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

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Chapter Four: Cycle One—Results, Review and Implications

4.1 Introduction

Tzu (2012, p. 133) stated “a journey of three thousand miles begins with one step” and so it was with this study. Cycle one was the first step on a journey to answer the three important questions regarding the use of e-textbooks to support Problem-Based Learning (PBL) in secondary school science classrooms. Those questions relate to e-textbook supported PBL interventions and were concerned with their design features, their impact on students and the constraints in using them in secondary schools. The results from the focus group interviews, PBL Evaluation Tool responses, informal classroom observations and Strobe Protocol observations were used to identify common themes that related to the research questions. The themes arose through analysis of pre- and post-PBL Evaluation Tool data, coding of the student responses to the intervention tools and a review of the focus group interviews.

4.2 The Cycle One Environment

Cycle one involved two Year 10 Science classes and covered two topics: Physics (Newton’s Laws) and Chemistry (Chemical Reactions). Forty-five students comprised the two classes, of which 24 took part in the study with the permission of their parents. Each topic lasted five weeks, and each was a specific topic covered by Year 10 students as part of the Australian National Science Curriculum. The students comprised 53% of the year cohort and selection occurred by achieving a combined score on tests and an examination of not less than 34% and not greater than 66%. The top 37% and the bottom 10% were removed to other classes since this was the policy

of the Science Department at the school at the time of this first iteration. There were four lessons per week consisting of two 80-minute periods and two 40-minute periods. The students worked on the problems in science laboratories where standard scientific equipment was available to them. Each student had access to a laptop from which they worked with the e-textbook in groups of four or five individuals.

4.3 Themes Arising from the Analysis of the Data

The analysis of the data from the two iterations of cycle one highlighted 18 different themes related to the research questions that this study attempted to answer. Table 4.1 presents the research questions, the themes that arose from the data's analysis, identification of the source of the themes from the various data tools and the source of the data in the appendix.

Table 4.1
A Summary of the Themes Identified in the Data from Student Responses by Research Question.

Research question	Themes	Data collection component	Data source in appendix A1.1 and A1.2
1. What constraints (if any) inhibited the implementation of the e-textbook supported PBL intervention?	Inadequate scaffolding	PBLETK	Table A1.5
		PBLETPME	Table A1.9, Table A1.10, Table A1.12, Table A1.27, Table A1.33 & Table A1.34
	Group dysfunction	FGI NL1	Question 4
		FGI CR1	Question 3
		ICO	25/08, 26/08, 28/08, 29/08 & 30/08
	Distraction	FGI NL1	Questions 1 & 6
		ICO	26/08, 09/09, 12/09 & 13/09
	Copying	FGI NL1	Question 7
		FGI CR1	Question 9
		ICO	28/08 & 03/09
	Nature of the Topic	FGI NL1	Question 1
		ICO	28/08 & 05/11
	Technology infrastructure	PBLETSE	Table A1.14
		FGI NL1	Question 1
		FGI CR1	Question 1
		FGI NL1	Question 7
		ICO	23/08, 26/08, 29/08 & 13/09
	Student expectations of teacher	FGI NL1	Question 8
		FGI CR1	Questions 3 & 4
		ICO	26/08, 28/08, 03/09 & 04/09
e-textbook design	ICO	26/08, 28/08, 04/09 & 08/11	
Prior knowledge	PBLETK	Figure A1.16	
	ICO	24/10, 05/11 & 07/11	

(continued)

Research question	Themes	Data collection component	Data source in appendix A1.1 and A1.2
2. What design features of the e-textbook supported PBL interventions most influenced student learning?	The topic	PBLETSE	Table A1.14
		FGI NL1	Questions 1 & 3
	Practical focus	PBLETSE	Table A1.16 & Table A1.38
		FGI NL1	Question 9
		FGI CR1	Question 1
	Group participation	FGI NL1	Questions 2 & 6
		FGI CR1	Question 6
		SPO	Table A1.21 & Table A1.40
	Feedback	FGI NL1	Question 7
		FGI CR1	Question 9
3. What was the overall impact of the e-textbook supported PBL interventions?	Content knowledge	PBLETK	Figure A1.7, Figure A1.16, Table A1.1, Table A1.2, Table A1.3, Table A1.4, Table A1.24, Table A1.26, Table A1.28, Table A1.29 & Table A1.30
	Misconceptions	ICO	23/10, 24/10 & 07/11
	Application of knowledge	PBLETK	Table A1.6, Table A1.11, Table A1.12, Table A1.14, Table A1.24, Table A1.25, Table A1.28 & Table A1.29
	Planning, monitoring & evaluation	PBLETPME	Table A1.12, Table A1.34, Figure A1.10 & Figure A1.13
	Student engagement	PBLETSE	Table A1.4, Table A1.5 & Table A1.6
		ICO	22/10, 23/10, 24/10 & 13/11
		SPO	Table A1.21

Note. FGI NL1 refers to focus group interview—Newton’s Laws, FGI CR1 refers to focus group interview—Chemical Reactions; ICO refers to Informal Classroom Observation, SPO refers to Strobe Protocol Observations, PBLETK refers to PBL Evaluation Tool-Knowledge, PBLETPME refers to PBL Evaluation Tool-Planning, monitoring and evaluation and PBLETSE refers to PBL Evaluation Tool-Student engagement

4.3.1 Themes relating to research question one arising from the analysis of the data: constraints

To not expect difficulties to arise while developing and implementing an e-textbook supported PBL intervention would be irresponsible, and so, the

identification of these difficulties was of paramount importance. The difficulties that the data highlighted included:

- inadequate scaffolding
- group dysfunction
- distraction
- copying
- nature of the topic
- technology infrastructure
- student expectations of teacher
- e-textbook design
- prior knowledge.

It was possible to group these themes into three broad categories that could be considered together owing to the similar underlying characteristics. Table 4.2 details these categories.

Table 4.2
Themes Contained in Each Category for Research Question One

Categories	Themes
Learning constraints	Group dysfunction Distraction Prior knowledge Copying Nature of the topic Student expectations of teacher
Pedagogical constraints	Inadequate scaffolding
Technical constraints	E-textbook design Technology infrastructure

4.3.1.1 Learning constraints

The criteria for inclusion in this category were any factors that affected the students' acquisition of knowledge and skills. These factors related to constraints that

the students should have been able to mitigate through their actions or interactions, but which they did not do for a variety of reasons.

4.3.1.1.1 Group dysfunction

Students working together in small groups is one of the main requirements for PBL (Dolmans et al., 2005), and in such settings, a crucial requirement is a collaboration between group members (Webb, 1982). Furthermore, Gillies (2004) demonstrated that students taught how to work in groups worked better than those who did not receive any instruction in how to work in groups.

Not all groups in the Newton's Laws iteration were cooperative, and they lacked the ability to work collaboratively. In some groups, there was no active involvement of some members while others were a source of distraction within the group. A student summed this situation up by saying "when it came to designing the rocket most of the group just switched off except for [name deleted] and I, and we were pretty much ... we were focused, we were knowing what we were doing where others were just playing Minecraft and just doing whatever they wanted" (FGI NL1 S6). Another student commented that "when you're in a group you sort of get a bit off put sometimes. You get a bit distracted especially when I don't know because we all like had to work together sort of thing, but other people in my group don't really work" (FGI NL1 S3). The Informal Classroom Observations also provided examples of inadequate student collaboration and unwillingness to organise and engage with the problem (ICO 26/08, 09/09, 12/09 and 13/09). The students were still dependent on the teacher to provide direction and motivation.

The Chemical Reactions iteration did not encounter the same level of group dysfunction as seen in the Newton's Laws iteration. This lack of dysfunction was not

surprising given that the students had already experienced one iteration of group-work and were able to work more collaboratively this time. Furthermore, groups for the Chemical Reactions iteration were assigned randomly rather than on friendship, which students found to be a preferable way of allocating groups. When asked in the focus group interviews about how they worked in teams, all of the students responded that they preferred this method of group allocation. One student noted that “I actually liked being put [emphasis added] into different groups” (FGI CR1 S1) and another summed up the group’s feelings by stating:

I felt like I was doing this program, Chemistry or whatever you want to call it, I was going to make sure I was participating in my group and I wasn’t going to slack out or anything like that like I wanted to help my group and have equal jobs I guess you’d call it. (FGI CR1 S3)

4.3.1.1.2 Distraction

When students use computers in a classroom, there is a tendency for inappropriate use. An example of this is playing games which can provide, at least from the teacher’s point of view, an unwelcome distraction from the learning experience the computers were supposed to encourage (Bate, Macnish, & Males, 2014).

This type of distraction was another constraint that was evident from the data during the Newton’s Laws iteration. Students playing games and socialising rather than focusing on the task at hand was observed during the lessons and commented on by students in the focus group interview. For example, one student commented that “Several in our group didn’t really do anything, just playing games the whole time” (FGI NL1 S5) and another stated that “it wasn’t that good having it on the laptops though because everyone just plays games” (FGI NL1 S3). This

particular PBL intervention required students to work on problems effectively as a group and anything that distracted them from this objective clearly constrained the achievement of any learning. However, this problem did not only occur in this class with students commenting that the issue arose in other classes that were not part of this study.

The issue with gaming distracting students occurred in the Chemical Reactions iteration as well. In the focus group interview, one student noted that “I know that there were a few others that definitely spent more time playing games” (FGI CR1 S5) and another commented that “Yeah there was like three playing games most of the time” (FGI CR1 S1). This issue was related to the fact that students were using their laptops extensively in the iteration, and this provided an easy way for them to become distracted. As one student noted, “It was easier to get distracted doing other things on your laptop” (FGI CR1 S1).

4.3.1.1.3 Prior knowledge

While it was not an issue in the Newton’s Laws iteration, there was a necessary assumption in chemistry that students had mastered previous information taught to them on the topic before commencing the next topic. It was necessary because it was not possible to continually revisit previous concepts while teaching the next topic. For example, when teaching chemical reactions, it was assumed that students could write chemical formulae for compounds and balance chemical equations. In the PBL Evaluation Tool, assessment of chemical reactions knowledge occurred initially with four multiple-choice questions with three choices in each question. Figure A1.16 shows the percentage of correct choices for each question. A Wilcoxon Signed Rank two-tail test for paired samples was performed on this data, and there was no significant difference between the pre- and post-intervention scores

($\alpha = .05$, $p = .226$). The four multiple-choice knowledge questions results showed no improvement in student understanding; however, they also did not show any detrimental effects of using e-textbooks and PBL to learn about chemical reactions. Thus, it was reasonable to conclude that the use of e-textbooks and PBL had a neutral effect using this measure. This lack of any significant impact may be owing to the students' inability to maximise their learning in this iteration because of a lack of the prior knowledge needed to engage successfully with the material presented. For example, students found it difficult to identify particular reactions despite learning chemical reactions the previous year (ICO 24/10). Students were also unable to identify important pieces of evidence from their reactions to use in their reports (ICO 05/11). Finally, students tended to 'go through the motions' of doing the experiments and were not able to explain why they were doing them (ICO 07/11).

4.3.1.1.4 Copying

Copying is one form of cheating (Lin & Wen, 2007), and cheating has increased in academic institutions including secondary schools (McCabe, Butterfield, & Trevino, 2012). During the Newton's Laws iteration, students copied the answers to questions in their e-textbook from other members of their group, which would not help them learn the material since they were not actively trying to assimilate new knowledge. Students in the focus group interviews made comments like "one person did something and then everyone else copied" (FGI NL1 S4) or "we did like a section each then we just all copied it, so I only know the section I did, like I don't know all the other stuff" (FGI NL1 S3).

Not all of the causes listed above were relevant in this case. For example, Figure A1.10 shows that 79% of students, pre-intervention, and 65%, post-intervention, believed that the task they were working on was useful, which

argues against task importance being a factor. Since Figure A1.13 shows that 54% of students, pre-intervention, and 65%, post-intervention, were confident of being able to complete the task, this also allowed the disregarding of self-efficacy. However, the lack of peer pressure to resist copying during this intervention, as illustrated by the students' comments in the focus group interview, was an important factor.

However, this result needed to be considered within the context of the PBL environment in which it took place. PBL emphasises collaborative group-work with students engaged in a cooperative learning effort. Students may, therefore, have seen copying each other's work simply as a manifestation of such cooperation. Hence, students needed to be aware of when collaboration was appropriate and when it was not appropriate.

During the Chemical Reactions iteration, students were also copying from each other. However, this was mainly for the writing up of the experiments they performed for each problem they worked on (ICO 05/11). While this was more understandable from the student's perspective since they all worked to produce the result, it was still undesirable from a teacher's perspective because there was a need to provide results for each student individually.

4.3.1.1.5 Nature of the topic

The Newton's Laws iteration covered motion and used the designing and building of rockets as a tool to facilitate and motivate students' learning of these laws. However, it was clear that the students saw rocket building as the topic rather than learning about Newton's Laws. When asked what motivated them in this topic, 67% of students, pre-intervention, and 75%, post-intervention, indicated that it was the rocket (see Table A1.14). This fixation of the students on the learning activity

used rather than the concepts that the vehicle was attempting to convey was a significant constraint on implementing PBL. When asked about what they liked about the topic, one student responded that “Well I definitely liked building the rockets, but I think filling out the workbook we might have sort of got off the topic a bit” (FGI NL1 S4).

A different situation arose in the Chemical Reactions iteration. Students have a perception that chemistry is theoretical and unrelated to the real world (Kubiatko, 2015) and they have difficulty with its abstract nature (Tatli & Ayas, 2013). As such, students tend to bring a negative attitude to chemistry, which affects their performance and approach. As one student bluntly put it when asked about the topic in the focus group interview “I just don’t like Chemistry” (FGI CR1 S4).

4.3.1.1.6 Student expectations of the teacher

Students have perceptions about teaching, and this is often a reflection of previous experiences. In both the iterations considered here, they expressed the desire to be provided with notes to help them learn rather than learning the information themselves. The transition to a new model where the students were largely responsible for their learning in the Newton’s Laws iteration came as a culture shock to many of them. The students still expected the teacher to be the source of all information. They did not have confidence in their group members and preferred to work alone. One student commented in the focus group interview that while the e-textbook helped “even though it was help, but it wasn’t like Mr Stewart’s help. Like Mr Stewart helped you along” (FGI NL1 S2).

This situation did not change in the Chemical Reactions iteration. For example, when asked in the focus group interview whether PBL was better or worse

than other methods one student responded that “we probably, I think we are just kind of used to taking notes and it probably is because it is a good way of learning” (FGI CR1 S1). Another student commented that “The problem with the studying because you didn’t know what you were having to study like what you were looking for if it was the correct information or not” (FGI CR1 S5). When asked if they learned more using the PBL method, one student responded: “I think learnt a bit more with the traditional method” (FGI CR1 S1).

4.3.1.2 Pedagogical constraints

A definition of pedagogy is the “instructional techniques and strategies which enable learning to take place. It refers to the interactive process between teacher and learner, and it is also applied to include the provision of some aspects of the learning environment” (Siraj-Blatchford, Sylva, Muttock, Gilden, & Bell, 2002, p. 10). As such, it is outside the learner’s direct sphere of influence and therefore beyond their immediate control. This inability of the learner to directly influence these factors delineates the pedagogical constraints discussed below from learning constraints.

4.3.1.2.1 Inadequate scaffolding

Scaffolding is an important aspect of the design for students new to PBL (Land & Hannafin, 1997) and can take two forms when used in e-textbook design: hard and soft (Saye & Brush, 2002). Hard-scaffolding can be ‘hardwired’ into the e-textbook whereas soft-scaffolds, which are described by Saye and Brush (2002, p. 82) as “dynamic and situational”, rely on the teacher to provide support on a needs basis.

Scaffolding, or the lack of it, was a major issue with students using the e-textbook in a group-work situation in the Newton's Laws iteration. Although nascent in many of the results, a perusal of the classroom observations crystallised the problem. Groups were unsure of the PBL process and had difficulty organising themselves in their groups to work on the problem. Assumptions regarding students being able to solve problems naturally and work efficiently in a group were overly optimistic.

It was interesting to note that student responses to questions in the PBL Evaluation Tool regarding organising groups and evaluating progress indicated that they knew how to work effectively in groups. For example, all students, pre-intervention and post-intervention, were able to provide some strategy for allocating time to tasks in groups (see Table A1.9) and 72%, pre-intervention, and 76%, post-intervention, could provide a strategy for evaluating their group's progress (see Table A1.10). When asked about evaluating how they were performing on a task, all students, pre-intervention and post-intervention, were able to provide a viable strategy (see Table A1.12) and all students could provide a strategy for allocating tasks to group members (see Table A1.5). However, when the students were working in their groups, it became evident that they were not able to put into practice many of the strategies they had articulated in the PBL Evaluation Tool. When asked about the PBL style, one student responded that "because I kind of feel, like I don't know, when we were learning about building the rockets, we kind of had to teach ourselves sort of thing." (FGI NL1 S3). Another commented that "Yeah, how [the teacher] probably could have done something about just to get us all into it instead of just being thrown in and like Yeah, we're going to build a rocket, and yeah" (FGI NL1 S4). The Informal Classroom Observations indicated that a large

amount of soft-scaffolding was required, especially at the start of the iteration, and that the hard-scaffolding provided by the e-textbook was ineffectual in equipping students to engage successfully in PBL.

In the Chemical Reactions iteration, students found it difficult to complete their reports, organise the equipment in their kits and find additional information when required. Once again students were able to articulate ways to allocate group members to a task (see Table A1.27), evaluate group progress (see Table A1.33) and evaluate task progress (see Table A1.34).

4.3.1.3 Technical constraints

All of the interventions required significant levels of infrastructure support to work effectively. Ritzhaupt, Liu, Dawson, and Barron (2013) and Liu, Horton, et al. (2012) noted that appropriate technical infrastructure must be available for students to use ICT effectively. Kim and Jung (2010) stated this was an important requirement specifically for e-textbooks.

4.3.1.3.1 E-textbook design

The e-textbooks themselves provided constraints on the PBL intervention implementation. Design issues, which included allowing students to skip ahead in the e-textbook, inability to play videos and students not saving work, all worked against the successful use of the e-textbook (ICO 26/08, 28/08, 04/09 & 08/11).

4.3.1.3.2 Technology infrastructure

Issues with technology were ubiquitous in the intervention and created much frustration among the students. In some cases, the students did not save their work regularly or not at all. However, the school's network clearly was unable to cope with the demands of 25 students accessing their e-textbook from the server. The

predominant issues involved loading e-textbooks and saving work. For example, students had to wait up to 10 minutes to load their e-textbook, and once these were loaded, they were unable to play the embedded videos (ICO 23/08). One student commented in the focus group interview that “I didn’t think mine worked. Everyone in my group they all got mixed up, like they kept losing it” (FGI NL1 S3). Students were constantly losing their work that they had saved in the previous lesson (ICO 13/09). The issues experienced in the Newton’s Laws iteration were largely resolved and therefore not evidenced in the Chemical Reactions iteration.

4.3.2 Themes relating to research question two arising from the analysis of the data: features of the e-textbook supported PBL intervention

In trying to develop a successful model for the use of PBL in science classrooms using e-textbooks, it was important to determine what factors most influenced student learning. A review of the results identified four themes: the topic, practical focus, group interaction and feedback. It was possible to group these themes into three broad categories that could be considered together owing to the similar underlying characteristics. Table 4.3 details these categories.

Table 4.3
Themes Contained in Each Category for Research Question Two.

Categories	Themes
Facilitation features	Practical focus
Interaction features	Group interaction Feedback
Enjoyment	The topic

4.3.2.1 Facilitation

Facilitation is taken to mean any feature of the interventions that assisted students in learning from the problems presented to them. The hands-on nature of the

problems together with a self-paced progression through each problem were features that students found helped them. The multimodal presentation of the problems to students also facilitated their learning.

4.3.2.1.1 Practical focus

The data were unequivocal in showing that students enjoyed the practical focus approach that both iterations afforded them. The teaching of physics and chemistry has traditionally been from a theoretical perspective with minimal practical work. Students appreciated the change.

When asked whether this activity would be enjoyable in the Newton's Laws iteration, only 15% indicated that it would be because it was a hands-on activity, but 50% gave the same response post-intervention (see Table A1.16). When asked the same question in the Chemical Reactions iteration, pre-intervention, 17% said it would be enjoyable because it was a hands-on activity and post-intervention, 56% (see Table A1.38). In both cases, students were not expecting a large amount of practical work that they encountered, and they found this to be a motivating factor. The focus group interviews substantiated the motivational effect of the practical work. Student statements referred to the practical nature of the iterations in their comments. For example:

It was interesting to find out how everything worked. It was like I said before, if it was something, chemistry, physics, you know it wouldn't ... and something hands-on that we got involved in and be interested in and having worked. It was more that you wanted to work it to find out, "Oh this is how it works."(FGI NL1 S6)

We did a few on precipitation reactions, oxidation reactions those sort of things that was really good 'cause we've never we've done lots of study from textbooks and theory work but never really hands-on stuff so that was good to do. (FGI CR1 S1)

4.3.2.2 Interaction

Interaction included any feature that involved students communicating with each other or the e-textbook. Feedback to students using tests and targeted support in areas that required remediation was one type of interaction. The second type of interaction involved the students interacting and supporting each other in groups.

4.3.2.2.1 Group interaction

Group interaction was crucial to the successful implementation of this model of PBL using e-textbooks (Dolmans et al., 2005; Webb, 1982). As mentioned previously, there were issues with some groups in the Newton's Laws iteration. However, other students found their groups helpful and they were well organised to carry out the tasks required. Within these groups, there was considerable use made of the individual talents of their members, and this benefited all members of those groups. When asked in the focus group interview about their problem-solving skills students indicated that group-work was a major factor. For example:

Yeah, for sure because, especially working in the team, I thought that was probably the best thing about it all because you'd get, you wouldn't just get one person's opinion, if you know what I mean, you'd have a whole, well in my group it was four people with me, so you'd have three other opinions and that was always good. (FGI NL1 S1)

Just really working with like a team and a group of four that you really got a lot of different opinions and perspectives, and you could help one another out, you could figure things out together. (FGI NL1 S2)

Furthermore, when students were asked specifically how they worked as a team, one student clearly felt that the group-work approach was better:

Yeah, I think that if we all did it by ourselves, we probably wouldn't have learned as much about every single basis, because I think by yourself if you're confused about something, you'd have to go and kind of figure it out yourself, but in a group one person might be amazing at it and they can explain it to everyone else. (FGI NL1 S5)

In the Chemical Reactions iteration, students enjoyed the social aspects of working in groups and found the support it provided beneficial; however, some groups were more functional and cohesive than others. All of the students in the focus group interviews felt that they worked better in groups in the Newton's Laws iteration. The fact that students did not choose their groups for the Chemical Reactions iteration was a positive factor in this result. The students also had a more mature approach to their group-work as well. When asked in the focus group interview about how they worked as a team, two responses illustrated this maturation of the students:

I felt like I was doing this program, Chemistry or whatever you want to call it, I was going to make sure I was participating in my group and I wasn't going to slack out or anything like that like I wanted to help my group and have equal jobs I guess you'd call it good. (FGI CR1 S3)

The first test [Newton's Laws iteration] was a bit of a wake-up call coz [sic] you did all the work then some bits you'd slack off a bit, then when you got the test back it sort of woke me up a bit to do a bit better in the second chemistry. (FGI CR1 S3)

4.3.2.2.2 Feedback

Students rightly expected feedback on how they were progressing through a topic and how well they understood the material they needed to learn. The provision of feedback to students occurred through questions in the e-textbook and by the teacher in the classroom. One student described succinctly how the e-textbook worked:

In the e-textbook if you get one wrong it would cross, but it would tell you what was wrong about it and they sort of give a small little hint about what one's right and what one's wrong, and that was a lot better than just trying to figure it out yourself. (FGI NL1 S5)

This type of feedback was what the e-textbook design was trying to achieve.

In the Chemical Reactions iteration, the positioning of the questions changed. Instead of being at the end of each subtopic they were at the end of a set of problems. This repositioning was owing to the e-textbook format changing from presenting one problem to the students to presenting a number of smaller problems. It was decided to provide feedback after they had completed a set of problems that were on a similar theme. This change proved to be a mistake. When asked about the what aspects of the e-textbook affected their learning, one student responded that:

I think as [named deleted] mentioned before with when you went to study the questions were at the end of the e-textbook whereas if you're reading a normal textbook after each thing you have learnt there is a list of questions and writing those out you're actually taking it in and you're able to identify things that might be in the test so that definitely helps like on the way rather than just learning it learning the next thing, learning the next thing and then having a list of questions at the end. (FGI CR1 S3)

4.3.2.3 Enjoyment

The enjoyment of science has been defined as “the extent to which a student enjoys science class” (Wang & Berlin, 2010, p. 2418). Some factors affect science enjoyment, including a student’s value of science (Ainley & Ainley, 2011), interest in science (Osborne, Simon, & Collins, 2003) and practical work (Bennett & Hogarth, 2009). In this study there was a difference in the students’ enjoyment between the two topics; Newtons Laws and Chemical Reactions.

4.3.2.3.1 The topic

The topic was important to the students in the Newton’s Laws iteration and provided them positive engagement. When asked how they motivated themselves, 29% of students, pre-intervention, and 46%, post-intervention, responded that it was the topic that provided the motivation (see Table A1.14). Furthermore, 38%, pre-intervention, and 29%, post-intervention, responded to the same question by

saying that a good result was the main motivator. A perusal of these responses indicated that the rocket was the result they were referring to in their responses. For example, one student responded that “I didn’t want it to not fly, so I thought of that.”

The focus group interviews reiterated the motivating effect of the topic where students commented that “Well I definitely liked building the rockets” (FGI NL1 S4) and “The topic had a lot to do with it, I guess, too. If it was something to do with flowers I don’t think we would have really been focused” (FGI NL1 S6). However, as mentioned earlier, it should not have become the whole focus of the iteration, but rather a means to an end.

In the Chemical Reactions topic, students did not find the topic as enjoyable as the Newton’s Laws iteration. In the focus group interviews one student noted that “I didn’t particularly enjoy it that greatly, I think I found it quite difficult” (FGI CR1 S3). Another student put it more succinctly “I just don’t like chemistry” (FGI CR1 S4). However, there were aspects of the topic that students did find enjoyable, particularly the practical problems. One student noted that “With the experiments you can do them however you wanted and you didn’t have to follow constantly the teacher and what they were doing” (FGI CR1 S5). There was an appreciation of the freedom to work on problems without following a given procedure. This is important because it is one of the central ideas of PBL.

4.3.3 Themes relating to research question three arising from the analysis of the data: overall impact

The instruments used in this study also evaluated the overall impact of the PBL intervention on the students, and analysis of the data identified six areas of interest:

- content knowledge
- misconceptions
- vocabulary
- application of knowledge
- planning, monitoring and evaluation
- student engagement.

4.3.3.1 Content knowledge and its application

The effect of the Newton’s Laws iteration on student knowledge was neutral with no significant improvement in student content knowledge occurring after the iteration. Figure A1.1 shows the percentage of correct choices for each question. A Wilcoxon Signed Rank two-tail test for paired samples performed on this data showed no significant difference between the pre- and post-intervention scores ($\alpha = .05$ $p = .137$). This lack of improvement in the student’s content knowledge was a cause for concern since the intervention was designed to improve such knowledge. However, this was contradicted when students had to circle up to six words in the list provided to them that they thought related to Newton’s Laws and rocket design, but about which they had no actual knowledge. Figure A1.4 shows the results of the students’ words choices. There was a noticeable difference pre- and post-intervention. In each case, fewer words had been circled post-intervention. A possible conclusion from this information is that the students understood the relevance and meaning of these terms. Since students used many of these terms in their responses to other questions (see Figure A1.7 for example), it was reasonable to conclude that they had gained an understanding of these terms.

When asked specific questions related to Newton’s Laws, the student responses indicated some improvement post-intervention in most of the areas with the exception being recognition of an application of Newton’s Laws. For example,

student's ability to explain an application of Newton's Laws both generally and specifically in relation to rocket efficiency only showed modest improvement. Applying Newton's Laws to rocket design did show a greater improvement, but this was from an already high initial result. Table 4.4 details the number of correct responses, pre-intervention and post-intervention.

Table 4.4
Percentage of Correct Student Answers to Questions Regarding Newton's Laws Pre-intervention and Post-intervention

Topic	Source	Percentage correct	
		Pre-intervention	Post-intervention
Recognition of an application of Newton's Laws	Table A1.1	17	14
Explaining an application of Newton's Laws	Table A1.2	24	46
Applying Newton's Laws to rocket design	Table A1.3	56	74
Applying Newton's Laws to rocket efficiency	Table A1.4	14	35

The effect of the Chemical Reactions iteration on student knowledge was also disappointing with no significant improvement in content knowledge occurring after the iteration. Figure A1.16 shows the percentage of correct choices for each question. A Wilcoxon Signed Rank two-tail test for paired samples performed on this data showed no significant difference between the pre- and post-intervention scores ($\alpha = .05$, $p = .226$).

When asked specific questions related to kinetic theory and reaction rates, student responses indicated only minor improvement post-intervention in most areas, the exception being kinetic theory. There were only modest gains, albeit from an initial value of zero, when students were asked to explain, measure or increase reaction rates. List factors that affect reaction rates showed a modest improvement,

but this is a low-order skill. The number of correct responses, pre-intervention and post-intervention, is detailed in Table 4.5. The result would again indicate that the students were not able to successfully assimilate knowledge from the Chemical Reactions iteration.

Table 4.5
Percentage of Correct Student Answers to Questions Regarding Kinetic Theory and Reaction Rates Pre-intervention and Post-intervention

Topic	Source	Percentage correct	
		Pre-intervention	Post-intervention
Kinetic theory	Table A1.24	4	0
List factors affecting reaction rate	Table A1.26	41	74
Explain reaction rate	Table A1.28	0	20
Measuring reaction rate	Table A1.29	0	10
Explain increasing reaction rate	Table A1.30	0	10

4.3.3.2 Misconceptions

There were also some misconceptions evident in the students' understanding of the concepts covered by the intervention. This development of misconceptions was a more disturbing development because once misconceptions are in place, they are hard to remove (Ozgur, 2013). Table 4.6 indicates the percentage of misconceptions regarding various concepts involving Newton's Laws. While recognising applications of Newton's Laws showed a decrease in misconceptions, there was an increase in misconceptions concerning applying Newton's Laws generally and specifically to rocket design. When asked how to improve a rocket's efficiency, students used relationships that do not exist. For example, one student tried to link mass with thrust incorrectly "Lighten the objects mass with a consistent amount of thrust."

Table 4.6
Percentage of Responses Containing Misconceptions Regarding Newton's Laws Pre-intervention and Post-intervention

Topic	Source	Percentage of responses containing misconceptions	
		Pre-intervention	Post-intervention
Recognition of an application of Newton's Laws	Table A1.1	52	23
Explaining an application of Newton's Laws	Table A1.2	4	5
Applying Newton's Laws to rocket efficiency	Table A1.4	33	40

Some misconceptions were also evident in the Chemical Reactions iteration regarding student responses to questions regarding kinetic theory and reaction rates (see Table 4.7), as indicated by the percentage of misconceptions regarding various concepts involving kinetic theory and reaction rates. There was some improvement in areas, including factors affecting reaction rates and increasing reaction rates, but there was an increase in misconceptions when asked to explain reaction rates. Student responses to the question asking them to explain reaction rates showed a common misconception in the current study where volume and concentration were confused. Volume will not affect reaction rate, and the effect of concentration of the reactants was one of the factors investigated in the Chemical Reactions iteration.

Table 4.7
Percentage of Responses Containing Misconceptions Regarding Kinetic Theory and Reaction Rates Pre-intervention and Post-intervention

Topic	Source	Percentage of responses containing misconceptions	
		Pre-intervention	Post-intervention
Kinetic theory	Table A1.24	5	14
Explain how to increase reaction rate	Table A1.25	36	23
Explain reaction rate	Table A1.28	16	40

4.3.3.3 Application of knowledge

The inability of students to apply their knowledge to various situations presented in this study, especially the design of their rocket, was particularly disappointing. However, it was not unexpected given the students' limited content knowledge combined with some misconceptions. The students had limited knowledge to apply to various situations and misconceptions about various concepts. While there was an improvement in student's ability to apply knowledge when asked about applying Newton's Laws to rocket design (see Table A1.4), 14%, pre-intervention and 35%, post-intervention, it was still less than was expected from the iteration. Moreover, when asked about improving a rocket's efficiency (see Table A1.6), there was a decline in the number of answers considering several factors from 43%, pre-intervention, to 23%, post-intervention.

Students also struggled to apply their knowledge in a meaningful way to the problems presented to them in the Chemical Reactions iteration. Although the students expressed a strong preference for hands-on work on the topic, they were unable to design experiments for a specific purpose, such as measuring the rate of reactions. When provided with a diagram containing equipment needed to measure the rate of a reaction, 0% of students, pre-intervention, and 10%, post-intervention, could describe the use of the equipment correctly (see Table A1.29).

4.3.3.4 Planning, monitoring and evaluation

Metacognition in this study has been narrowly defined to pertain to students' planning how to work on the problem and monitoring and evaluating themselves as they work on the problem. Students in the Newton's Laws iteration were able to discern a difference between planning and completing a particular task to solve a problem, in this case, building a rocket. A Spearman–Brown split-half

reliability coefficient was used to test the two Likert scale questions regarding planning and completing for equivalency. The planning question pre- and post-intervention had an $r_{SB1} = 0.74$ and the completing question had an $r_{SB1} = 0.76$. These results indicated a strong level equivalency between the pre- and post-intervention responses, and so, there was little difference between the pre- and post-intervention results. The pre-intervention results for questions 15 and 17 had an $r_{SB1} = 0.71$ and the post-intervention results had an $r_{SB1} = 0.87$. However, task allocation was still at a rudimentary stage, which may be acceptable in the early stages of PBL but may become a hindrance as problems become more abstract and less structured.

When asked how they would evaluate their performance, student responses referring to communication within the group remained constant at 20%, pre-intervention and post-intervention, and responses indicating the result decreased from 20%, pre-intervention, to 10%, post-intervention. Responses citing progress made increased from 60%, pre-intervention, to 70%, post-intervention (see Table A1.12). It was encouraging to note that all students could provide a strategy for evaluating their performance and that progress made on their problem was the major way they evaluated their progress.

Regarding metacognition in the Chemical Reactions iteration, the main issues concerned planning each activity and evaluating performance. A Spearman–Brown split-half reliability coefficient was used to test the two Likert scale questions regarding planning and completing for equivalency. The planning question pre- and post-intervention had an $r_{SB1} = 0.86$ and the completing question had an $r_{SB1} = 0.75$. These results indicated a strong level equivalency between the pre- and

post-intervention responses, and so, there was little difference between the pre- and post-intervention results. The pre-intervention results for questions 15 and 17 had an $rSB1 = 0.86$ and the post-intervention results had an $rSB1 = 0.73$. There was no change in students' attitudes as to what was important in planning or completing an investigation into chemical reactions after the iteration. Since students had already completed one iteration where they were required to undertake many of the activities described in these metacognitive scales, this result was not surprising. It indicated that students realised the importance of these factors in PBL. The majority of the students giving each factor an importance rating of four or more reinforces this idea.

When asked how they would evaluate their performance, student responses referring to communication within the group increased from 21%, pre-intervention, to 41%, post-intervention, and responses indicating the result increased from 5%, pre-intervention, to 50%, post-intervention. However, responses citing progress made decreased from 74%, pre-intervention, to 9%, post-intervention (see Table A1.34). These results were not surprising given the format of the Chemical Reactions iteration. The students were working on some smaller problems, and so, overall progress in each one would be quite small. The students also had to produce an assessed report after each problem, which would explain the increase in the importance of the 'end result.'

In developing a solution to the problem, students also need to access information and decide how they would search for and assess information. Students considered using multiple sources of information in the Newton's Laws iteration with the internet being the most common, pre-intervention, at 40% and books most common, post-intervention, at 48%. In all cases, the searches were general in nature

and did not specify a particular piece of information that they would search for using resources available post-intervention. When asked about assessing the information they had found, the most common response was to compare it with other members of their group: 61%, pre-intervention, and 80%, post-intervention (Table A1.11 and A1.13).

In the Chemical Reactions iteration, students searching for information was again mainly focused on the use of the internet with 44% indicating they would use the internet, pre-intervention, and 41%, post-intervention (Table A1.35). Ninety-three per cent of responses post-intervention were general searches rather than specific ones. In assessing information found, the most common response was comparing it with other group members at 82%, pre-intervention, and 84%, post-intervention (Table A1.36).

4.3.3.5 Student engagement

Student engagement has also been narrowly defined to include self-efficacy, task difficulty and task attractiveness in this study. Self-efficacy affects confidence in secondary school science students (Chen & Usher, 2013), and the lack of improvement in student confidence post-intervention was an area of concern in the Newton's Laws iteration. The attractiveness of the task to the students was evident from the focus group responses and student responses to questions regarding how they motivated themselves and what they found enjoyable. However, this was a double-edged sword as students also saw the topic as a self-contained unit with little relevance to the 'real world' indicated by their response to the usefulness of the topic. Thus, two aspects of the topic's attractiveness are opposed to each other—its innate appeal to students as a new and hands-on activity juxtaposed to its usefulness.

However, it was encouraging to see students willing to tackle difficult tasks and the enjoyment of the task, although diminished post-intervention, was still high.

In the PBL Evaluation Tool, student engagement was first assessed using two Likert scales. They ascertained student's beliefs about their confidence in completing a PBL project without help and the usefulness of the project to them as students. The first Likert scale asked students to rate their confidence level in completing the PBL task. Figure A1.13 shows the results of the first Likert test; pre- and post-intervention differences were tested for using a Wilcoxon Signed Rank two-tail test for paired samples. No significant difference was found between the pre- and post-intervention scores ($\alpha = .05$, $p = .140$).

The first Likert scale showed only very small gains in student confidence post-intervention with decreases in confidence at the lower (less confident) end of the scale. There was no quantum lift in student confidence, which was surprising given the level of engagement shown by them during the iteration. The second Likert scale asked students to rate how useful they thought the task would be to them as students. Figure A1.10 shows the results of the second Likert scale. There was no significant difference between the pre- and post-intervention scores ($\alpha = .05$, $p = .464$) using a Wilcoxon Signed Rank two-tail test for paired samples.

This second Likert scale showed that students considered the topic less useful to themselves post-intervention. This result was unexpected given the students' responses to the next question (see Table A1.14) where 46% of students, post-intervention, indicated that the topic was the motivation for working on the task or that they wanted a good result. The students saw the topic as being entire unto itself with no application beyond the topic.

When asked whether the task would be easy or difficult (see Table A1.17), the students' results showed that 87%, pre-intervention, and 72%, post-intervention, found it easy. However, when asked whether the task would be enjoyable (see Table A1.16), 87% of students, pre-intervention, found it enjoyable and 72%, post-intervention, found it enjoyable. In the Newton's Laws iteration, students found the task to be easier than expected but also found it less enjoyable.

In the Chemical Reactions iteration, student engagement was also assessed using two Likert scales. The Likert scales ascertained student's beliefs about their confidence in completing a PBL project without help and the usefulness of the project to them as students. The first Likert scale asked students to rate their confidence level in completing the PBL task. Figure A1.22 shows the results of the first Likert test. There was no significant difference between the pre- and post-intervention scores ($\alpha = .05$, $p = .874$) using a Wilcoxon Signed Rank two-tail test for paired samples.

The first Likert scale showed only small gains in student confidence post-intervention with some decreases in confidence at the lower (less confident) end of the scale. As in the previous iteration, there was no major lift in student confidence. The second Likert scale asked students to rate how useful they thought the task would be to them as students. Figure A1.20 shows the results of the second Likert scale. There was no significant difference between the pre- and post-intervention scores ($\alpha = .05$, $p = .374$) using a Wilcoxon Signed Rank two-tail test for paired samples.

This second Likert scale showed that students considered the topic less useful to themselves post-intervention. When asked what their motivation was for

working on the task (see Table A1.37), 33% of students, post-intervention, indicated that their grades were a major concern. Only 4% indicated that the topic was the motivation for working on the task or that they wanted a good result. In this iteration, students were focused on their grades more than the topic, which, given its proximity to the end of the semester and issuing of reports, was not surprising.

When asked whether they would find the tasks easy or difficult (see Table A1.39), the students' results showed that 67%, pre-intervention, and 52%, post-intervention, found the tasks easy. However, when asked whether the task would be enjoyable (see Table A1.38) 54%, pre-intervention, found it enjoyable and 59% of students, post-intervention, found it enjoyable. Thus, while they found the task more difficult than expected, they still found it enjoyable.

4.4 The Implications of the Results for Future Interventions

In this journey so far, both the Newton's Laws and Chemical Reactions iterations have produced some themes that inform the research questions. These themes have clear implications for the further development of the e-textbook supported PBL intervention. Table 4.8 and 4.9 presents these implications and relates them to the research questions. The design of the next e-textbook drew from these implications to improve the efficacy of their use in the classroom.

Table 4.8
The Implications of The Newton’s Laws Iteration Related to the Research Questions

Research question	Implications	Strategies
1. What constraints (if any) inhibited the implementation of the e-textbook supported PBL intervention?	<p>Students need more support regarding hard-scaffolding to achieve a better understanding of science concepts. Productive and efficient group-work is not achievable in all cases without the significant hard-scaffolding of the processes involved. Students need to know how to interact in a productive way that involves teamwork, rather than individual efforts, for working as a group that can evaluate what they are doing and rectify any issues.</p> <p>The benefits of PBL beyond the task at hand need to be made explicit to students. Students need support in quantifying what constitutes progress in a group and how to tackle issues that affect progress as they arise. Modification of Newman’s (2005) questions so that students feel more at ease in answering them.</p> <p>The role of the teacher as a facilitator in a PBL exercise needs to be flexible and able to provide the soft-scaffolding on an as-needed basis to students. Students still expect and indeed need input from the teacher, and this input needs careful crafting so that it is still true to the ideals of PBL.</p>	<p>Develop more hard-scaffolding within the e-textbook including how to work in groups.</p> <p>Explicitly state the function of PBL to students.</p> <p>Reduce and simplify questions.</p> <p>Review role of facilitator.</p>
2. What design features of the e-textbook supported PBL intervention most influenced student learning?	<p>The e-textbook can be improved by providing better feedback to students and controlling their progression through the book so that mastery of one area is a prerequisite for proceeding to the next one. The e-textbook should limit student’s ability to play games during class time. Saving of student work should occur automatically as they move through the e-textbook.</p> <p>More scaffolding needs to be included to help students work effectively in groups. Poor group-work skills are the major constraint to effectively implementing PBL.</p>	<p>Improve feedback so that it targets specific issues identified through formative testing of students.</p> <p>Use new platform that controls students progress, limits gaming and automatically saves students work.</p> <p>See strategies for Research Question 1.</p>
3. What was the overall impact of the e-textbook supported PBL intervention	<p>Students’ content knowledge regarding the use of terminology, identification and application of concepts needs to improve. Students require more feedback on their progress in understanding science concepts. The e-textbook should have the facility for students to make notes.</p> <p>Students need support in organising specific searches for information rather than a general approach to seeking information.</p>	<p>Add a glossary to provide definitions of key terms.</p> <p>Provide targeted feedback on concepts covered in each problem.</p> <p>Add note taking facility.</p> <p>Add hard-scaffolding for research techniques</p>

Table 4.9
The Implications of the Chemical Reactions Iteration Related to the Research Questions

Research question	Implications	Strategies
1. What constraints (if any) inhibited the implementation of the e-textbook supported PBL intervention?	<p>Students lack the content knowledge to explain concepts adequately, and further support is required. A glossary needs to be provided to assist them in acquiring an appropriate vocabulary for discourse in science.</p> <p>Students need more support than was provided, regarding hard-scaffolding, to achieve a better understanding how to use equipment in science.</p> <p>Students require more hard-scaffolding to understand what is happening at the molecular level during chemical reactions.</p> <p>Students need more support from the e-textbook to develop their problem-solving skills.</p> <p>Students need support to learn from their practical work, and this is especially so when recording results and analysing those results.</p> <p>They also need support to plan, search and evaluate information and monitor progress.</p>	<p>Improve glossary to provide definitions of key terms.</p> <p>Add hard-scaffolding showing how equipment can be used to investigate science problems.</p> <p>Add hard-scaffolding to help students understand what is happening at the molecular level during chemical reactions.</p> <p>Soft-scaffold on a need's basis.</p> <p>Add hard-scaffolding showing how to plan, search and evaluate information and monitor progress.</p>
2. What design features of the e-textbook supported PBL intervention most influenced student learning?	<p>The hands-on approach to learning chemistry in PBL needs to be developed further to ensure that students see and value the link between their practical work and the theory behind it. Improving the e-textbook will involve providing progressive feedback to students so that they can determine their mastery of one area before proceeding to the next one.</p>	<p>Soft-scaffold on a need's basis.</p> <p>Provide feedback to students after each problem.</p>
3. What was the overall impact of the e-textbook supported PBL intervention	<p>Students, for the most part, find chemistry challenging and compounding this was the addition of an unfamiliar teaching method, PBL. Therefore, scaffolding needs to be provided to ensure students are comfortable with PBL in the context of a topic in chemistry. Specifically, they need support to increase their confidence through continuous feedback on their progress.</p>	<p>Improve hard-scaffolding of PBL in e-textbook.</p> <p>Improve feedback on student progress.</p>

4.5 Summary

The completion of the first cycle was successful regarding providing a basis for the further refinement of the e-textbooks and their use to support PBL in science classrooms. Through the use of evaluation tools, interviews and observations, valuable information was acquired that allowed for some implications for the design of e-textbooks and their use in PBL. These implications concerned scaffolding problem-solving and group-work, providing feedback on progress, engendering a greater appreciation of practical work and an appreciation of the value of problem-solving.