2018

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

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Chapter Eight: Conclusion

8.1 Introduction

The final chapter concludes the study by discussing the design principles that developed from the Design-Based Research (DBR) process. Principles, such as argumentation and multimodal presentations, form the basis of a model that may be used to develop e-textbooks for secondary school science and possibly other subjects. The chapter also proposes some areas for future research, for example, gender differences in using Problem-Based Learning (PBL) science classrooms and further cognitive tool development.

Chapter Seven raised many considerations from the three cycles of this study. These considerations included how to improve learning outcomes for groups of students, provision of scaffolding, facilitation of problem-solving in students, cognitive tools provided to students and feedback to students. It is from these considerations that the development of design principles for e-textbooks occurred.

8.2 E-textbook Design Principles

This research concerned the in-situ development, deployment and cyclic improvement of e-textbooks to support PBL in secondary school science classrooms. The cyclic improvement of the e-textbooks, through DBR, resulted in eight design principles that this study suggests could be considered when developing e-textbooks for PBL in secondary school science. Through necessity, these principles are not confined to the e-textbook per se but include the PBL environment in which students work and of which the e-textbooks are a significant component. These principles are:

- an e-textbook supported PBL signature pedagogy;
- heterogeneous groupings of students;
- appropriate hard- and soft-scaffolding;
- development of argumentation;
- development of problems appropriate for the students;
- use of multimodal presentations;
- suitable feedback for students;
- technology infrastructure—fit for purpose.

The sections below discuss each of these principles, which when put together, form a coherent signature pedagogy (Shulman, 1987) for secondary school science.

8.2.1 An e-textbook supported PBL signature pedagogy

In discussing the signature pedagogy of e-textbook supported PBL in this thesis, it is important to unpack the term within the context of this study. Within this study, the underpinning principles of a signature pedagogy are (a) that the PBL environment is fluid and (b) that it is subject to modification based on the results of preceding actions. The requirement to modify the pedagogical approach means that facilitators are encouraged to engage in pedagogical reasoning (Shulman, 1987; Starkey, 2010) to ensure that students have access to well-designed learning environments. This design typically will contain a mix of instructional methods including, but not necessarily limited to PBL. Two examples will illustrate this point.

The first example was in the Newton's Laws iteration in cycles one, two and three. The topic covered concepts, including velocity, acceleration, vectors and Newton's Laws. It would have been too time-consuming to use PBL for all of these concepts, and therefore, some concepts were covered in a traditional way. Using a combination of approaches afforded several advantages, including an increase in the amount of time that was available to cover some of the concepts using PBL.

Allowing sufficient time is important when students have not been exposed to PBL before and are coming to terms with the process as well as the concepts (Hoffmann & Ritchie, 1997). Sufficient time also allows for upskilling of students on basic concepts (e.g., manipulating equations to find unknowns) to be applied in the PBL phase. Finally, the determination of potential impediments to successful PBL implementation and their remediation in the hard-scaffolding of the e-textbook are allowed given time. For example, the provision of extra scaffolding in the e-textbook regarding the application of equations to specific problems like acceleration.

The second example was the Chemical Reactions iteration in cycles one and three. This iteration required significantly more background information because of the cumulative nature of the topic of chemistry. For instance, students need to be able to write molecular formulae to explain their results using chemical equations to develop an understanding of different types of chemical reactions. Molecular formula writing requires the use of a periodic table to predict the formation of ions. By teaching these concepts to students, it was again possible to provide more time for them to work on the problems relating to chemical reactions. Furthermore, issues with some students not being able to work with formulae and equations were identified and remediated in the e-textbook through the incorporation of cognitive tools, such as molecular formula and equation writers.

The notion that facilitators have a responsibility to engage in pedagogical reasoning is the first and fundamental component of the signature pedagogy for secondary school science teaching using e-textbook supported PBL. The other seven design principles that follow are pointers that shape this signature pedagogy.

8.2.2 Heterogeneous groupings of students

While the literature is equivocating on ability grouping of students, for example, Hornby and Witte (2014) and Steenbergen-Hu, Makel, and Olszewski-Kubilius (2016), the results of this study support heterogenous groups. Early assumptions regarding students working effectively in groups proved to be overly optimistic. Friendship groups were found to be counterproductive in this research with too much off-task behaviour and little meaningful engagement with the problem. Similarly, homogeneous ability groupings tended to produce groups that were unable to assist each other in a productive way, which led to dysfunction. Heterogeneous groupings were the most efficacious in terms of providing a strong foundation from which productive group interaction could occur. The characteristics of these groups included their ability to work together to achieve a common goal, problem-solving, by interacting in a positive way that supported each member. Heterogeneous groups were found to engage in argumentation and challenge each other's ideas.

8.2.3 Appropriate hard- and soft-scaffolding

The balance between hard- and soft-scaffolding was dynamic throughout this study and dependent upon several factors. Hard-scaffolding integrated into the e-textbook had the advantage of enabling the facilitator to focus on issues that were less predictable and often more transient. However, hard-scaffolds were also inflexible and unresponsive to specific student needs that arose within each iteration. As the study progressed, it was possible to predict some potential issues (e.g., working in groups, applying mathematical formulae and equation writing) and incorporate them into the hard-scaffolds of the e-textbook. Other issues that were specific to particular groups or particular problems were not predictable and could

only be soft-scaffolded. By achieving a balance, albeit a dynamic one, between the two types of scaffolding, it was possible to maximise independent student learning while providing support on an as-needed basis. The balance between hard- and soft-scaffolding ultimately comes down to the skill and judgement of the teacher in supporting the PBL experience of the students.

8.2.4 Development of argumentation

Argumentation is an essential component of group-work in PBL that leads to better understanding of the problem and its solution within the group, but it does not develop spontaneously. Argumentation intrinsically develops in groups, and its enablement by facilitators was of limited use with secondary school students within the context of this study. The promotion of effective group dynamics where students feel able to express their ideas and receive critique about them from others in the group assists the development of argumentation. Prerequisites including researching information, evaluating it and presenting it to others who listen actively and respond in an informed way are important for argumentation to develop in a group. These prerequisites can be hard- and soft-scaffolded in the PBL environment, and argumentation can develop from this environment supported by suitable facilitation. Without the basic prerequisites of effective group dynamics, facilitation of argumentation is difficult.

8.2.5 Development of problems appropriate for the students

The development of problems suitable for students that allow them to engage successfully with PBL is the most obvious and yet one of the most difficult aspects of the PBL environment to accomplish. It is obvious since the problem is essential to the PBL process and it is difficult given the complex design

considerations required in the development of the problems. The problem in PBL does not stand alone but coexists in an ecosystem with the students and their classroom environment. In developing problems, it is necessary to consider their features. Factors such as clarity, familiarity, relevance and the functions of the problem are key considerations. Factors such as the promotion of teamwork, promoting argumentation and stimulating interest are required if problems are to achieve their goal of promoting learning. Consideration of each of these factors can occur within the typology of problems described by Jonassen (2000) to develop a range of problems that can achieve a myriad of different outcomes. In this study, the time available and the readiness of students to engage in PBL limited the types of problems used. However, age-appropriate problem development does provide an area for future research.

8.2.6 Use of multimodal design

One clear advantage of a technology-based PBL platform is that it can present the problem and scaffolding for students using a variety of modes and as such, the differing learning styles of the students may be accommodated. For example, problems can be presented to students using visual, audio and text-based modes. An e-textbook format has the added advantage of being easy to develop in-situ and, as such, the particular requirements of each institution can be considered and the e-textbook tailored to meet them. There is the potential for an initial misunderstanding to develop as to the purpose of the e-textbook when students first encounter them. The misunderstanding stems from their use of traditional textbooks, which have a different function to the PBL e-textbook. Traditional textbooks present information to students for them to assimilate with a set of questions to check for understanding of the content. PBL e-textbooks require students to find information

for themselves and to evaluate their own understanding. However, continued use and appropriate scaffolding incorporated into the e-textbook can mitigate this effect.

8.2.7 Constant feedback for students

Students should receive constant feedback on their learning within the PBL environment so that they are able to monitor their progress, test for prior knowledge and identify any misconceptions. Diagnostic tests that identify student strengths and weaknesses allow each student to have specific feedback. By using e-textbooks, this feedback can be tailored to individual needs and can be extended to provide remediation as required. Furthermore, the feedback can use different modes that suit the learning styles of each student, which may amplify its effects.

8.2.8 Technology infrastructure – fit for purpose

Schools use a variety of network systems and have different policies regarding technology purchased by students. Some schools allow students a wide range of choice in the technology they bring to the classroom, while others are more prescriptive about what is allowed. The use of a network system that is as cross-platform as possible is a desirable feature of the e-textbook design. By using one platform, it is possible to combine Flash animation, VBScript, ActionScript and artwork into a single deliverable package for students. Students can access this package either over a network via a server or installed locally on the laptops. However, the large range of laptops, with various OS software, available to students in the school in the current study meant that the goal of a true cross-platform system was out of reach. Such constraints may not be the case in other schools.

8.3 Implications for the Future of E-textbook Supported PBL

The production of in situ e-textbooks that are responsive to the needs and capabilities of students and their teachers holds great promise. To provide the means whereby PBL instruction can be tailored to suit the learning environment in which it occurs will be a strength of the e-textbook. Unlike other web-based programs, for example, Alien Rescue (Liu, Horton, et al., 2012), which require teams of programmers and designers, e-textbooks can be developed in the schools and used by the practitioners, who would require only simple programming skills. As such, they can undergo development that is responsive to the needs of students and teachers in various schools. The e-textbook format also allows students to work in both the virtual and physical worlds with support for working in groups, problem-solving and researching provided to students working with real-world problems.

8.4 Suggestions for Future Research

The use of computers in secondary schools continues to rise with increased emphasis on their use in education (Thomson, 2015). However, the use of ICT is still a multifaceted issue that is difficult for educators (Kaouri, 2017). Nevertheless, such technologies have “the potential to accelerate, enrich, and deepen skills, to motivate and engage students” (Noor-Ul-Amin, 2013, p. 39). Thus, there is the potential to achieve great things if there is the research for educators to draw upon as they strive to integrate ICT into their classrooms. The necessity for a sound research base that reflects real-world classroom issues is imperative if effective use is to be made of the technology available at present. Some suggestions for future research that integrate ICT, in the form of e-textbooks, with PBL are discussed below.

First, more studies in the area of gender could provide useful insights as to how males and females do or do not differ in the PBL environment and how e-textbooks could assist different genders in learning through PBL. While research regarding gender differences is extant in regard to PBL in university education (Du, 2011; Hirshfield & Koretsky, 2017; Pease & Kuhn, 2011), there is less literature available in secondary school settings. Consideration of gender differences would greatly assist in ameliorating any inequalities that may exist between males and females using PBL in secondary school science classes.

Second, the use of e-textbooks in different subject areas would provide a wider scope for their use in secondary school classrooms. Tay, Lim, and Lim (2015, p. 92) note that "the subject area is also a possible factor that affects ICT integration and usage in schools." Given that different subjects can affect the use of ICT, of which e-textbooks are an example, it could prove enlightening to investigate their use in a subject such as economics, mathematics, English and other disciplines. Such research would enable the development of a wider range of e-textbooks created through a broader knowledge base of teachers.

Third, the creation of e-textbooks in-house, where their applicability to specific learning environments is assured, requires the ability and willingness of educators to develop such e-textbooks. Wastiau et al. (2013) reported that teachers' confidence and attitude towards ICT use influenced student confidence and attitude towards ICT. While such correlations are important, it is also necessary to determine why teachers tend not to use ICT in classrooms. Chen (2008) noted that:

> Educational reform may encourage teachers to integrate technology to engage students in activities of problem solving, critical thinking, and collaborative learning, but a culture emphasizing competition and a

> high-stakes assessment system can strongly discourage teachers from undertaking such innovative initiatives. (p. 73)

Fourth, while teachers may be willing and able to use ICT as required by the Australian Curriculum (ACARA, 2015a) for PBL, there are barriers that affect its adoption. Thorsteinsson and Niculescu (2013, p. 320) described some of these barriers where "the teacher had to adopt multiple roles, including … solving any technical problems, in terms of both hardware and software, teaching fundamental skills and training students." Research into how teachers can be supported in the classroom to develop and use ICT tools like e-textbooks could benefit those who wish to engage in meaningful ICT integration but face numerous hurdles.

The further development of cognitive tools for use in e-textbooks to support PBL could facilitate and enrich the inquiry process. Importantly, cognitive tools can allow students to engage in activities that would not normally be possible or accessible to secondary school students as in Alien Rescue (Liu et al., 2014) where, for example, students can design and launch probes to other planets. Such tools can also be used to fill gaps in students' prior knowledge and support their acquisition of new knowledge. The continued production of improved cognitive tools for inclusion in e-textbooks will enhance their ability to support PBL in secondary schools.

Finally, it would be useful to research whole school initiatives to support PBL. Such research would not only involve science teachers but practitioners across all fields. The advantage of such a development would be the creation of a bespoke PBL program suited to the needs of students, with a uniform approach across all disciplines within the school.

8.5 Concluding Comments

Chapter eight has included a description of the design principles of e-textbooks derived from the research conducted for this thesis. These design principles relate not only to the e-textbook itself but the wider environment in which PBL takes place. Some suggestions regarding further possible research areas were put forward in relation to improving e-textbooks and embedding a problem-based approach to secondary school classrooms.

This longitudinal study was conducted over four years using students in Year 10 studying various topics in science. A variety of instruments were used to determine the effect of e-textbooks on the ability of the students to learn science concepts using PBL. These tools provided authentic feedback that accurately reflected changes in students learning as the e-textbooks evolved.

In producing e-textbooks for secondary school science students, it was possible to develop in students the ability to work collaboratively on problems with the teacher acting as a facilitator. The process is not straightforward and requires constant refinement and re-evaluation of what is happening in the classroom. As such it will remain a work in progress since new students arrive with different abilities, skills and goals. The flexibility of the e-textbook developed in-situ is an asset in this situation.

Finally, with the use of technology in schools increasing, the harnessing of tools like e-textbooks affords future generations of students the chance to learn and develop skills important in the 21st century. The development of e-textbooks allows teachers the opportunity to create bespoke educational material that is relevant to

their students, develops the skills of the students and instils in them an inquiring mindset. Such developments will be to the benefit of future generations.

8.5.1 A Personal Reflection on the Study

During the course of this study, I have become convinced that PBL is an important tool that can be utilised to improve student engagement and understanding in science. The initial difficulties in incorporating PBL were frustrating but underscored the important point that careful review and refinement of teaching practises is necessary to improve education. I remain convinced that a pragmatic approach is the best one to use in teaching science as it relies on evidence-based decision making. Pragmatism allows for the incorporation of many different teaching strategies based on student needs and constraints that exists in today's classrooms.