. a clinical photograph, two radiographs and two study casts. In this first tutorial, after S7 had read the problem statement to the group, the scribe or 'clerk' (S5) recorded all relevant facts with the last offered by S4 at the beginning of excerpt 1 (T1, 0:04:48.1). This was followed by S6's suggestion to consider the multiple sources of clinical information. Initially this created some dissonance and added initial 'cognitive load' (Kirschner, Sweller, & Clark, 2006) to the problem process as indicated by the lengthened silence (0:00:24.3) where the group began to fracture into sub-groups as students sought to examine the new information. For third-year PBL students now working in clinics with real patients, the heightened complexity of the simulated clinical task was designed to challenge them and increase motivation and engagement. Under the structure of a PBL format, this cognitive load was then strategically distributed amongst the collective (Hmelo-Silver, Duncan, & Chinn, 2007). In this case, this was when S5, the group 'clerk', refocused group attention with a request to 'discuss it one by one' (T1, 0:05:55.5) starting with the clinical photograph (T, 1 0:05:59.5).

After some pauses while students considered the photograph, S8 proffered the first 'fact' for whiteboard recording as 'concave profile' (T1, 0:06:09.7). As the photograph was shared, group members built on this by listing additional observed 'facts' for recording on the whiteboard.

Excerpt 1 'Maybe we can discuss it one by one'

0:04:48.1	S4	and Mr Chan is referred to see a dentist (0:00:34.7) ((scribe returns to table))
0:05:24.8	S6	Did anyone have anything to add? Otherwise let's move on to those materials ((S2 and S4 take the radiographs and put them onto the light board; S6, S7 and S8 examine the photo; S1 and S5 examine the study casts))
0:05:55.5	S5	Maybe we can discuss it one by one=
0:05:55.7	S7	=Okay
0:05:59.5	S5	Maybe we can first (.) discuss about this (.) photo (0:00:02.8). Maybe we can write down some facts (0:00:02.4) derived from this photo.
0:06:09.7	S8	Concave profile haha ((S3, S4 and S5 look at the photo))

In the ensuing group discussion stimulated by the clinical photograph, the group proposed many discipline-specific terms that prompted the facilitator to probe prior knowledge. In Excerpt 2, below, the facilitator then further focuses the specific, in-depth discussion of issues pertaining to the clinical photograph. S4 contributes her first response by identifying the starting point for analysis of a clinical photograph as 'the profile' (T1, 0:13:50.2). After discussion of the clinical photograph, S4 proposes the hypothesis that there was a problem with 'reduced lower facial height' (T1, 0:14:47.2). This then prompted disagreement by S5 (T1, 0:14:54.5) and further probing by the facilitator who challenged notions of 'normal' (T1, 0:14:55.8).

Excerpt 2 'Reduced lower facial height?'

0:13:32.2	F	Where did you learn all these terms?
0:13:35.0	All	Orthodontics
0:13:42.0	F	Okay, so when they=when you learn (.) about how to describe (.) this (.) photo, where do you start?
0:13:50.2	S4	The profile=
0:13:51.6	F	=Yeah, the profile (.) but there are a lot of components making up this profile, (.) right? So usually systematically ((using the photo to demonstrate)) either you start from top to bottom, inside out or outside in, or from bottom to top. Do you want to add anything? (0:00:25.0)
0:14:35.6	S3	The facial (.) proportion=
0:14:40.7	F	=Good ((nods)) facial proportion. What do you think? ((S5 and S6 look at the photo placed in the middle of the table))
0:14:47.2	S4	Reduced lower facial height? (0:00:02.7) Is that?
0:14:54.5	S5	I think it's pretty normal ((Ss laugh)) ((picks up the photo and looks again))
0:14:55.8	F	Again, what is normal? What is lower facial height? Measure from where to where?

In further seeking to establish information from the clinical photograph, the facilitator then focuses on the lips. There is an ensuing discussion punctuated by long silences that may indicate a possible knowledge gap across the group. Of

interest in tracing consequential progression is that after another attempt by S4 to contribute to this topic by commenting erroneously on muscle tone, she is silent for an extended period (~8) minutes and does not verbally re-engage until at 0:28.09.9 in Excerpt 3 below. During her extended period of silence, the entire group physically moves from sitting around the table to a sidewall within the room to view the panoramic radiographs on the light box (see Excerpt 3). S4, however, does not contribute to the group discourse as her peers consider the two radiographic X-rays and the facilitator probes for collective prior knowledge regarding both the process of reading radiographs as well as considering the problem at hand. After this sustained silence, S4 responds to the facilitator's revoicing and direct question regarding classifications (T1, 0:28:09.9).

Excerpt 3 'Maybe'

0:26:05.5	F	That means in simple terms the lower jaw (.) that is in front of upper jaw (.) whether one is protrusive or one is ah: retrusive or a combination. So, basically you see the lower jaw is in front. Okay↑ So, this is class three. (.) So, what is class one and class two? (0:00:18.4)
0:27:55.1	(S6)	(Upper jaws) (0:00:7.8)
0:28:09.9	S4	The class two is protrusive maxilla so the maxilla is more (lengthened)
0:28:21.0	F	Maybe↓ the maxilla is more in front, okay
0:28:27.6	F	Then what is the normal relationship I suppose to be class one? Normally (.) is the maxilla at the same place horizontally as the lower jaw? ((students shake heads)) No. So? (0:00:22.1)
0:29:06.5	S8	Eh, I think in class one, the maxilla is just slightly in front of the mandible but in class two, it is very ((gestures with hands)) in front yeah ha
0:29:19.8	F	Okay↓
0:29:27.9	F	Why do we do cephalometric radiograph?
0:29:34.1	S4	To do the analysis so that can compare patient's ah:: skeletal pattern and not the population or (0:00:5.2)
0:29:46.8	F	So what kind of analysis are you going to do? (0.5) You said 'analysis'.

The issue of bone growth seemed problematic for this group and was reinforced by S4's silence and difficulties in responding to facilitator questions. The topic was later identified as an area for independent study and reporting back in T2. Of interest to the notion of consequential progression is to explore how this identified knowledge gap was addressed individually in SDL time and how this then contributed to building collective understanding in T2.

7.4.4 Event 2: Self-Directed Learning (SDL)

As indicated in Fig. 7.2, the recording of online SDL occurred directly following the T1 during which the entire third-year cohort had simultaneously encountered the same problem for the first time. This initial independent learning session was conducted in the student computer laboratory in order to utilize

the screen capture software (Camtasia™). While on-screen activity was recorded, a video recording was also running to capture around-screen talk and activity. Six students, including the focus student (S4) volunteered to be recorded during the computer laboratory SDL session. Of these, S1, S4, S7 and S8 had been in the same T1 group recorded on the event map (Fig. 7.2). S9 and S10 had agreed to participate in the study but had been in two separate PBL groups. Notable in achieving the goals of the PBL instructional design process was that these students from three different groups started the SDL session with a shared understanding of the problem and issue to be researched.

In what follows, we track online activities and the around-screen talk generated by this cross-tutorial group of students. In doing this, we can trace not only group learning processes in action during SDL, but also, more importantly for the focus of this chapter, how S4's screen activity is consequential to both the prior tutorial and to her participation in the second tutorial. Tables 7.2 and 7.3 present excerpts from activity timelines for screen capture and indicate some areas of collective interest that generated group talk. It should be noted here that the activity was 'multi' in that all screens were recorded. Talk and activity were simultaneous, and so the visual activity represented on the screen often prompted group commentary as is indicated by the number of students contributing to the topic. Of interest in linear terms, however, is the cascade effect that individual or group commentary would bring to the screen activity. In some cases, when students commented on multimodal texts on their screens, others at separate computers then navigated to the same link or resource.

Table 7.2 Online learning (via dedicated LMS: Part 1)

Time	Student	Modality	Topic
0:04:00	S8	LMS > Learning Resources > Lecture Capture	Occlusion in restorative dentistry
0:04:03	Ss7, 9,10	LMS > Learning Resources > Lecture Capture	Occlusion in restorative dentistry
0:05:04	S9	Discussion	Webinar features
0:05:15	S8	LMS > Learning Resources > Video	Gag reflex, swallowing
0:05:32	S8	LMS > Learning Resources > Lecture Capture	Impact of oral conditions on life quality
0:05:39	Ss7,9,10	LMS > Learning Resources > Lecture Capture	Impact of oral conditions on life quality
0:06:35	S9	Question	PBL inquiry material
0:07:02	S8	LMS > Evaluation	Questionnaire
0:07:15	S7	LMS > Course Tools > Discussion board	Stressed patient
0:07:24	S8	Question	Definition of stressed patient
0:07:35	Ss1,8,9,10	LMS > Course Tools > Discussion	Corticosteroid
0:07:55	S4	E-Library > Dental Update	Factors affecting jaw growth; mandibular and maxillary growth
0:09:01	S4	Question	Current problem: Class III malocclusion only?
0:09:05	Ss9,10	Discussion	Current problem: Classification of malocclusion

Table 7.3 Online learning (via dedicated LMS: Part 2)

Time	Students	Modality	Topic
0:13:33	Ss7,8,10,4	Discussion	Current Problem: Development of jaw bones
0:13:45	S4	E-Library > Orthodontic Cyber Journal search	Factors affecting jaw growth
0:13:50	S8	LMS > Learning Resources > Video	Anatomy of Skull
0:13:59	Ss4,10,7	LMS > Learning Resources > Video	Anatomy of Skull
0:14:42	S4	E-Library > Science Direct search	Jaw/Mandibular growth
0:14:48	S8,10	Discussion	Resource Session
0:15:00	S8	LMS > Learning Resources	Ion excitability
0:14:25	S9	E-Library > PubMed search	Malocclusion oral health; Orthognathic surgery; Orthodontics
0:15:13	S10	E-Library > Journal of Orthodontics	Malocclusion
0:15:14	S8, S1	Discussion	LMS Resources
0:15:49	S4	E-Library > Journal of Orthodontics	Factors affecting jaw growth
0:18:23	S8	Question	Current Problem: What to look for
0:18:33	Ss8,10,9,4	Discussion	Orthodontic textbook
0:19:23	S9	E-Library > PubMed search	Perception of facial attractiveness
0:19:27	S7, S8	Discussion	Past problem
0:20:53	S4	E-Library > Science Direct search	Growth of jaw bones
0:21:41	Ss10,8,1	PDF Journal article > Discussion	Bone development
0:26:08	S4	Print: Journal article	Orthodontic treatment
0:26:12	S8	LMS > Learning Resources	Mandibular fractures
0:26:55	Ss4,10,7,9	Email: Journal article PDF	Growth in Orthodontic treatment
0:27:04	S8,	LMS: Problem Archive	Bone development
0:27:39	Ss4,8,1	Email: Journal article PDF	Orthodontic treatment

On beginning their on-screen work, the entire student group began with the (LMS). This group did not immediately navigate to the link for the current problem. Instead, they were greatly interested in the newest feature, the inclusion of lecture captures of faculty presentations from end-of-unit 'resource sessions' and public presentations for the continuing education of practising dentists. Online searching through the LMS focused on the problem at hand with one digression over a discussion board posting on corticosteroids. S4 did not join the general discussion on the new features but began searching for information on her key knowledge gap – jaw growth. Her question, when posed, was highly directed as she clarified which class of malocclusion was the focus of research. In her ensuing activity (Table 7.3) she remained focused on this topic weaving between modalities from online searching to viewing an anatomy video, to saving, printing and emailing relevant journal articles. S4's

switch in screen activity at 0.13.59 from a focused search on the electronic library was prompted by the cascade effect initiated by S8's discovery, four computer screens away, of an online anatomy video.

In a trilingual territory such as the Hong Kong Special Administrative Region (HKSAR), Chinese (specifically Cantonese, as below) is often the students' chosen language of communication outside formal learning contexts, which are in English. In Excerpt 4, we see the students engaging in informal talk in Cantonese whilst searching online and utilizing the dedicated LMS.

Excerpt 4 'So should I print it out?'

0:21:52.6	S8	[啊]我知你講咩喇 (bone development)
		[aa]ngo zi nei gong me laa (bone development)
		[Ah] I know what you're talking about (bone development)
0:21:54.9	S10	係呀即跟住佢就=
		hai aa zik gan zyu keoi zau=
		Yes she then=
0:21:56.6	S1	Endocondral ossification
0:21:59.9	S4	咁使唔使印呢?
		gam sai m sai jan ni?
		So should I print it out?
0:22:00.2	S10	別啊: 唔係呀係呀
		Ah: m hai aa hai aa
		Ah: mm yes yes
0:22:01.8	S4	都夠啦
		dou gau laa
		It's enough
0:22:05.0	S10	係呀係呀
		hai aa hai aa
		Yes yes
0:22:08.1	S8	Year one
0:22:09.3	S1	唔係講方向架咩°°咩向下°°
		m hai gong fong hoeng gaa me°°me hoeng haa°°
		Isn't it about direction °°something downward? °°
0:22:14.0	S4	有冇個factor點樣影響架=
		jau mou go factor dim joeng jing hoeng gaa=
		Is there a factor and how does it affect the=
0:22:18.5	S10	=即係你講malocclusion?
		=zik hai nei gong malocclusion?
		=So you mean malocclusion?
0:22:21.1	S4	Ah::影響咗growth
		Ah::jing hoeng zo growth
		Ah::affects the growth

In summary, it is evident from the time-stamped screen activities and the recorded around-screen talk that S4 used the SDL session in the computer laboratory to search for resources and information that would address the knowledge gaps implicitly identified in T1. It is also evident from the summary of her information searching immediately following T1 (see Tables 7.2 and 7.3) that this had been the issue of jaw growth and malocclusion. At the end of the

excerpt above, S4 still exhibits some hesitation and/or confusion over the topic of malocclusion (SDL, 0:22:14.0–0:22:21.1). Of interest is how this online searching and peer discussion become consequential to her second and final tutorial.

7.4.5 Event 3: The Second Tutorial (T2)

What becomes evident in T2 is the consequential progression of S4's learning across the three key components of the problem cycle. In the second tutorial, S4 displays her growing mastery of disciplinary knowledge. The silence in her first tutorial reflecting her confusion or lack of knowledge regarding bone growth prompted further research on the topic through online searching during SDL immediately following T1. In Excerpt 5 below, we see a transformative moment in S4's learning during T2 when she displays confidence by interjecting on behalf of S1 who is not able to respond to the facilitator's prompt regarding remodelling (T2, 0:49:09.9). The ensuing exchange indicates improved control of key concepts.

Excerpt 5 'What causes the remodelling?'

0:48:42.1	F	What kind of drugs? I'm always interested to know. ((Ss laugh)) (.)<u>What</u> causes the remodelling?
0:48:44.5	S1	Ah the cartilage, the carti=
0:48:53.8	F	=Cartilage?=
0:48:54.6	S1	=For=forgot sorry (cartilage)
0:49:09.9	S4	Is that the cartilage deposition posteriorly↑ and then ossify the bone and some remodelling occurs in another side to keep the shape?
0:49:18.6	F	Yes, but (.) we're talking about (.) what determines the (.) remodelling process. (.) So do you mean the condyle will continue to to grow? When you said the remodelling is because of deposition of the bone?
0:49:42.2	S4	Ah there there will be some (.) continued rotation of the mandible ah=in the adulthood but only a slight change=
0:49:50.6	F	=Continued rotation oka:y. Continued (.) rotation is towards which direction?
0:49:58.2	S4	For males it is more=more forward rotation and for females is more backward rotation
0:50:07.5	F	What is forward rotation, what is backward rotation?
0:50:09.2	S4	Ah forward is the vertical height will reduce and backward the vertical height will increase that the ((hands show a T shape and smiles to S6))
0:50:18.1	F	(That means) clockwise or anticlockwise=
0:50:22.9	S4	Oh, backwards=backwards is anticlockwise and forwards is clockwise ((S6 whispers))
0:50:34.1	F	So:: males will tend to rotate which direction?
0:50:38.1	S4	<u>Clock</u>wise (.)
0:50:47.1	F	Vertical=vertical growth, (.) increase in vertical growth?
0:50:51.9	S4	Decrease (.)
0:50:58.5	F	<u>De</u>crease but it's clockwise?
0:51:06.6	S4	You mean the mandible grows in anticlockwise but it=I don't know how to describe, it is (.) forward growth of mandible? =

At the end of this long exchange between S4 and the facilitator in excerpt 5, S4 admits her struggle to describe the complex physical features of mandibular growth patterns (T2, 0:51:06.6). The facilitator then interjects with 'Just draw it' (T2, 0:51:22.6) asking S4 to move to the whiteboard to create a visual representation of her description.

Excerpt 6 'Just draw it'

0:51:22.6	F	=Just draw it (.) arrow direction ((S4 moves to draw on the board while S8 and S1 discuss between themselves))
0:51:41.1	F	This is no::t rotation, it is AP, you are just shifting the whole thing AP.
0:51:58.5	S4	The bac=forward rotation is here↑ a::nd backward rotation ((finishes and walks back to her seat))
0:52:17.5	S4	°I didn't draw it round enough, I'll draw it again° ((returns and draws another one))
0:52:37.3	S4	This is (.) backward.
0:52:42.3	F	And this is female=
0:52:48.9	S4	=Yeah=
0:52:49.7	F	=Okay
0:52:50.3	S4	And forward is (.) you imagine it's (.) yeah another (one)
0:52:52.9	F	(But) then the:: vertical dimension is different (.) This is increased in facial height if this is backward. But you're talking about male is increased on vertical dimension right?=
0:53:04.8	S4	=Oh, decrease=
0:53:05.7	F	=Male is decreased. Okay?
0:53:11.6	S4	I dunno. It's written in the book that, the cranial facial growth in adult and when other dimensions cease, the vertical change still predominate ((looking up at the facilitator)) and there is a tendency for the male to have forward rotation (.) yeah
0:53:32.2	F	That means decrease in vertical dimension=
0:53:37.0	S4	=Mmm (0:00:10.0) ((S4 whispers to S6)) (0:00:24.2)
0:54:10.0	F	Okay

From this more dialogic exchange between the facilitator and S4 in excerpt 6, we see a transition from the use of visual tools as receptive prompts such as in T1 to a new visual text. This is the productive creation of a visual tool that cognitively assembles knowledge from both self-directed research and the printed texts and images she has brought to T2. In excerpt 6, S4 is challenged throughout the exchange with the facilitator to verbally articulate her understanding regarding 'jaw growth' whilst simultaneously visually representing this knowledge. Consequentially, we see this topic as the most challenging learning issue identified from T1.

7.5 Discussion

This study adopted IE to trace knowledge construction using multimodal texts across tutor-facilitated and student-directed learning. The small corpus of classroom interaction data (video/audio recordings) across one problem cycle over two weeks of learning was framed by using three lenses. First, by

investigating 'whole-part, part-whole relationships', it was evident that students accessed a range of multimodal texts including educational technologies to support learning within and across a problem cycle. Second, we traced 'consequential progression' and the 'historical and over-time relationship between and among texts and contexts'. A rationale for this was to establish if and how knowledge construction in T1 became socially and academically consequential to SDL and T2. Evidence was found that the use of multimodal texts within a problem cycle supported a discursive shift from *stimulus* for hypothesizing to *basis* for research and final *evidence* for hypotheses.

Few studies have explored PBL interactional data in the context of education theory. The focus on instructional approach to the detriment of clarity in PBL's relationship to theory building has been argued as a deficit in PBL research (Norman & Schmidt, 2000). Most studies acknowledge the underlying premise that, theoretically, PBL is constructivist in orientation (Gijselaers, 1996; Jonassen, 1997). More recently, researchers in clinical sciences have suggested a new form of 'information-processing constructivism' that moves away from the social nature of learning and focuses on the construction of new knowledge from multiple sources as a method of acquiring domain-specific knowledge (Schmidt & Moust, 2000). In exploring the role of multimodal texts across this social constructivist learning process, we now draw upon two explanatory theories. The first is Kress's notion of multimodality and a theory of semiotics or meaning making. The second is Vygotsky's sociocultural notion of mediating tools.

7.5.1 Theory of Semiosis

For Kress (2000, 2010), the possibilities of new modalities, particularly as they are focused on the visual, demand a 'new agenda of human semiosis in the domain of communication and representation' (Kress, 2000, p. 183). Building from his definition of multimodality, Kress's theory of communication focuses on three central concepts: materiality i.e. the (physical) materials of representation; mode i.e. the semiotically articulated means of representation and communication; and medium i.e. transmission and dissemination (ibid., pp. 186).

The third-year undergraduate students in this study engaged seamlessly with multiple physical and virtual materials of representation as part of their PBL process. These material representations ranged from print-based texts to clinically relevant materials such as study casts and radiographs to online resources to drawings made in class. Significant to the findings of this study was Kress's (2000) observation that

> Technologies of information lend themselves to 'visualisation', the phenomenon in which information initially stored in written form is 'translated' into visual form, largely because the transport of information is seen as more efficient in the visual rather than the verbal mode (p. 183).

From the analysis above, we can see the translation of knowledge gained in SDL as well as from the textbook brought into class into a visual form. Hence, the facilitator's strategy to ask S4 to 'just draw it' in T2 generates a cognitively

demanding task that asks the student to represent her knowledge visually. By transposing what was viewed during her online search and the picture in the text in front of her, the learner creates an 'intervisual link' (Kress, 2000, p. 196) that all who are present can associate with. They have all viewed and analysed the radiographs and have both separately and with peers examined images of jaw growth in their independent study. These intervisual relations then support and enhance collective and individual cognition.

7.5.2 Semiotic Mediation

Under the Vygotskian view of constructivism in a learning context, 'semiotic mechanisms mediate social and individual functioning' (John-Steiner & Mahn, 1996, pp. 192–193). External physical tools and internal psychological tools, therefore, contribute to the social acquisition of learning by 'tying mental functioning to cultural, institutional, and historical settings' (Wertsch, 1994, p. 204). Within the social learning process that is PBL, the accessing of visual tools and learning objects in the final tutorial becomes socially and academically relevant. From the IE above, we can see that the appropriation of mediating tools was dependent on their relevance to new knowledge. In T1 students were engaged physically with touching and manipulating study casts, as well as touching and viewing radiographs and the clinical photograph. In SDL, students moved to virtual images and exploring the learning issues in greater depth. In the final tutorial, students did not touch the physical objects, nor did they share virtual images via the interactive whiteboard. Instead, students drew representations on the whiteboard to illustrate the point currently being made. As (Bruner, 1962) noted,

> if neither hand nor intellect alone prevails, the tools and aids that do are the developing streams of internalized language and conceptual thought that sometimes run parallel and sometimes merge, each affecting the other (p. vii).

From this study, it was evident that the physical and psychological merged seamlessly both during specific PBL events and across the entire problem cycle. Significant to this notion of 'merging' in semiotic mediation was the transition from the *receptive* appropriation of curriculum materials to the *productive* creation of a drawing as a meaning-making tool in the social context of a PBL tutorial. The culmination of S4's accessing of a range of tools for learning in building disciplinary knowledge was the confident production and explication of an original visual representation of 'jaw growth'.

7.6 Conclusion

This chapter has taken a dual focus to explore 'inside' PBL. First, we have adopted a relatively new research methodology – interactional ethnography – to provide a principled and coherent framework for data collection and management. To understand how students experience PBL across a problem cycle, new methodologies must be adopted that look beyond evaluative data or short-term

learning experiences to examine learning in situ, particularly as students engage with online resources during independent study. The data and analysis presented in this chapter adopts an IE approach to trace 'how' knowledge is constructed in context and over time.

By adopting this framework, we have sought to explore the 'way' students experience and understand two 'black box' facets of their PBL learning, independent learning and online learning. IE provides a means of creating a conceptually organized archive; a systematic approach to analysing video records at multiple levels of scale; and an ethnographic framework for searching and retrieving video records that are intertextually tied. As such, an ethnographic approach affords educational researchers a principled approach to exploring how students learn. This approach enabled a systematic and microanalytic analysis of student learning in PBL in addressing the following key research question: *How and when do multimodal texts support knowledge construction across a problem cycle*? Analysis presented in this chapter focused specifically on two areas of the 'black box' of PBL as we explored how students engaged with online learning independent study and the ways multimodal texts and mediating tools supported learning within and between the first and final tutorials.

Second, we have drawn upon two analytic lenses as explanatory theories. Multimodality within a theory of semiotics enabled us to examine how the various multimodal texts that our focus student and her PBL group drew upon supported cognition and transformative learning. Vygotskian sociocultural theory of learning, specifically as it related to mediating tools, provided another explanatory theory to allow us to understand how physical tools support learner cognition in a social context. By focusing on multimodal texts and independent study, the results provide new insights into how blended approaches in PBL curricula support student learning and how students use visual objects to support learning. IE analysis of transcribed talk data tracked conceptual growth across one problem cycle. It was evident that students seamlessly integrated various face-to-face and virtual semiotic modes across a problem process to achieve learning outcomes.

The introduction of IE research holds great potential for understanding the learning process in PBL. The results of such investigations should inform the design of integrated, problem-based curricula in clinical education.

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