Chapter 3
Technology and Group Processes in PBL Tutorials: An Ethnographic Study

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3.1 Introduction

Educational technologies in their many forms can provide a diverse array of multimodal information. They may also provide novel spaces for new forms of learning collaborations—both virtually and face-to-face. When problem-based learning (PBL) in the health sciences was conceived, the original available spaces for learning were the tutorial classroom and self-study spaces such as university medical libraries. As technological affordances have grown, new opportunities have arisen to support a technology-enhanced notion of the inquiry process—PBL2.0 (Bridges, Botelho, Green, & Chau, 2012; Bridges, Botelho, & Tsang, 2010) which takes a blended approach to infusing face-to-face interactions with educational technologies. This emerging field has grown in research interest with a recent systematic review (Jin & Bridges, 2014) indicating three broad areas of implementation: (a) learning software and digital learning objects: (b) learning management systems and (c) large-screen visualizations such as plasma screens as well as hardware with additional functionalities such as Interactive Whiteboards (IWBs).

Some technological innovations have explored how PBL in the health sciences can be enacted as a totally online, distance education experience using either synchronous (Hmelo-Silver et al., 2015; Ng, Bridges, Law, & Whitehill, 2013) or asynchronous

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S. Bridges et al. (eds.), *Educational Technologies in Medical and Health Sciences Education*, Advances in Medical Education 5,
DOI 10.1007/978-3-319-08275-2_3

(Bridges, Corbet, & Chan, 2015) facilitated interactions. Others, however, have sought to enhance the traditional on-campus problem cycle (Barrows, 1988; Lu, Bridges, & Hmelo-Silver, 2014) with new technologies to further support, scaffold, and manage the inquiry process. Digital affordances such as video and virtual cases (Antoniou, Athanasopoulou, Dafli, & Bamidis, 2014; Chan, Lu, Ip, & Yip, 2012; Chi, Pickrell, & Riedy, 2014), including interactive virtual patients and 3-D models (Poulton, Conradi, Kavia, Round, & Hilton, 2009; Savin-Baden, Poulton, Beaumont, & Conradi, 2015; Silen, Wirell, Kvist, Nylander, & Smedby, 2008; Yang, Zhang, & Bridges, 2012) have been introduced to support learner engagement and cognition in PBL curricula. Purpose-designed tools such as concept mapping software (Novak & Cañas, 2008) enable scaffolding of knowledge building processes (Bridges et al., 2015, Bridges, Dyson, & Corbet, 2009) in PBL and further establish conceptual or epistemological links by interconnecting meaningful knowledge construction and its application to clinical contexts (Kinchin, Cabot, & Hay, 2008). Creative adaptations of traditional learning management systems (Tedman, Alexander, & Loudon, 2007), embedding online facilitator and curriculum evaluations (Tedman, Loudon, Wallace, & Pountney, 2009) as well as electronic curriculum mapping systems (Willett, 2008; Wong & Roberts, 2007) have also supported the management of complex, integrated PBL curriculum designs. An earlier study (Kerfoot, Masser, & Hafler, 2005) on the installation of hardware within PBL tutorials in the form of computers and wall-mounted plasma screens was found to have impacted positively on the tutorial process but indicated issues as to how these technologies may affect tutorial dynamics.

Whilst prior work has examined the consequential nature of online resources from face-to-face tutorials to self-directed learning (Bridges, 2015), of interest to the study reported here is how new educational technologies influence face-to-face interactions in PBL tutorials, particularly where infrastructure such as IWBs are installed. The use of IWBs is a new phenomenon in education with early adoption being in school settings (Beauchamp & Parkinson, 2005; Higgins, Beauchamp, & Miller, 2007; Schmid, 2008) and a 2005 review indicated their potential for enhanced interactivity (Smith, Higgins, Wall, & Miller, 2005). Criticisms of their implementation in schools indicate the key issue of teacher uptake with some concerns that IWBs are utilized as 'a visual textbook' without a radical change of pedagogic approaches (Miller & Glover, 2010a, 2010b). However, little work has examined the role of IWBs in higher education. In particular, even less research is examining their use in small, group, problem-based health sciences curricula. The emerging work on IWB implementation in PBL curricula indicate the positive effects of using IWBs on student learning and collaborative discussions (Bridges et al., 2010; Bridges, Botelho, et al., 2012; Lu & Lajoie, 2008) but more research is needed in this new field.

Of specific interest to this study is the space of learning and how PBL group dynamics can be inhibited or enhanced when new technologies are introduced to face-to-face tutorials. As part of a larger ethnographic research programme examining PBL in situ, classroom video data was collected for the same technology-rich PBL-problem scenario over two separate time points. The first PBL group worked with uneven distribution of mobile devices and a standard, nonelectronic whiteboard (printboard) while the second PBL group worked fully with laptops and an IWB. This data trail enabled comparison of group dynamics pre-and post-redesign of

the PBL classroom spaces whereby IWBs linked to a laptop controlled by the group scribe/clerk were installed in each room. The research question for this study was, *How are group dynamics affected by the introduction of an IWB in a face-to-face health sciences PBL tutorial?* Analysis aims to provide a unique account of shifting group processes as undergraduates and tutors adapt over time to a technology-infused PBL curriculum at a time of educational innovation and change.

3.2 Background

Educational technologies can provide rich PBL problems/cases in virtual spaces (Hanson, 2011) to facilitate a range of inquiry-oriented designs where students construct their own understandings. They can also provide access to and structure information by embedding expert knowledge and skills with multimedia in virtual spaces made available for self-directed learning (Lechner, Thomas, & Bradshaw, 1998; Schultze-Mosgau et al., 2004). Finally, educational technologies can provide a platform to elicit articulation, collaboration, and reflection (Quintana et al., 2004). Such affordances can scaffold teaching and learning by allowing students to learn in complex domains (Hmelo-Silver, 2013; Hmelo-Silver, Duncan, & Chinn, 2007) and by assisting learners to construct explanations by making tasks manageable (Derry, Hmelo-Silver, Nagarajan, Chernobilsky, & Beitzel, 2006). Whilst yielding promising results indicating potential fitness for educational purpose in healthcare education settings, more research into PBL and educational technologies is required. The classroom applications of IWBs have seen a growing focus in educational technology research. An IWB is a large, touch-sensitive electronic board that connects to a laptop and a data projector. The laptop's desktop is projected via the board enabling any software, digital materials, and learning platforms accessed on the laptop to be displayed. The board's touch-screen function allows direct input via finger or stylus and can replicate the keyboard functions. IWB interactive tools evident in use in the research team's experience in health sciences education include: drag and drop; hide and reveal; highlighting; spotlighting; and annotation of digital objects displayed using the overlay function. The latter annotated images are then converted to PDFs and distributed amongst PBL group members.

Smith et al.'s (2005) critical review of IWBs in learning indicated two core arguments in favor of their introduction in classrooms—motivation and visualization; however, a limitation to the research studies reported was their reliance on perception rather than learning outcome data. Critics of claims as to the effectiveness of IWBs (Schroeder, 2007) have called for a more principled analysis of their effects on student learning, particularly indicating a need for longitudinal studies. A more recent review by Miller and Glover (2010a, 2010b) indicates the key role of IWBs in encouraging a pedagogic shift from presentational to interactive approaches and methods.

One large-scale study (Lewin, Scrimshaw, Somekh, & Haldane, 2009; Lewin, Somekh, & Steadman, 2008) examining achievement effects of the introduction of IWBs into primary school literacy and numeracy classrooms in the UK found a direct impact of IWBs on student performance in national test scores in mathematics and science and indicated length of time in IWB-embedded teaching was key to

improvement. Their investigation of classroom practices indicated a shift from teacher-centeredness to a collaborative pedagogy whereby the IWB acted as a mediating tool. Evident pedagogically was the added value of IWBs in that teachers were able to make tacit knowledge visible through explicit probing questioning. Curwood (2009) also indicated the possibilities of IWBs for differentiated learning for both higher level and special needs of students. The study of IWBs in higher education undertaken here sought to explore inside the 'black box' of IWBs in classrooms by undertaking ethnographic exploration of interactivity and pedagogy with higher level students in situ, in this case, in undergraduate dental education. First, however, a review of the use of IWBs in the health sciences, and particularly in PBL will situate the study more closely to the research context.

3.3 Interactive Whiteboards in the Health Sciences and PBL

As noted above, the majority of current studies have been based on the views of teachers and pupils in school settings and research into the implementation of IWBs in higher education (see, for example, Knight, 2003) is scant, with even less work in the health sciences. One area of particular paucity in the literature is how IWBs are used in small group, inquiry-based contexts such as PBL in higher education and this remains a site for ongoing investigation. Among the limited studies of IWBs in universities, the literature is generally positive about the effectiveness and potentials of using IWBs. Al-Qirim's (2011) study of IWBs in a technology programme reported barriers such as the compatibility and complexity of IWBs as well as users' inexperience with their different features and made a series of recommendations for pedagogical reform. In the health sciences, Murphy et al. (1995) reported an innovative experiment using an IWB to teach clinical cardiology decision analysis to medical students. The LiveBoard in their study allowed the integration of decision-analytic software, statistical software, digital slides, and additional media. Such multimedia aspects and digital interactivity were conducive to extensive student participation with medical students indicating positive feedback about this teaching innovation.

While early studies on the introduction of large-screen displays for computer-augmented PBL groupwork have been conducted (see, for example, Koschmann, Myers, Feltovich, & Barrows, 1994), the use of IWBs is a relatively new phenomenon in PBL curricula (Lu, Lajoie, & Wiseman, 2010). In small group, collaborative contexts in higher education, Schroeder's (2007) case study of IWB utilization by freshmen students engaged in inquiry-oriented learning in a US college library environment found that "IWBs and the activity they encourage can positively influence affective learning in the classroom" (p. 1). Two of the authors (Bridges et al., 2010) adopted an interactional ethnographic (IE) framework to analyze video recordings and student learning artefacts of student engagement with digital materials within and across a problem cycle. This study of a PBL group's use of an IWB across tutorials and self-study found that multimodal application and integration with IWBs was "seamless and supported whole-group engagement in the process" (p. 1131). In another study in undergraduate dentistry, they (Bridges, Bridges,

Botelho, Green, & Chau, 2012) adopted IE to trace knowledge construction across a problem cycle and explored how students engaged with online learning during independent study. They noted that the use of multimodal texts and mediating tools supported learning within and between tutorials. Lu et al.'s (2010) study described the nature of scaffolding of collaborative problem solving under the two conditions—a traditional whiteboard (TW) group and an IWB group. They concluded that IWBs can help by expanding the scaffolding choices for students' learning. Their earlier 2008 study identified relationships between medical students' collaborative decision-making and communicative discourse and found that IWB group participants engaged in more adaptive decision-making behavior earlier than the TW group, which led to shared understandings and subsequently to more effective patient management in a simulated medical emergency (Lu & Lajoie, 2008).

3.4 The PBL Model

Before embarking on analysis of tutorial discourse in blended learning environments, it is important to clarify the model of PBL utilized at the time of this study. This has been described in detail elsewhere (see for example, Bridges, Green, Botelho, & Tsang, 2014); however, in brief terms, the model enacted in this study more closely follows the 'closed-loop' model (Barrows, 1986; Walker & Leary, 2009) with two face-to-face tutorials acting as bookends opening and closing the learning cycle. The initial tutorial exposes students to the problem statement and related inquiry materials for activation of prior knowledge, establishment of facts and ideas, hypothesizing, and determining topics (learning issues) for independent research. The second tutorial collects and reviews the information researched. This is then synthesized and applied to the problem at hand. Between the two tutorials are dedicated sessions for student research (self-directed learning), workshops, and experiential learning such as clinical sessions and field trips, etc.

3.5 Materials and Methods

3.5.1 Approach

Within the framework on an ongoing Interactional Ethnography (IE) (Bridges, Bridges, Botelho, Green, & Chau, 2012; Bridges et al., 2014), classroom video data was collected to examine PBL knowledge co-construction in situ. As an approach, Interactional Ethnography allows principled collection of classroom data (Castanheira, Crawford, Dixon, & Green, 2001; Green & McClelland, 1999) by documenting and analyzing events and incidences over time. This can then be explored in terms of consequential progression, i.e., how one "anchor" event or one participant or group's actions can be consequentially significant to events prior and post. Analysis can therefore build a chain of logic in understanding pedagogic processes. Given the collection of a cumulative database of PBL tutorials over time, we

were able to undertake comparative analysis to examine the same technology-rich PBL problem scenario across multiple years. Of interest to the guiding research question for this study was that the 2008–2009 group context was non-IWB whilst the 2012–2013 group context was after the learning space had been redesigned including, among other features, the installation of IWBs. Ethical approval was gained by the Hong Kong West Cluster Institutional Review Board.

3.5.2 Data Collection

A comparative study between a nonelectronic whiteboard (WB) group and an IWB group was conducted. First-year PBL groups in a 5-year Bachelor of Dental Surgery (BDS) curriculum were recruited over a period of 4 academic years. The WB group ($n=8$) were in the 2008–2009 cohort prior to the redesign and remodeling of the PBL learning spaces, including installation of new IWB hardware. The second, IWB group ($n=9$) were in the 2012–2013 cohort following a major upgrade of all PBL tutorial rooms. Two cycles of PBL tutorials based on the same PBL problem/scenario were video and audio recorded in the second semester of 2008–2009 and 2012–2013 respectively. For the first-year undergraduate dental curriculum in the second semester of both the 2008–2009 and 2012–2013 academic years, 13 problem cycles were conducted across two 'modules'—instructional blocks of 6–8 weeks. The PBL problem/scenario on epidemiology and regional oral health in China was selected as an anchor for comparative analysis. This occurred as the final problem in Module IV in 2008–2009 and the third problem in Module IV in 2012–2013. Only the first tutorial (T1) of these two specific problem cycles was selected for analysis of interactional discourse given the significant focus on problem exploration. The problem itself was multimodal in that the sequential disclosure of the narrative structure of the scenario was embedded with links to three key web-based resources, including a public health database. One of the web links was also provided at each tutorial in the form of a hard copy booklet.

Data is represented in Excerpts 3.1–3.5 with time stamps (hours: minutes: seconds), de-identified speakers (S1 = Student 1; Ss = Students; F = Facilitator) (See Appendix B for transcription conventions used (Jefferson, 2004)). The de-identified video frame grab indicates key interactants (Facilitator—solid Red; Scribe/clerk—outlined Yellow (including IWB and linked laptop); Student speakers—outlined Green).

3.5.3 Analysis

3.5.3.1 Technology and Group Fragmentation (2008–2009)

In 2008–2009, eight students and one experienced facilitator engaged in the traditional PBL process of identifying the facts, ideas, and learning issues of the paper-based problem scenario at hand (Barrows, 1988). The problem scenario inquiry

materials intended to stimulate the learning process were in the form of a hard copy of a public health booklet and URLs for students to search online datasets. Resources in the room included students' own mobile devices (5 laptops), a traditional whiteboard (WB) (also referred to as a printboard) and wireless internet connectivity. Excerpt 3.1 illustrates how students began the first stage of the problem process—identifying the facts. The facilitator, seated in red, listens to S1 read out the problem scenario while the scribe/clerk (yellow) begins recording on the WB. The ensuing activity is analyzed below.

Excerpt 3.1 Identifying facts (2008–2009 WB group)

Time	Speaker	Discourse
00:39:45[a]	S1	Alice is a final year student (4.0) in English journalism
00:39:55	Ss	((S6 writes fact on whiteboard; Ss read problem inquiry materials separately; S4 looks at his laptop screen and booklet))
00:40:45	Ss	((S6 checks with S1; Ss read their booklet separately; S2 checks his laptop, S1 looks at S2's laptop screen; S6 walks toward S3 and looks at S3's laptop screen and then looks at the booklet))
00:40:49	Ss	((Ss browse on their laptops))
00:42:37	S3	Research ((unclear)) public ((unclear)) indi:ces::

[a]Initial 35 min of tutorial devoted to wrapping up the previous case

In the above excerpt from the nonelectronic whiteboard (WB) tutorial, student discussions are focused around the problem scenario, information in the problem inquiry booklet, accessing and reading the online information given as problem-specified URLs. The transcriber's notes in double parenthesis within the excerpt combined with the contemporaneous video frame grab illustrate the multiple physical activities students are engaged in either individually or in conjunction with peers. Those individuals with laptops ($n=5$) are checking online information separately (see video frame grab above). S1 identifies a fact after reading the scenario and then the scribe lists this fact on the whiteboard. Significant to group interactions is the lengthy silence (~3 min). During this time, 5 of the 8 students have used their own laptops to access various web links provided to support the problem scenario. The video frame grab indicates the physically fragmented nature of this problem exploration phase. The group has fractured into two subgroups and four individuals with this fracturing driven by access to laptop screens. All are engaged in a similar activity, i.e. examining problem-related web pages; however, group cohesion is disrupted not only physically and socially due to distribution of screen access but also cognitively in terms of collaborative knowledge construction. Screens were displaying different materials or different pages of the same URL with each subgroup potentially navigating through different online information. The long silence and information accessing activity can be seen as counter-productive to group discussion as each screen was leading students to a different subset of information. In this case, therefore, rather than being a resource for collaboration (Jin, 2012, 2014) the lengthy period of silence can be viewed as an example of cognitive conflict inhibiting collective thinking and group discussion. For the facilitator, the challenge

becomes how to focus student attention and manage the lack of synchronicity due to this accessing of various mobile devices simultaneously. In Excerpt 3.2 below, the facilitator responds to this challenge by physically repositioning himself as seen in the red image in the video frame grab.

Excerpt 3.2 Generating ideas (2008–2009 WB group)

Time	Speaker	Discourse
01:12:56	F	So:: you go to the World Health W-H-O web(.)page::: ((facilitator stands up and walks clockwise to look at S2's laptop screen)) ((silence))
01:13:09	S4	And there is a:no:ther:: [file]
01:13:11	F	[Is there](3.0)W-H-O?
01:13:17	S8	D::de:cayed::, missing, and filled ((facilitator walks back toward S8 and examines her laptop screen)) (3.5)Decayed::, [missing, and filled]
01:13:25	S3	[Doesn't really ma]tter if it's really decayed, or [just a little]
01:13:28	F	[This is for] Hong:: Kong::: ((facilitator briefly points to S8's laptop screen)) (5.4)This is only giving(0.5)giving you all these er::: da:ta. It does not actually tell:: you how::: ((facilitator briefly points to S7's laptop screen then walks back to his seat)) (2.0)What is the standard use? (.)How do you de:fine:: a missing tooth? (2.5)You don't see a tooth in the jaw. ((facilitator looks at Ss))
01:13:53	S3	Yeah.(.) Isn't that:[((unclear))]?
01:13:56	S5	[But it may not] be:: because of caries=
01:14:00	F	=It may not be because of car:ies::=
01:14:03	S3	=It maybe congenital
01:14:04	F	It maybe congenital, (.)it may be?
01:14:06	S1	Congeni:tal:?=

(continued)

Excerpt 3.2 (continued)

Time	Speaker	Discourse
01:14:07	F	=Trau:ma::. (2.0)So if you include that in your stu:dy::, it would distort your pic:ture::. So there is::(.) some:where (0.5)in the W-H-O page:: ((facilitator holds his handout and shows to Ss)),(3.8) something like this ((facilitator looks at the handout))
01:14:34	Ss	((Ss start to search online; S4 passes the laptop to S6; facilitator gives the handout to S1; S1 reads this handout with S2 together and S2 starts to search in his laptop))
01:14:39	F	It::(.) should be accessible(1.5) in one of your W-H-O(.) s::ites. ((facilitator walks clockwise to check S3's laptop screen, and waves his hand to ask S3 to scroll down the screen; S1 looks at S2's laptop screen while S2 searches online)) ((facilitator looks at S3's laptop screen)) (8.0)Homepage, (3.0)alright::, ((facilitator points out the laptop screen)) if you go to the homepage,(1.3) you see the methods and indices (4.3) Methods and indices, alright? ((individuals check online using separate laptops)). So here you see a number ((facilitator points at laptop screen)) of links which give will::(1.0)may have some reference reference to to to the present studies like(.) dentition status, C-P-Is::. (5.4)That is telling you how::(2.0)you can get access
01:15:09	Ss	((S2, S3, S6, S7 check online by using separate laptops, S1 gives the handout to S8; S4 looks at S3's laptop screen; S5 looks at S6's laptop screen))
01:15:36	S3	Different indices, different ((unclear)) site. ((facilitator looks at S2's laptop screen and then walks toward S7)
01:15:40	F	Alright, find the website? (.)The the the site?= ((facilitator checks S7's laptop screen))
01:15:42	S7	=Yeah.=
01:15:44	F	=So this is on ca:ries::: prevalence. (6.0) But there is another site (0.4) which gives you actually the me:thod:ology. ((facilitator points out the screen; S8 briefly looks at S7's laptop screen))

Excerpt 3.2 illustrates further group fragmentation when accessing inquiry materials online while these first-year undergraduates generate ideas. In seeking to manage the growing lack of coherence amongst the group, the facilitator physically moves from his seat and joins one subgroup to examine what they are viewing. He then suggests all students access the provided WHO webpage in order to include some data presented in references. Given that just over half the students have mobile devices, the group becomes slightly more cohesive as indicated by the image displayed in Excerpt 3.2 (see video frame grab above) with a shift to paired activity on a shared screen. In order to support whole-group cohesion, the facilitator walks around the table checking the 5 laptop screens and providing whole-group tips for searches. The discourse from 01:12:56 to 01:15:44 is dominated by facilitator talk in managing and directing the group through online searching processes for 'methods and indices' in the WHO webpage. At this stage of the problem process, the group is still focused on complex information searching and its management rather than generating ideas based on the accessed information. Noticeable in contrast to the 2012–2013 group below, when the website is not synchronously visible to every group member, students engage in facilitator-directed activity rather than independent self-navigation in their information accessing.

3.5.3.2 Technology-Enhanced Collective Cognition (2012–2013)

In the 2012–2013 tutorial, the same public problem was provided. In this instance, it was accessed on the designated PBL group scribe's laptop linked to an IWB. The problem scenario was accessed via timed release on the Learning Management System as a PDF with URLs provided as hyperlinks. As in 2008–2009, the hard copy of the booklet was also provided to the group. An immediate observation was that, by utilizing an IWB, student discussions were collectively focused around the data displayed on the common large screen. This finding concurs with one of the earliest studies of introducing laptops to PBL (Koschmann et al., 1994) which indicated student preference for a single, large-screen display. Although the number of mobile devices utilized had increased to one device per student, large-screen IWB visualization mediated their collaborative learning experience and supported group talk. The scribe's control of the screen display scaffolded the group's accessing of the various inquiry stimuli (the public health websites and databases) and collaborative construction of group notes.

Excerpt 3.3 below illustrates the discourse surrounding the shared website displayed for large-screen viewing. S4 (center of image, outlined in green) generates a hypothesis regarding epidemiological data on dental caries amongst 12 year olds. She discusses making comparisons and uses nonverbal gesture pointing to the IWB to support her hypothesis (see video frame grab below). The ensuing 1 min of silence leads to the response from S2 who requested an evidence-base for the point. S4 seeks to reconcile this possible difference of opinion and used the IWB as a mediating tool to progress the discussion about 'according to age group…'. From 23:36 to 24:15 the group is engaged with collectively examining a statistical table.

Turns are taken without the disruption of asynchronous and disconnected screen representations on separate laptops as in the 2008–2009 non-IWB tutorial. The group then quickly resolves the hypothesis of 'service provided for students' and determines that the percentage of tooth decay is related to region, 'rural area'.

Excerpt 3.3 Shared visualization (2012–2013 IWB group)

Time	Speaker	Discourse
00:22:11	S4	Ac:tual:ly for mainland Chi::na(.) the percentage of:(.) tooth decay does not drop er when, when the children go to 12 years old. I think it's due to they have no er dental ser:::vice provided for student, students… ((silence))
00:23:28	S2	°So how can you explain::°, which table °are you referring to°?
00:23:36	S4	Er:::Go to the website(3.0) This one, 12 years old, 48% °to°, 40%
00:23:49	S5	But in the upper(1.0) table…
00:23:51	S4	Go to 5 years old
00:23:53	S5	But in the countryside, this is a rural area, 21. This one says it's 21. And then, the lower percent is that=
00:24:02	S4	=Lower one, ((gestures at screen and scribe scrolls down)) lower one first, lower one first. Dental caries of::
00:24:08	S5	Rural area=
00:24:09	S4	=According to age group=
00:24:10	S8	=Then we are referring to the rural area.(1.3)The countryside has different::
00:24:15	S4	O::kay(2.8)Oh, maybe maybe the countryside has, er, student den:tal↑ service

In the IWB tutorial, the students self-manage the group discussion using the IWB display as a specific strategy to move the PBL process forward. In Excerpt 3.4 below, S3 offers the suggestion that they 'look at the second website' (00:35:23). This is an important action supporting group cohesion and S7 confirms this as such. After agreement from S7, the scribe shifts from the website displayed on the IWB to another URL and S3 continues with data analysis from this site (see video frame grab below). This type of group self-regulating activity illustrates the heightened centrality of the scribe as a key player not only in the clerical role of recording and organizing facts, ideas and learning issues into coherent notes (cf. Yew & Schmidt, 2009). The IWB scribe's information-seeking process drives what is available for collective view.

Excerpt 3.4 Shared mediation (2012–2013 IWB group)

Time	Speaker	Discourse
00:32:50	S7	What is our ideas? Have some data(.) inside ((laugh)) Do you think those are valid? I am wondering::
		((silence))
00:34:14	S8	Maybe um:: We can take a look at the::(.)another website—the °Hong Kong website
		((silence)) ((scribe navigates to website))
00:35:23	S3	So, do, do we look:ing at the second website?=
00:35:26	S7	=Yes
00:35:27	S3	You, you're sure:: °the° second website is, all talking about Hong Kong? Oh, okay: here:: ((scribe stops scrolling)). ((Silence 1 min 11 s))
		Er, okay, from these:: da::ta, we can conclude that (0.5)percentage with history of tooth decay is same as the::percentage affected because the figure is the same

Significant to both group dynamics and the PBL process is the fluidity of the intervisual shift (Kress, 2000) where students recall prior visualisations to inform their understanding of ensuing images and visual content from one screen to the next (see also Bridges, Botelho, et al., 2012). The group has seamlessly employed the IWB as a shared learning tool in the Vygotskian sense using the large screen to mediate and enhance collective argumentation. Indeed, in the intervening time between Excerpts 3.4 and 3.5, a student requests the scribe to scroll 'lower, lower, please' to navigate the group's attention to the data he wished to discuss. As such, a new, multimodal self-regulating strategy is enacted. The inclusion of a large-screen visualization via, in this case, an IWB, has supported collective argumentation and inquiry. This would be seen as generalizable to other large-screen visualizations from other data projection technologies or from a large plasma screen.

The use of the IWB as an enabler for social mediation to support a PBL group's engagement in collaborative argumentation is also illustrated in Excerpt 3.5. Once they have compared the first two datasets, the students turn to the third website for more evidence to reconcile issues surrounding survey design and sampling in public health. After posing two possible rationales for why the data from China and Hong Kong differ, the group reaches a small impasse indicated by the silence at 00:48:06 (see video frame grab below). The suggestion by S3 to then navigate to the third URL provided in the problem statement leads to further discussion of the types of variables that can be included in an oral health survey. As in Excerpt 3.4, the group's

shift in discussion is self-facilitated and mediated through the IWB. S3 suggests navigating and once the website is visible, S8 recognizes it as the government booklet publishing oral health survey results.

Excerpt 3.5 Shared mediation (2) (2012–2013 IWB group)

Time	Speaker	Discourse
00:47:41	S2	Or, we can simply put er ((gestures to IWB)) that the sampl°ing° methods, is different for China and Hong Kong.=
00:47:48	S1	=Yes::
00:47:48	S2	Sampling method is different for (2.5)Hong Kong and China. ((scribe records on IWB word document))
00:48:06	S1	May:be:: to be more accurate, it is the distribution of the(1.5)peo:ple:: performed the survey
		((silence))
00:48:55	S3	Oh? We have(.)we have(.)we have web:site
00:48:59	S8	This is the, actually, the:: booklet=
00:49:01	S3	=Oh::, booklet
00:49:12	F	So, any more ideas from this website?
00:49:17	S8	I think we have missed out um the° number of oral diseases° because I found that tooth mor:tal:ity was::
		((silence; scribe changes screen to word doc then returns to website))
00:49:45	S3	((pointing at scribe's laptop screen))
00:49:54	S2	Seems strange that, ah, for the web:site: place no such disease of periodontal disease, which is, quite::(0.3) a big concern of the dental aspect. So I guess, but the tooth mor::mor:the tooth mor:::mortality, is it related?
00:50:16	S8	The missing teeth are:: ((unclear))
00:50:29	S8	There are also other information (.)like the::, sugar consumption. (2.8) Maybe we can °look at it°. (3.8)Information on(2.5) sugar consumption, (6.5)((unclear))

The facilitator moves into the recognized strategy of pushing for explanations and generating further hypotheses thus prompting the contributions from S8 and S2 highlighting the impact of variables on survey design and results. This is consistent with what have been identified previously as effective facilitation moves by Hmelo-Silver and Barrows (2006, 2008).

3.6 Discussion

3.6.1 Collaborative Inquiry in Groups

A central feature of PBL is the group. Studies in higher education exploring collaborative learning processes in small groups, in contrast to student and staff perception or satisfaction surveys, have examined facets of the group learning dynamic in terms of group size (Lohman & Finkelstein, 2000); the social context of learning (Imafuku, 2012, Smith & MacGregor, 1992); motivation and group function (Skinner, Braunack-Mayer, & Winning, 2012); social cohesion in cross-cultural contexts (Woodward-Kron & Remedios, 2007); the role of silence (Jin, 2012, 2014); and interprofessional interactions (Imafuku, Kataoka, Mayahara, Suzuki, & Saiki, 2014). These studies have indicated how the complex, highly variable, and nuanced nature of small-group interactions influence the processes and outcomes of this form of inquiry-based learning. What was evident in the analysis above was that the two groups operated quite differently. The argument proposed is that, while acknowledging the difficulty of cross-group comparisons due to the variability of many of the factors listed above, the way technology was accessed and utilized within the face-to-face learning space became critical to the different ways the two groups functioned. Shared visualization controlled by the 2012–2013 group's scribe was seen as supporting group cohesion during the inquiry process.

Another central feature of PBL is the problem/case/scenario itself. While designs of different problem types and the structuring of their delivery has been extensively discussed in the literature on paper-based cases, the impact of new, emerging multimodal cases drawing on heightened images and internet capabilities has only recently become the focus of attention. Research in secondary education has examined the implications for learning when teachers are designing new text types for IWBs (Jewitt, Moss, & Cardini, 2007). The literature on PBL video cases is building; however, research on the new types of demands of problems using hyperlinks to websites has received scant attention. Certainly, the issue of information management was an obvious challenge for the groups in the problem scenario above. Their negotiation of three websites within the narrative of the problem structure placed high demands on individual and collective information processing. While the debate regarding cognitive load in complex cases has been recognized in the PBL literature (Kirschner, Sweller, & Clark, 2006), the counter-argument is that there are multiple scaffolds evident within the PBL process (Hmelo-Silver et al., 2007) with one of these being the traditional whiteboard.

Evident in the small-scale study above is the positive effect of using an IWB as a scaffold for a problem/case/scenario which includes embedded links for navigation to multiple websites. Large-screen IWB visualization served as a mediating tool in students' collaborative learning process. The scribe recorded group members' key ideas based on these multiple websites, which helped to scaffold their

collective argumentation and inquiry. The group notemaking as displayed via a word document on the IWB was composed, edited, and stored in a more elaborated format than on the traditional whiteboard. In addition to this new form of text creation was the scribe's key role in physically controlling the navigation of the various websites. She not only navigated upon instruction from a group member, but also autonomously engaged in on-screen resource sharing, often anticipating or interpreting contemporaneous group discussion. Future analysis of the scribe's role in controlling the IWB display should provide further emic insights into PBL learning with IWBs.

The relationship between a multimodal problem design and the affordances of the physical space of learning are not to be underestimated. Whilst following a narrative structure, the triggers embedded in the problem design were hyperlinks to the internet. In the 2008–2009 context where just over 50 % of the group had access to a laptop with wireless internet connection, the accessing of different web links and online resources led to fragmentation. Social cohesion was reduced with subgroups forming in dyads or triads around a single laptop screen. Collective cognition was inhibited by the lack of common focus or being 'on the same page'. Facilitator behavior was then focused on supporting cohesion. The facilitator did this physically by moving to share a screen with a subgroup and by directing the group to explore specific web pages. For the 2012–2013 group, the varied, individual accessing of multiple resources continued; however, the IWB linked to the scribe's/clerk's computer provided a collective focus for discussion and this time they were literally 'on the same (albeit virtual) page'. In this instance, the facilitator and students worked collectively from the central IWB display whilst recognizing the space for the differing displays on individual screens and drawing these into the discussion.

Finally, a third key component of PBL is the facilitator. Of the strategies identified as employed by an expert facilitator (Hmelo-Silver & Barrows, 2006), three are particularly relevant to the use of whiteboards: (a) checking consensus that the whiteboard reflects discussion; (b) cleaning up the board; and (c) encouraging construction of visual representations. The use of an IWB is a logical technological extension of these strategies; however, while studies on PBL facilitation skills are still gaining attention (Shankar & Malhotra, 2010), there are, to date, no existing studies in healthcare education on facilitation strategies where educational technologies such as IWBs are employed. The challenge for future research is to provide more detailed analyses to examine what new strategies are required for PBL facilitation with IWBs. McCaughan (2015) elaborated on the theoretical foundations of the "nondirective" tutor role as espoused by early proponent, Howard Barrows who saw the tutor role as critical to the group process. While the two facilitators in the study reported above may, arguably, have had different styles and levels of nondirective behavior in their usual practice, evident from the textured analysis of video recordings was that the fragmentation of the 2008–2009 group led to specific facilitator behaviors such as walking around the group to view screens and steering

website navigation across multiple laptops. Evident in the 2012–2013 tutorial was that the facilitator and the student members of the group used the central, scribe-controlled, large-screen display as the locus of attention and discussion.

3.6.2 Theoretical Implications

This study is intimately concerned with thinking and knowledge acquisition processes in small-group inquiry. It has examined tutorial discourse and nonverbal behaviors to uncover how PBL groups are brought forward towards new individual and collective understandings. As Mercer and Howe (2012) elucidate, sociocultural theorists

> would never argue against the study of individual processes of thinking and learning, but we believe that the relationship between social activity and individual thinking is a vital, distinctive characteristic of human cognition, and one which underpins cognitive development (p.12)

The focus of this study has taken up this position to examine the relationship between a technology-mediated social activity in the form of blended PBL group tutorials and the individual thinking that is evident in the transcribed student and facilitator discourse. In further considering the role of IWBs in health sciences education, the epistemological stance of the sociocultural perspective views knowledge as

> not just an individual possession but also the creation and shared property of members of communities, who use 'cultural tools' (including spoken and written language), relationships and institutions (such as schools) for that purpose (ibid p.12).

Evident from the analysis of facilitation strategies and the use of IWBs above, is support for a view of knowledge becoming 'shared property' after being created in a collaborative context. The cultural tools drawn upon to support and develop this knowledge is both the spoken discourse of learners, the written and multimodal curriculum inquiry materials and, in a new 21st century environment, the appropriation of an IWB.

3.7 Limitations

The discussion of the results should be seen in terms of their limitations. First, the study is restricted to video recordings of two PBL tutorials with two separate cohorts. Although the two PBL problem scenarios were the same, the tutors and composition of the year 1 PBL groups differed. Additionally, the only affordance of the IWB that was utilized in this dataset was large-screen visualization of the scribe's laptop screen. Other functionalities of IWBs and their affordances for learning should be examined in more complex PBL interactions.

3.8 Conclusions

This study illustrates how integration of an interactive whiteboard (IWB) as a mediating tool into face-to-face PBL tutorials can positively reshape the learning dynamic, particularly when the PBL problem/case/scenario draws upon multimodal sources to support and stimulate the inquiry process. From the comparative study above, new practices are seen to be emerging in technology-infused, blended approaches to face-to-face tutorials in undergraduate health sciences education. The incorporation of an IWB was seen to play an important and synergistic role with other key components of PBL. While it has been established that facilitators draw upon a repertoire of strategies that can be flexibly adapted to meet the goals of PBL (Hmelo-Silver & Barrows, 2006), where an IWB is introduced, expansion of this repertoire is evident as (a) gaining students' joint attention for collaboration and reflection; (b) eliciting articulation of ideas via IWB visualization; and (c) managing the recording of multimodal group notes in digital formats. Despite the limitations to generalizability from two single cases, the findings from this detailed, ethnographic study have the potential to extend opportunities for exploring changing group dynamics, including facilitation strategies, where IWBs and other forms of shared visualization are employed in PBL and other inquiry-based learning contexts.

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