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2018

The design and development of E-textbooks to support problem-based learning in secondary school science classrooms

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# Chapter One: Introduction

## 1.1 Introduction

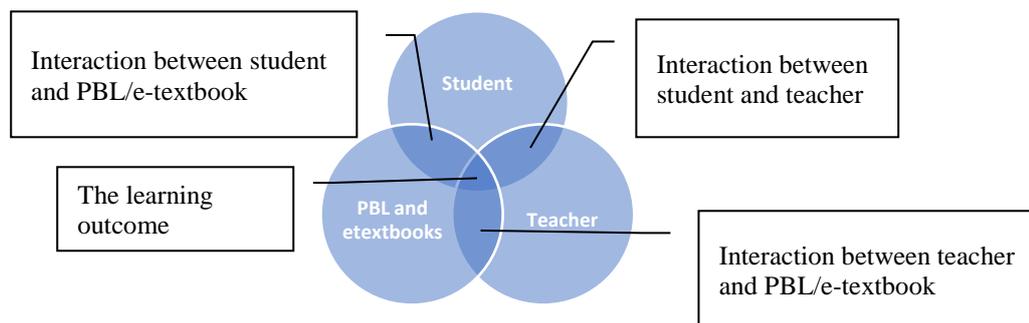
Students entering classrooms currently are quite different from those of 20 years ago. They are so different that new terms have been adopted to describe them. Howe and Strauss (2003) described students born between 1982 and 2003 as “Millennials” (p. 1), while Prensky (2001, p. 1) considered them “Digital Natives.” Whatever the terminology used to describe the group, the challenges they present to educators are considerable. Prensky (2001, p. 70) noted that “Today’s students [millennials] are no longer the people our educational system was designed to teach.” Prensky’s (2001) claims, while appealing at a superficial level, are not without controversy. For example, considering these ‘natives’ as a heterogeneous group is somewhat simplistic. Bennett, Maton, and Kervin (2008, p. 778) noted that “technology skills and experience are far from universal among young people.”

It is perhaps useful to consider students as ‘digital natives’ of a particular country in a technological world with a variety of languages and customs (techniques) where few of them are well travelled or multilingual. They may very well be expert users of Facebook™ or Twitter™ and yet have poor research and evaluation skills. Bennett et al. (2008, p. 781) noted that “students’ everyday technology practices may not be directly applicable to academic tasks, and so education has a vitally important role in fostering information literacies that will support learning.” Therefore, it is useful to consider how to develop technologies like e-textbooks to support student learning in areas such as Problem-based Learning (PBL).

## 1.2 Overview

This study considers the use of e-textbook systems as a learning tool to support PBL in secondary school science classrooms. This study has some interconnected aspects: the students, educational approach (PBL), tools available to support the approach (e-textbooks) and implementation of the design (e.g., scaffolding) in facilitating student learning. The students, educational approach, tools available and implementation through scaffolding by the teacher, to achieve the learning outcomes, form the basis of this study. Figure 1.1 shows the interconnected nature of these four aspects. Specifically, this study aims to determine:

- how students will learn in a PBL environment and what limitations exist (if any);
- how students interact with e-textbooks in such an environment;
- how e-textbooks can be utilised to support students in a PBL environment;
- what role does the teacher's beliefs and actions have in such an environment; and,
- the educational outcomes achieved in such situations.



*Figure 1.1.* Interconnection between students, PBL/e-textbook and teacher (Macnish, Bate, & Stewart, 2017).

This study uses the Design-based Research (DBR) methodology. Barab and Squire (2004, p. 2) defined DBR as “a series of approaches, with the intent of producing new theories, artefacts, and practices that account for and potentially impact learning and teaching in naturalistic settings.” The production of new theories and practices in naturalistic settings is an important feature of this study. Herrington and Reeves (2011) stressed the importance of solving problems in the situation where they arise and with the materials that are present rather than using, as Barab and Squire (2004, p. 1) described it, “research paradigms that simply examine these processes as isolated variables within laboratory or other impoverished contexts of participation (that) will necessarily lead to an incomplete understanding.”

### **1.3 Framework and Research Questions**

The research questions for this study focus on three main areas: the implementation of PBL in a secondary school science classroom, the role e-textbooks can play to support the implementation of PBL and the extent to which such an intervention is successful. Consideration of PBL implementation and the role of e-textbooks allows for the development of a solution from a conceptualisation of the problem and formation of initial design principles. Finally, development of the research questions occurs as a mechanism to test the design principles.

#### **1.3.1 The Purpose of the Study**

Over recent years newspaper headlines have been replete with stories regarding declining numbers of students choosing science and mathematics courses. Kennedy, Lyons, and Quinn (2014) noted that declines in Year 12 student enrolments occurred in all but one of the sciences between 1992 and 2012. Lyons (2006) noted that students in various countries found that students felt science

courses were didactic, lacking context and excessively hard. This study proposes that PBL supported by e-textbooks can help overcome some of these issues.

This study's investigation into the use of e-textbooks to support student learning through PBL has the potential to add to the understanding of how ICT can assist their learning. Being able to respond to the needs of students through an innovative ICT-based educational intervention is one aspect of this study. The approach used in this study is PBL, which originated in medical education where it was developed to address the problem of poor clinical performance by medical students (Hung, Jonassen, & Liu, 2008), and is practised widely by medical schools in America and Europe (Savery, 2006). The integration of PBL into school-based educational settings is a matter of some debate in the literature. Some report the enthusiastic uptake of PBL by secondary school institutions (Frey, Fisher, & Allen, 2009; Hung et al., 2008; Savery, 2006), while others are ambivalent about its impact (Ertmer & Simons, 2006; Liu, Wivagg, Geurtz, Lee, & Chang, 2012; Walker et al., 2011).

PBL is one of a suite of techniques that utilise “anchored instruction and project-based science” (Hmelo-Silver, 2004, p. 237). However, a clear definition of what constitutes PBL is elusive (Davis & Harden, 1999; De Graaf & Kolmos, 2003; Gijbels, Dochy, Van den Bossche, & Segers, 2005; Lloyd-Jones, Margetson, & Bligh, 1998; Newman, 2005; Ravitz & Blazevski, 2010). Therefore, it is necessary to identify some key components of PBL and derive from these an operational definition for PBL. A fruitful place to start is the original definition as proposed by Barrows (1996, pp. 5–6), who noted several features of PBL:

- Learning is student-centered;
- Learning occurs in small student groups;
- Teachers are facilitators or guides;
- Problems form the organizing focus and stimulus for learning;
- Problems are a vehicle for the development of clinical problem-solving skills;
- New information is acquired through self-directed learning.

While this description provides a starting point, it also raises some important issues. The first is the role of the teacher/facilitator. Neville (1999, p. 393) stated that “Several controversies have arisen over the optimal role of the faculty person in facilitating a PBL tutorial group.” Haith-Cooper (2000, pp. 268–269) noted that there are different roles for facilitators described in the literature, particularly regarding the style and frequency of the intervention they use. Ertmer and Simons (2006) stressed the importance of facilitators in providing scaffolding to students but noted that it is difficult for teachers to scaffold appropriately for their students. Ertmer and Simons (2006, p. 45) further noted that “Scaffolds may assume multiple forms depending on the learning environment, the content, the instructor, and the learners.” Therefore, even if the teacher will act as a scaffolder, it is difficult to delineate the exact role of the teacher as a facilitator since it will depend on the learning environment. Saye and Brush (2002) described two different types of scaffolding: soft and hard.

The soft-scaffolds, which Saye and Brush (2002, p. 82) stated “are dynamic and situational ... require[ing] teachers to continuously diagnose the understandings of learners and provide timely support based on student responses.” It is not possible to quantify soft-scaffolding with any degree of specificity because it is highly variable and context dependent. For the purposes of this study, the role of the teacher

was to provide students with hard-scaffolding incorporated into the problems presented to them in e-textbooks. Soft-scaffolding then became the responses the teacher provided to immediate student needs while they worked on the problems.

A second issue is the very nature of the problems. Jonassen (2000) listed just two essential features of problems: they are unknown, and they have value. However, Dolmans, De Grave, Wolhagen, and Van Der Vleuten (2005, p. 735) cautioned that developing successful problems is difficult and asserted that “In order to stimulate students towards constructive and contextual learning more complex, realistic, open-ended, and ill-structured problems are needed that fit with students’ prior knowledge.” Davis and Harden (1999, p. 136) noted that the problem scenario should “present basic science concepts ... to encourage integration of knowledge” and “contain cues to guide the student and ... encourage students to elaborate and to search for explanations.” Therefore, designing appropriate problems for secondary school students is a complex task requiring the consideration of many factors.

Finally, as noted by Ravitz (2009), a corresponding learning opportunity for clinical problem-solving skills is not available for secondary school students. Furthermore, there are two aspects to problem-solving: outcome and process. Outcome refers to successfully completing the problem using criteria described by Jonassen (2000) and process means following the procedure in solving the problem, for example, the eight PBL tasks described by Newman (2005). Both the final outcome and the process are important.

While PBL is attractive as a pedagogical approach, its implementation in schools is not without problems. Ertmer and Simons (2006) noted that the change in the roles of the participants and the time required for implementation are areas of

concern. Another area of concern is the ability of teachers to support learners in a PBL environment (Simons & Klein, 2007). This study investigates whether ICT, in the form of e-textbooks, could help overcome, or at least mitigate, some of these concerns. Liu, Wivagg, et al. (2012), noted that while such technological tools are not essential, they can help with some of the issues inherent in implementing PBL in a classroom.

Numerous definitions for the term e-book exist (Borchers, 1999; Dennis, McNamara, Morrone, & Plaskoff, 2015; Maynard & Cheyne, 2005). However, for this study, an e-textbook is defined by the researcher as having the following criteria: it is in digital form, it contains text, graphics and multimedia and it provides interaction with the material it contains.

E-textbooks that satisfy these criteria have several advantages over traditional textbooks. Shiratuddin, Hassan, and Landoni (2003, p. 213) described several features of e-textbooks that are not available in traditional textbooks, including linking different areas within an e-book, use of a variety of media types (audio and movie clips), greater storage capacity and the ability to locate specific content quickly. Furthermore, Dennis et al. (2015, p. 5253) argued that the current students, the so-termed ‘millennials’, who have grown up with a plethora of technical gadgets at their disposal, find traditional textbooks unsatisfactory.

The use of technology, such as e-textbooks, should not be considered separately from the pedagogical framework a teacher may choose to use. Mishra and Koehler (2006) described the evolution of what constitutes teacher knowledge from its origins in an emphasis on content, through content and pedagogy, to content, pedagogy and technology (TPACK). It is the interconnectedness of the three entities

that are important (Mishra & Koehler, 2006; Mishra, Koehler, & Kereluik, 2009). The TPACK model “emphasizes the role of teachers as decision makers who design their own educational technology environments as needed, in real time” (Mishra et al., 2009, p. 52). This emphasis is important for this study where development of e-textbooks is interwoven with a pedagogical approach, PBL, to teach particular content knowledge. This has been termed a digital pedagogy where “digital technologies change the way we teach and promote learning” (Maor, 2017, p. 72).

### **1.3.2 Conceptualisation of the problems**

In its first phase, DBR (Reeves, 2006) requires a conceptualisation of the problem. Within this study, two main problems require consideration: the PBL environment and the use of e-textbooks in the PBL environment. While a number of studies have reported on the success of PBL interventions (Lee & Bae, 2008; Liu, Horton, Toprac, & Yuen, 2012; Schmidt, Rotgans, & Yew, 2011; Vasconcelos, 2012; Wong & Day, 2009) areas of concern remain, especially in the secondary education sector. These concerns include lack of basic skills in students (Ravitz, 2009), their finding problem-solving difficult (Ertmer, 2010), students not collaborating in an efficient manner (Ertmer & Simons, 2006), time constraints (Dahlgren, Castensson, & Dahlgren, 1998), replacing learning with problem-solving (Newman, 2005) and lack of designing good problems (Dolmans et al., 2005). These concerns lead to the clarification of the first problem: While PBL can be a very successful method of teaching, there are some constraints to address so that in secondary education, PBL is a useful tool.

The main Information and Communication Technology (ICT) focus for this study is on the use of e-textbooks. Some studies have reported success in using

e-textbooks (Chau, 2008; Lau, 2008; Maynard & Cheyne, 2005; Sun, Flores, & Tanguma, 2012); however, there are some issues that require resolution. These issues include students being unfamiliar with many of the tools that e-textbooks provide (Dennis et al., 2015), their preference for textbooks rather than e-textbooks (Woody, Daniel, & Baker, 2010), declining enthusiasm among students over time (Lam, Lam, Lam, & McNaught, 2009), a need to consider e-textbooks from a pedagogical and content point of view as well as a technical one (Mishra et al., 2009) and a lack of ICT literacy among students (Katz, 2007). These concerns lead to the clarification of the issue of using e-textbooks for PBL: E-textbooks can be valuable tools for student learning. However, students may not be equipped to utilise these tools and as such may come to prefer the more familiar textbook, especially once the perceived novelty has worn off. Furthermore, in developing e-textbooks, teachers need to adopt a holistic TPACK approach (Lin, Tsai, Chai, & Lee, 2012) that goes beyond just technical concerns.

### **1.3.3 Development of a solution**

The delineation of the problems inherent in this study permits the exploration of potential solutions, which is the second phase of the DBR protocol. The solution, in this case, will take the form of a series of design principles that can be implemented, tested and refined, which is the third phase of the DBR protocol. Initial design principles are presented and elaborated on in Table 1.1. These design principles have led to the development of three research questions for this study:

1. What constraints (if any) inhibited the implementation of the e-textbook-supported PBL intervention?
2. What design features of the e-textbook supported PBL intervention most influenced student learning?

3. What was the overall impact of the e-textbook supported PBL intervention in terms of students':
  - content knowledge;
  - problem-solving skills;
  - transfer of problem-solving skills to other topics.

Table 1.1  
*Initial Design Principles for the E-textbook PBL Environment*

Design principles	Elaboration of design principles
Develop students' basic ICT skills, especially related to e-textbooks	These skills would include note-taking, using bookmarks, search tools and hyperlinks.
Scaffolding problem-solving by providing hard- and soft-scaffolds	Hard-scaffolds are those incorporated, based on prior experience, into the PBL task and e-textbook before students starting it, whereas teachers provide soft scaffolds when needed (Saye & Brush, 2002).
Encourage students to work collaboratively	Students will work in teams and will be introduced to the idea of PBL, the expectations of them in their teams and the roles they will have to perform.
Provide a structure that makes students accountable for collaboration	The students will be assessed on how well they work as a team in completing the PBL tasks.
Develop authentic small scale PBL environments	Owing to the short duration of topics at the school, only small-scale PBL tasks will be developed, but they will be "complex, realistic, open-ended, and ill-structured problems ... [that] fit with students' prior knowledge" (Davis & Harden, 1999, p. 136).
Assess learning as well as problem-solving	The instruments used in this study will evaluate not only students' knowledge but also their problem-solving ability.
Integrate pedagogical and content knowledge into the e-textbook design	The e-textbook design will encourage the development of problem-solving skills as well as provide students with the appropriate content knowledge needed to work on the problem.

## 1.4 Significance of the Research

The significance of this study is that it can contribute to the body of knowledge regarding the implementation of PBL in schools and the use of technology, in the form of e-textbooks, to support such pedagogical initiatives. The DBR model used in this study requires, in the first phase, an "analysis and exploration of ... [the]

problem” (Herrington & Reeves, 2011, p. 597). This study explores an e-textbook supported PBL classroom context, specifically to generate knowledge about the role of ICT in supporting a PBL model. The research seeks to make knowledge contributions to many, if not all, of the following research gaps relating to PBL and the support that e-textbooks can lend to the learning process.

#### PBL research gaps:

- A lack of research on the use of PBL in secondary schools (Veletsianos & Doering, 2010);
- Insufficient information on outcomes that would be appropriate for PBL in secondary schools (Albanese & Mitchell, 1993; Ravitz, 2009);
- Limited knowledge of what guidance is to be provided to students (Ge, Planas, & Er, 2010);
- Conditions under which PBL works or fails to work (Dolmans et al., 2005);
- Forms of PBL that are most likely to be successful (Walker & Leary, 2009);
- Little research on how teachers can prevail over obstacles to using ICT for PBL (Liu, Wivagg, et al., 2012).

While secondary schools have used PBL, more research will inform the application of this pedagogical approach to such educational institutions especially in the area of science education. Furthermore, the use of technology to support PBL and overcome possible implementation hurdles, including the provision of scaffolding and measuring progress, are other fertile areas for research.

#### E-textbook research gaps:

- A lack of literature on the use of e-textbooks in general (Nicholas & Lewis, 2009);
- The preference of students for textbooks rather than e-textbooks (Woody et al., 2010);
- Aspects of e-textbooks that are most useful (Dennis et al., 2015).

The use of e-textbooks developed in situ provides a platform through which to implement PBL. However, it is necessary to ascertain the features of e-textbooks that are useful and ways to encourage their use among secondary students.

## **1.5 Organisation of the Study**

This thesis contains eight chapters. Chapter one provided background and context for this study as well as its significance and purpose. Chapter two presents a review of the literature pertaining to two important aspects of this study: PBL and e-textbooks. Chapter three provides a description of the methodology used in this study including the collection and treatment of the data. Chapters four to six present the results and analysis of each of the three cycles in the DBR process related to the three research questions. Chapter seven discusses major findings from the analysis of results in relation to the three research questions. Finally, chapter eight concludes the thesis, presents the design principles derived from the study and proposes areas for future research.