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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 Five: Cycle Two—Results, Review and Implications

5.1 Introduction

When Alice asked the Cheshire cat “Would you tell me, please, which way I ought to walk from here?” the Cheshire cat responded, “that depends a good deal on where you want to get to” (Carroll, 1865, p. 89). Cycle two was the next step on a journey to answer the three research questions regarding the use of e-textbooks to support Problem-Based Learning (PBL) in secondary school science classrooms, and in doing so, finding a destination. These questions related to how e-textbooks supported PBL interventions and were concerned principally with the design features of e-textbooks, their impact on students and the constraints in using them in secondary schools.

5.2 A Recapitulation of Cycle One

The completion of the first cycle provided 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, the acquired information allowed for some developments in the design of e-textbooks and their use in PBL. These developments 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. These developments would be achieved, in part, by using new software to develop and deploy the next generation of e-textbooks.

5.3 The Cycle Two Environment

Cycle two involved one Year 10 Science class and covered two topics: physics (Newton's Laws) and structures (Compression and Tension). Twenty-six students comprised the class, of which 12 took part in the study with the permission of their parents. Each topic lasted four weeks, and each was a topic covered by Year 10 students as part of the Australian National Science Curriculum. The 26 students comprised 93% of the year cohort, and selection occurred by achieving a combined score on tests and an examination of not less than 34%. The remaining 7% of students were moved to other classes since this was the policy of the Science Department at the School at the time of this second cycle. There were four lessons per week consisting of two 80-minute periods and two 40-minute periods. The students worked on the problems, presented in the e-textbook, 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.

5.4 Themes Arising from the Analysis of the Data

The analysis of the data gathered from the two iterations of cycle two revealed 17 different themes related to the research questions that this study attempted to answer. Table 5.1 presents the research questions and the themes that arose from the data analysis. A discussion of each of these themes occurs in the following paragraphs.

Table 5.1

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 A1.3
What constraints (if any) inhibited the implementation of the e-textbook supported PBL intervention?	Group dysfunction	FGI NL2	Question 6
		FGI CT2	Question 1
		PBLETK	Table A1.5
		ICO	03/08, 06/08, 11/08, 24/08, 16/11 & 23/11
		PBLETPME	Table A1.9, Table A1.10, Table A1.12 & Table A1.14
	Function of e-textbook	FGI NL2	Questions 2 & 7
		FGI CT2	Question 7
	Functionality of e-textbook	FGI NL2	Question 7
		FGI CT2	Questions 5, 7, 8 & 9
	Distraction	FGI NL2	Question 9
	Technology infrastructure	FGI NL2	Question 3
		ICO	28/07 & 24/11
	Lack of argumentation	ICO	03/08, 05/08, 06/08, 13/08 & 20/08
	Inadequate scaffolding	FGI NL2	Question 1
		ICO	03/08, 05/08 & 13/08
	Understanding PBL	FGI NL2	Questions 2, 3, 7 & 8
		FGI CT2	Question 2
What design features of the e-textbook supported PBL intervention most influenced student learning?	Hands-on	FGI NL2	Question 1
		FGI CT2	Question 2
		PBLETSE	Table A1.16 & Table A1.54
	Self-paced	FGI NL2	Question 1
	Multimodal	FGI NL2	Questions 1 & 3
	Feedback	FGI NL2	Questions 7 & 9
		FGI CT2	Question 7
	Group-work	PBLETK	Table A1.5 & Table A1.46
		PBLETSE	Table A1.7 & Table A1.55
		SPO	Table A1.22 & Table A1.57
		FGI CT2	Question 7
	Enjoyment	PBLETSE	Table A1.16 & Table A1.54

(continued)

Research question	Themes	Data collection component	Data source in appendix A1.1 and A1.3
What was the overall impact of the e-textbook supported PBL intervention?	Content knowledge and its application	PBLETK	Figure A1.2, Table A1.1, Table A1.2, Table A1.3, Table A1.4, Table A1.6, Table A1.43,Table A1.44 & Table A1.45
	Misconceptions	PBLETK	Table A1.1, Table A1.2, Table A1.4, Table A1.6, Table A1.43 & Table A1.45
	Planning, monitoring & evaluation	PBLETME	Table A1.10, Table A1.11, Table A1.12, Table A1.49, Table A1.50, Table A1.51 & Table A1.52
	Student engagement	SPO	Table A1.22 & Table A1.57
		PBLETSE	Table A1.14, Table A1.15, Table A1.16, Table A1.7, Table A1.53, Table A1.54 & Table A1.55

Note. FGI NL2 refers to focus group interview—Newton's Laws, FGI CT2 refers to focus group interview—Compression and Tension; 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

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

Cycle two of the intervention revealed several themes about the constraints that inhibited the implementation of an e-textbook supported PBL intervention. These themes included:

- group dysfunction
- function of e-textbook
- functionality of e-textbook
- distraction
- technology infrastructure
- lack of argumentation
- inadequate scaffolding
- understanding PBL.

It was possible to group these themes into three broad categories that could be considered together owing to the similar underlying characteristics. Table 5.2 details these categories.

Table 5.2

Themes Contained in Each Category for Research Question One

Categories	Themes
Learning constraints	Group dysfunction Distraction Function of e-textbook
Pedagogical constraints	Lack of argumentation Inadequate scaffolding Understanding PBL
Technical constraints	Functionality of e-textbook Technology infrastructure

5.4.1.1 Learning constraints

These themes related to constraints that the students should have been able to mitigate through their actions or interactions, but which they did not for various reasons. The themes include group dysfunction, distraction and the function of the e-textbook. There is a discussion of each of these below.

5.4.1.1.1 Group dysfunction

Participant responses in focus group interviews and classroom observations indicated that the groups did not operate optimally. Three behaviours in groups are indicative of dysfunction, described as; "Fight, flight and pairing" (Wood, 2004, p. 3). Fight behaviours involve specific hostile acts by one or more group members towards others. Flight involves group members ceasing to involve themselves in the group, and pairing occurs when two group members work together but exclude the rest of the group. During this cycle, each of these behaviours was evidenced in the groups, in both iterations. Comments from students during their focus group interviews exhibited:

> Fight
> Instead of relying on me to do it and then giving you all of the information like at one point I felt like giving the wrong results because they didn't do anything. (FGI NL2 S5)

> Flight
> I think coz [*sic*] some people got confused by it and didn't understand they just they didn't contribute to it very much, so some people just decided to forget about it and let other people do the work in that group. (FGI NL2 S4)
>
> Pairing
> Oh they would just mess around like they were close friends so they would mess around with each other and not really participate in the work. (FGI NL2 S5)

Informal recorded observations of the students in both iterations also showed group dysfunction on numerous occasions (ICO 03/08, 06/08, 11/08, 24/08, 16/11, 23/11). Overall, the students displayed difficulty in working together on the PBL problems. When asked how students would allocate group members before the iteration for the Newton's Laws topic, they offered a range of responses: 25% would allocate people to tasks, 58% would determine who was best suited, 17% would base their decision on the interests of the group member and 0% indicated that they would work as a group. Post-iteration, on the same topic, 50% stated they would work as a group with 20% and 30% respectively listing best-suited individual and interests of the group member. A similar trend arose for the Compression and Tension topic. Students considered that tasks were easier to complete in groups, although no one mentioned group-work as an advantage in the focus group interviews for Newton's Laws and only one student specifically mentioned group-work in the focus group interviews for Compression and Tension. One student in the Newton's Laws focus group interview commented that:

> Most of us did the work and did it fairly well, but then when it did come to difficult things, there were two people that stopped working a bit. I could feel myself doing it as well sometimes (FGI NL2 S4)

When the group-work no longer made the task easier, the students were more likely to give up, and the group became dysfunctional.

5.4.1.1.2 Distraction

The use of ICT in classrooms by students raises the possibility of inappropriate use distracting them from the actual task that they were involved with at the time. Liu et al. (2016) noted that teachers had a perception that students would be distracted when using digital devices, and Ditzler, Hong, and Strudler (2016) found that students also acknowledged the problem of being distracted. The focus group interview after the Newton's Laws iteration indicated that students were distracted from the topic because two students indicated:

> Some people get distracted with their computer I guess. (FGI NL2 S3)
>
> It's quite easy especially with Macs too, coz [*sic*] Macs you just swipe across, and then you've got your desktop, and if there's a game open on your desktop it's so easy to use. (FGI NL2 S5)

Distractions owing to gaming were not a problem with the Compression and Tension iteration. In this case, the students were more inclined to socialise at a group level rather than using their laptops inappropriately. This reduction in gaming may also have been a function of the number of technical issues that students experienced during the iteration. Both these issues were evident in the Informal Classroom Observations (ICO 16/11, 17/11, 23/11 and 24/11).

5.4.1.1.3 Function of the e-textbook

The e-textbook was designed to facilitate PBL for the students using it and not as a digitised traditional textbook that students use in science. The mismatch between the intended role of the e-textbook and the students' expectations of the e-textbook created a disequilibrium in those using the e-textbook. One student in the

Newton’s Laws focus group interviews stated that: “With the e-textbook the videos were handy, but you had no other information on the topic whereas a normal textbook you can go through and read exactly what is there” (FGI NL2 S1). When questioned further, it became clear that the students had different expectations of the e-textbook as the following dialogue indicates:

> So there wasn’t very much written information on there. (FGI NL2 S4)
>
> Yeah so I guess some parts of the e-textbook were better than the textbook, but then some parts of the textbook are better than the e-textbook. (FGI NL2 S3)
>
> Yeah. (FGI NL2 S4)
>
> The part no the fact that in the textbooks like this one (indicating textbook on the table) here you can go straight to that page. (FGI NL2 S3)
>
> It’s got all of the information. (FGI NL2 S5)

According to additional testimony, the students expected the e-textbook to provide them with all the information they needed as was the case with their other textbooks. The idea that this e-textbook would not do that apparently did not sit well with these students.

5.4.1.2 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 et al., 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.

5.4.1.2.1 Lack of argumentation

Argumentation has been defined as the "ability to examine and then either accept or reject the relationships or connections between and among the evidence and theoretical ideas invoked in an explanation" (Rozenszayn & Assaraf, 2011, p. 124). Furthermore, Jonassen (2011) considered argumentation an important tool in PBL. However, Ryu and Sandoval (2015) cited five studies that indicated that students do not engage in meaningful argumentation. Moreover, Gillies and Haynes (2011) stated that argumentation is a skill that requires perspicuous instruction to students rather than relying on instinct.

Observation of students during their group-work on the various problems showed a lack of any argumentation in their discussions (ICO 03/08, 05/08, 11/08, 16/11, 17/11 and 23/11). There was little consideration of alternative views with students resorting to trial and error to develop solutions to their problems. The results of these trials themselves did not engender any argumentation, but rather, another round of trial and error testing. Intervention by the researcher to encourage a more analytical approach to their problem solving did not help, with students turning their focus to the researcher rather than continuing the discussion among themselves. Furthermore there was no mention of argumentation by the students in their focus group interviews.

5.4.1.2.2 Inadequate scaffolding

In this cycle, there was more hard-scaffolding in the e-textbook, including how PBL works and information about each of the problems the students would encounter. This increased scaffolding seemed to make little difference in the Newton's Laws iteration. The students still had difficulty in organising their groups effectively and working on the problems in a methodical way, especially regarding collecting data from the experiments they conducted. Soft-scaffolding did not make any difference. For example, students were not recording results appropriately (qualitative data instead of quantitative data). The researcher intervened to illustrate how one group had recorded appropriate quantitative data from their experiment. Their results and another group's qualitative results were used to initiate a discussion regarding the more meaningful way to record results. Despite this, there was no improvement in the recording of results (ICO 04/08 and 13/08).

The recording and presentation of data did not occur for the Compression and Tension topic for two reasons. First, the students had now been exposed to one PBL iteration and were more familiar with the process since it had scaffolded them for the Compression and Tension topic. Second, the problems lent themselves to the generation of qualitative data that the students were more able to record.

5.4.1.2.3 Understanding PBL

Some studies have documented resistance by students to PBL for a variety of reasons, for example, Alessio (2004); Baseya and Francis (2011); Biley (1999); Boone (2013). However, it was possible to generalise, to some extent at least, the responses of the students under a zeitgeist of not understanding the purpose of PBL. Following the Newton's Laws iteration, focus group interviews highlighted the issues around this lack of understanding about the purpose of PBL. In response to a question about the purpose of PBL, one student noted that "Yeah so, we do level 1 maths, so that's [and] problem solving's not a difficult task for me it's just that I need instructions to do it" (FGI NL2 S5). This student had clearly confused solving a problem in mathematics with PBL. When asked about whether PBL was a better method of learning, another student responded: "I think the thing with being able to retain the information is we do study skills, and at study skills, we're taught to write notes about it" (FGI NL2 S4). These responses highlighted a conflict that exists between different teaching methodologies used in the school and the problem of trying to introduce something perceived as novel.

Finally, the students expected that they would be told how to solve the problem they were working on rather than developing a solution by themselves. When asked if the e-textbook helped them with their problem-solving, the students were expecting the e-textbook to do the work for them. The students' expectations are illustrated in the comments below:

> Yeah like even information to get us started on the problem like get us started on the experiment would be like really, really appreciated. (FGI NL2 S5)
>
> We were just given the things and were told prove Newton's First Law! (FGI NL2 S4)
>
> It's like there's a picture and then prove this with the stuff in the picture (shrugs shoulders). (FGI NL2 S5)
>
> Yeah … he gave us a picture of the materials we needed which was good, but it didn't say like how to set it up, so we're kinda [*sic*] thinking like. (FGI NL2 S3)

A similar issue arose during the Comprehension and Tension focus group interviews. Students expected to be able to build a bridge without thinking about the design of the bridge and how to work with the materials available. The responses of two students to a question about the purpose of PBL illustrate this:

> It was hard to try to figure out how to do the design of the bridge just without actually building at the same time. We had to do the design before we could build it and we had to figure out if we had enough resources to make it work. (FGI CT2 S2)
>
> Yeah we didn't get to see our resources before we actually made a bridge, we knew what we were getting, but we didn't like actually like to. (FGI CT2 S1)

5.4.1.3 Technical constraints

All of the iterations required significant levels of infrastructure support to work effectively. Ritzhaupt et al. (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 about e-textbooks.

5.4.1.3.1 Functionality of the e-textbook

Students reported issues with the e-textbook's functionality in both iterations of cycle two. The first issue was a constraint of the program used to implement the e-textbook. A new program was used to develop and implement the e-textbook, and there were issues with various functions. The issues centred around the use of videos, saving work and printing notes. These issues clearly caused frustration with the students. In the Newton's Laws focus group interview, one student noted that "I liked the videos, but sometimes it got a bit hard to retain the information in the videos and then you'd have to watch the whole thing …over again to find like a little bit of information from like the end of it" (FGI NL2 S2). Another student felt that "the videos were really small as well" (FGI NL2 S5). However, having students watch a short video several times would not be too onerous and would allow them to acquire more information from multiple viewings. The second issue was the result of accommodating a variety of student's laptops with varying resolutions. In the Compression and Tension focus group interview, students commented on issues with saving work properly when exiting the e-textbook. The e-textbooks used later allowed students to save their work.

5.4.1.3.2 Technology infrastructure

In this cycle, there were numerous issues involving the technology infrastructure when students were using their e-textbooks. These issues tended to be related to accessing the network and printing information from the program on their own laptops. The students mentioned these in their interviews:

> It was just a bit harder to access it cause we had to go onto our VMWare, which is another application on our computer, and it's a bit slow it's not that the application itself is slow it's just that VMWare is. (FGI NL2 S3)
>
> If you wanted on your actual computer, you would have to copy it from that application that was on VMWare and then put it onto your like Word document or Pages on your computer as well. So it's like a process of swiping back and forward and copying information. (FGI NL2 S5)

The availability of the network and slow download speeds caused considerable frustration in both iterations (ICO 28/07 and 24/11). The inability of the network to allow students to print documents made producing reports time-consuming, and the lack of an email facility for them prevented the results of the tests at the end of each problem from being forwarded to the researcher.

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

Cycle two of the iteration identified six themes in relation to features of the e-textbook supported PBL intervention that most influenced student learning. These themes included:

- hands-on
- self-paced
- multimodal
- feedback
- group work
- enjoyment.

It was possible to group these themes into three broad categories that could be considered together owing to the similar underlying characteristics. Table 5.3 details these categories.

Table 5.3
Themes Contained in Each Category for Research Question Two

Categories	Themes
Facilitation features	Hands-on Self-paced Multimodal
Interaction features	Feedback Group-work
Enjoyment	Enjoyment

5.4.2.1 Facilitation

Facilitation was taken to mean any feature of the iterations 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.

5.4.2.1.1 Hands-on

Students studying science prefer hands-on learning experiences (Blankenburg, Höffler, & Parchmann, 2015; Swarat, Ortony, & Revelle, 2012). When asked what they liked in the Newton's Laws topic during their focus group interviews, students responded with comments like "I liked the rocket" (FGI NL2 S2), "The practical activities we completed" (FGI NL2 S3) and "We got to organise our own sort of investigations on how we got to like take into" (FGI NL2 S1). These responses indicate that the students enjoyed the hands-on nature of the PBL. However, such enjoyment contradicted the student's responses to the question in the

PBL Evaluation Tool regarding enjoyment of the topic (Table A1.16). Pre-iteration, 50% of students who said they would enjoy the activity indicated that it was because of its hands-on nature. They represented 34% of all students who responded (activity enjoyable and not enjoyable). Post-iteration, this changed to 14% of students who indicated the hands-on nature as the enjoyable aspect of the experience, and they represented 7% of students overall. However, the number of students who found the experience to be not enjoyable also increased: 34%, pre-iteration, and 50%, post-iteration. Nevertheless, even students who did not find the experience enjoyable still acknowledged the hands-on nature as a positive aspect. As one student noted, "The practical tasks were fun and so was building the rocket, but everything else was boring."

In the Compression and Tension iteration focus group interviews, students again mentioned the hands-on approach as a positive aspect. In the PBL Evaluation Tool (Table A1.54), 40% indicated the hands-on nature of the activities as enjoyable, pre-iteration, and this increased to 50%, post-iteration. These results would indicate that students did enjoy the iteration.

5.4.2.1.2 Self-paced

Self-paced learning has been described as being "constructed in such a way that a learner proceeds from a topic or a segment to the next academic activity and learning material at his own speed" (Bautista, 2015, p. 162). The students in the Newton's Laws iteration commented on their preference of a self-paced mode of study. In the focus group interview, one student noted that "Yeah and it also helped like instead of the teacher going on and on without you could do it at your own pace" (FGI NL2 S1). Informal observations of the class also showed students working at different rates on the problems (ICO 18/08). There was no mention of the self-paced feature for the Compression and Tension topic despite it also being self-paced; however, again, Informal Classroom Observations noted students progressing at different speeds on the problems (ICO 18/11 and 24/11).

5.4.2.1.3 Multimodal

The e-textbooks were all designed to be multimodal. The model selected as the basis for this multimodality was the VARK model (Fleming & Mills, 1992). Khanal, Shah, and Koirala (2014) found that there was a strong preference for multimodal presentation. In this model, information is presented to students in a variety of ways: visual (diagrams and graphs), aural (speaking), reading (text) and kinaesthetic (simulations). Therefore, it was not surprising that most students expressed a preference for this aspect of the e-textbook. The responses of two students to a question about what they liked in the topic in the Newton's Laws focus group interview illustrated this:

> I thought it was good how you had the audio telling you what to do, and then you had pages where you could write notes and all that. (FGI NL2 S3)
>
> It was interactive, visual, and you could hear like listen to it as well instead of just looking at something on a board there was videos and things like that. (FGI NL2 S3)

However, this was not universal, and one student expressed a clear preference for a unimodal approach when asked about whether they thought the e-textbook was better:

> Like for me when we finished with that e-textbook I had to go through my actual science textbook and read over that chapter again because I wasn't really learning anything from the e-textbook …So yeah. I prefer to take notes (FGI NL2 S5)

This response was difficult to analyse since the e-textbook did provide note-taking facilities for each of the problems as well as a notepad for general notes. It is possible that this student viewed the other modes as a distraction.

5.4.2.2 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 involved students interacting and supporting each other in groups.

5.4.2.2.1 Feedback

Feedback is information provided to a student as a result of particular actions by that student and is a very important aspect of learning (Hattie & Timperley, 2007). Feedback in the e-textbooks consisted of performance in tests and corrective presentations in areas where a student's results indicated a more specific response was required. Students in the Newton's Laws topic found the feedback useful. In the focus group interviews, two students commented on the feedback:

> Yeah, there was kinda [*sic*] like things that you would a little test to see how you are going. (FGI NL2 S3)
>
> Those things helped retain the information as well because with the test how it would correct and incorrect and telling you the correct answer that helped. (FGI NL2 S4)

However, in the Compression and Tension topic, the opposite was true. In the focus group interview, the students indicated that the feedback in the e-textbook had no value as indicated in the discussion below:

> Like some of the problems of like problem-solving and they like get you to take like a tiny multiple-choice test about it. (FGI CT2 S3)

Yeah, they were weird. (FGI CT2 S4)

I just felt that like that was pointless. (FGI CT2 S3)

The explanation for this dramatic change was the timing of the last topic, which was at the end of the year with grades and subject selections for next year already finalised. The effect of the timing was made clear by the students in the focus group interview when they stated that:

And they just feel like this is pointless. (FGI CT2 S3)

And after exams it's not getting tested or anything. (FGI CT2 S2)

It's after your mark, and it's a bit of laziness. (FGI CT2 S3)

[And] everyone is tired and doesn't want to [work]. (FGI CT2 S2)

5.4.2.2.2 Group-work

Despite the dysfunctional nature of the groups mentioned earlier, group-work was still a common consideration among students when asked about the allocation of people to tasks and task difficulty. When asked how they would assign individual group members to a specific task, none of the students indicated that they would work together as a team, pre-iteration (Table A1.5). Post-iteration, this increased to 50% for the Newton's Laws topic (Table A1.46). For the Compression and Tension topic, the results regarding working as team were 11%, pre-iteration, and 78%, post-iteration. As the iteration progressed, students were working as a group on each aspect of the problem rather than assigning individuals to specific tasks. When asked if the topic would be difficult, no student indicated group support as a reason for it not being difficult, pre-iteration, compared with 34%, post-iteration. For the Compression and Tension topic, there was no change between the pre-iteration result of 11% indicating group support and the post-iteration result. For the Newton’s Laws topic, there was a preference for working as a team by those students who believed the task would be easy, post-iteration, with 100% indicating group support as the reason.

The Strobe Protocol Observations indicated that the groups were exhibiting on-task behaviour almost all the time in the Newton’s Laws iteration. There was a decrease in on-task behaviour in the Compression and Tension iteration with only half of the groups engaged. The Compression and Tension iteration was at the end of the year, and most students were not continuing with science the following year, and so, they did not engage with the PBL problem as enthusiastically. As one student in the Compression and Tension focus group interview succinctly expressed “It doesn’t count. Most of us aren’t even doing science next year at all.” (FGI CT2 S5).

5.4.2.3 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 et al., 2003) and practical work (Bennett & Hogarth, 2009). When asked if they felt the task would be enjoyable (Table A1.16 and A1.54), 67% of students responded positively, pre-iteration, for the Newton’s Laws topic and 50%, post-iteration. For the Compression and Tension topic, 50% responded, pre-iteration, and 62.5%, post-iteration positively. However, the students’ responses were not unequivocal with many stating they enjoyed some aspects of the iteration and not others. For example, when asked whether the task would be enjoyable, one student responded, “Rockets are exciting, and the rest of the program was boring”, and another student noted that “The practical tasks were fun and so was building the rocket, but everything else was boring.”

5.4.3 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 e-textbook supported PBL intervention on the students regarding the goals of PBL. Analysis of the data identified four key themes:

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

A discussion of each of these themes occurs in the following paragraphs.

5.4.3.1 Content knowledge and its application

The Newton's Laws iteration did not affect students' knowledge with no significant improvement post-iteration. Figure A1.2 shows the percentage of correct responses to 10 multiple-choice questions regarding Newton's Laws. A Wilcoxon Signed Rank two-tail test for paired samples performed on this data showed no significant difference between the pre- and post-iteration scores ($\alpha = .05$ and $p = .064$). However, when considering specific questions (1, 6, 7 and 8) there was a significant improvement post-iteration ($\alpha = .05$ and $p = .006$). Furthermore, these questions related to different areas within the topic: Newton's Second Law, calculation of force, inertia and Newton's Third Law. There was no appreciable difference between the pre-iteration and post-iteration results 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 A1.5).

Questions relating to Newton's Laws indicated some post-iteration improvement in certain areas, the exception being applying Newton's Laws to rocket efficiency. For example, students' ability to recognise and explain an application of Newton's Laws showed modest improvement. Applying Newton's Laws to rocket design showed no improvement and the ability to apply Newton's Laws to rocket efficiency decreased post-iteration. Table 5.4 details the number of correct responses, pre-iteration and post-iteration.

Table 5.4
Percentage of Correct Student Answers to Questions Regarding Newton's Laws Pre-iteration and Post-iteration

Topic	Source	Percentage correct	
		Pre-iteration	Post-iteration
Recognition of an application of Newton's Laws	Table A1.1	27	40
Explaining an application of Newton's Laws	Table A1.2	42	45
Applying Newton's Laws to rocket design	Table A1.3	60	60
Applying Newton's Laws to rocket efficiency	Table A1.4	14	0

In the pre-iteration phase, students would be relying on naïve ideas from their experiences to answer the questions concerning Newton's Laws. However, post-iteration the students were more able to articulate a more sophisticated answer to these questions. The students' inability to apply Newton's Laws to the rocket they were building stemmed from them not fully explaining how to improve its efficiency. In other words, they assumed some facts to be obvious and did not bother stating them.

In the Compression and Tension iteration, there was a similar result with no significant improvement in students' content knowledge post-iteration. Figure A1.24

shows the percentage of correct choices for each question. A Wilcoxon Signed Rank two-tail test for paired samples performed on these data showed no significant difference between the pre- and post-iteration scores ($\alpha = .05$, $p = .347$).

When asked questions that related specifically to the topic of Compression and Tension, student responses were mixed. When asked about stress reduction and stability, there was a substantial improvement in the students' knowledge. However, when asked about an example of compression reduction, there was a considerable deterioration in the students' demonstrated understanding. Table 5.5 details the number of correct responses, pre-iteration and post-iteration. These results would indicate that the students were able to assimilate some knowledge from the Compression and Tension iteration successfully.

Table 5.5
Percentage of Correct Student Answers to Questions Regarding Stress, Stability, and Compression Reduction Pre-iteration and Post-iteration

Topic	Source	Percentage correct	
		Pre-iteration	Post-iteration
Describe stress reduction	Table A1.43	20	50
Explain tower stability	Table A1.44	25	78
Describe compression reduction	Table A1.45	75	34

5.4.3.2 Misconceptions

Misconceptions belong to one of four different sub-groups: preconceived notions, non-scientific beliefs, conceptual misunderstanding or vernacular misconceptions (Committee on Undergraduate Science Education, 1997). Table 5.6 indicates the percentage of misconceptions regarding various concepts involving Newton's Laws. The identification of no misconceptions regarding explaining and applying Newton’s Laws was encouraging post-iteration, and the slight increase in misconceptions regarding recognising Newton’s Laws was not substantial. Owing to these findings, it would appear that students had clarified their understanding of Newton’s Laws. Furthermore, the students could apply these laws correctly to different situations.

Table 5.6
Percentage of Responses Containing Misconceptions Regarding Newton’s Laws Pre-iteration and Post-iteration

Topic	Source	Percentage of responses containing misconceptions	
		Pre-iteration	Post-iteration
Recognition of an application of Newton’s Laws	Table A1.1	18	20
Explaining an application of Newton’s Laws	Table A1.2	50	0
Applying Newton’s Laws to rocket efficiency	Table A1.4	43	0
Explain how you increased the efficiency of your rocket	Table A1.6	22	0

In the Comprehension and Tension iteration, responses contained more misconceptions with each question showing an increase in the number of misconception post-iteration. Table 5.7 indicates the percentage of misconceptions regarding various concepts involving Compression and Tension. The results in Table 5.7 are indicative of a perceived lack of interest by the students in the topic, especially post-iteration. As discussed earlier, the students had finished their course, their grades finalised, and subject selections chosen for next year. As a result, they became uninterested in the topic.

Table 5.7
Percentage of Responses Containing Misconceptions Regarding Stress, Stability and Compression Pre-Iteration and Post-Iteration

Topic	Source	Percentage correct	
		Pre-iteration	Post-iteration
Describe stress reduction	Table A1.43	0	33
Explain tower stability	Table A1.44	10	22
Describe compression reduction	Table A1.45	0	50

5.4.3.3 Planning, monitoring and evaluation

Students were asked to rate the importance of five aspects of planning and completing problems relating to the design and construction of a rocket using a Likert scale. A Spearman-Brown split-half reliability test was used to determine if there was any difference between the students rating of the importance of the five aspects, pre-iteration and post-iteration, in planning and completing the problem. The planning question pre- and post-iteration had an rSB1 = .294 and the completing question had an rSB1 = -.177. These results show no equivalency between the pre- and post-iteration responses, so there was a large difference between the pre- and post-iteration results. Comparing students' responses to the planning and completing questions showed that the pre-iteration results for these questions had an rSB1 = .93 and the post-iteration results had an rSB1 = .98. This result would indicate that the students did not see a significant difference between these aspects of planning or completing a problem pre-iteration and post-iteration (Table A1.7).

When asked the same questions in the Compression and Tension iteration, the results were similar. The planning question, pre- and post-iteration, had an rSB1 = .26 and the completing question had an rSB1 = .48. These results showed a greater level of equivalency between the pre- and post-iteration responses, compared with the Newton's Laws iteration, for the completing question. Comparing students' responses to the planning and completing questions showed that the pre-iteration results for the planning question and completing question had an rSB1 = .619, and the post-iteration results had an rSB1 = .522. While there was a decrease in the post-iteration value, comparing the planning and completion of the problem, it was not a significant one (Table A1.8).

When asked how they would evaluate their performance on the problem and in the Newton's Laws iteration, 36% of the students indicated they would do so by communicating, pre-iteration, compared with 20%, post-iteration. The two other responses were the end result, which 27% of students indicated, pre-iteration, and 30%, post-iteration and progress made, which 45% indicated, pre-iteration, and 50%, post-iteration. When asked to consider how they would evaluate each step, 50% of students indicated they would compare with another group member, pre-iteration, which increased to 78%, post-iteration. The number of irrelevant responses decreased from 37.5%, pre-iteration, to 11%, post-iteration (Table A1.10 and A1.12). In the Compression and Tension iteration, there was a difference in the responses to how students would evaluate their performance with only 12.5% indicating they would use communication, pre-iteration, and this declined to 0%, post-iteration. The other two responses were the end result, which 37.5% of students indicated, pre-iteration, and 67%, post-iteration, and progress, which 50% of students indicated, pre-iteration and 33%, post-iteration (Table A1.49 and A1.51).

In working to develop a solution to the problem, students also needed to access information and assess it. Students considered using multiple sources of information in the Newton's Laws iteration with the internet being the most common, pre-iteration, at 55% and internet and books being equally common, post-iteration, at 42% each. 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. When asked about assessing the information they had found, the most common response was to compare it with other members of their group: 67%, pre-iteration, and 60%, post-iteration (Table A1.11 and A1.13).

In the Compression and Tension iteration, students searching for information were again mainly focused on the use of the internet with 53% indicating they would use the internet, pre-iteration, and 55%, post-iteration (Table A1.50). Eighty-two percent of responses, post-iteration, were general searches rather than specific ones. In assessing information, it was found the most common response, pre-iteration, was comparing it with other group members at 78%. However, this declined to 37.5%, post-iteration, which was equal to the response of testing the information (Table A1.52).

5.4.3.4 Student engagement

The PBL Evaluation Tool first assessed student engagement by using two Likert scales. These scales ascertained student's beliefs about their confidence in completing a PBL project without help and the utility of the project to them as students. The first Likert scale asked students to rate their confidence level in completing the PBL task. Figure A1.14 shows the results of the first Likert test. A Wilcoxon Signed Rank two-tail test for paired samples tested for pre- and post-iteration differences. There was no significant difference between the pre- and post-iteration scores ($\alpha = .05$, $p = .14$). The second Likert scale asked students to rate how useful they thought the task would be to them as students. Figure A1.11 shows the results of the second Likert scale. There was no significant difference between the pre- and post-iteration scores ($\alpha = .05$, $p = .064$) using a Wilcoxon Signed Rank two-tail test for paired samples.

The first Likert scale showed only very small gains in student confidence, post-iteration, with decreases in confidence at the lower (less confident) end of the scale. There was no quantum lift in student confidence. The second Likert scale showed that students considered the iteration to be less useful to themselves, post-iteration. This result was not unexpected given the students' response to the next question (see Table A1.14) where 30% of students, post-iteration, indicated that because they had to do it was the motivation for working on the task or that they wanted a good result. The students saw the iteration as being entire unto itself with no application beyond the iteration.

When asked whether the task would be easy or difficult (see Table A1.17), the students' results showed that 33%, pre-iteration, and 30%, post-iteration, found it easy. However, when asked whether the task would be enjoyable (see Table A1.16), 67% of students, pre-iteration, and 51%, post-iteration, found it enjoyable. In the Newton's Laws iteration, students found the task to be more difficult than expected but also found it less enjoyable.

The Compression and Tension iteration also assessed student engagement using two Likert scales. The Likert scales ascertained students' 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 A1.28 shows the results of the first Likert test. A Wilcoxon Signed Rank two-tail test for paired samples was used to test for differences pre- and post-iteration. There was no significant difference between the pre- and post-iteration scores ($\alpha = .05$ and $p = .138$). The second Likert scale asked students to rate how useful they thought the task would be to them as students. Figure A1.27 shows the results of the second Likert scale. There was no significant difference between the pre- and post-iteration scores ($\alpha = .05$ and $p = .655$) using a Wilcoxon Signed Rank two-tail test for paired samples.

The first Likert scale showed small gains in student confidence, post-iteration, but 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 showed that students considered the iteration not useful to themselves pre- and post-iteration. When asked what their motivation was for working on the task (see Table A1.53), none of the students, post-iteration, indicated that their grades were a major concern. Only 50% indicated that a good end result was the major motivation and 25% indicated that the iteration was the motivation for working on the task, post-iteration. In this iteration, the main focus of the students was on the outcome rather than their grades. This result was not unexpected since the students' grades did not depend on their results in this topic.

When asked whether they would find the tasks easy or difficult (see Table A1.55), the results showed that 55% of students, pre-iteration and post-iteration, found the tasks easy. When asked whether the task would be enjoyable (see Table A1.54), 50% of students, pre-iteration, found it enjoyable and 62.5%, post-iteration, found it enjoyable. Thus, they did not find the task more difficult than expected and found it to be more enjoyable.

5.5 The Implications of the Results for Future Iterations

In this second cycle, both the Newton's Laws and Compression and Tension iterations produced some themes that inform the research questions. These themes have implications for the further development of the e-textbook supported PBL intervention. Table 5.8 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 its use in the classroom.

Table 5.8

The Implications of Cycle Two Related to the Research Questions

Research question	Implications	Strategies
1. What constraints (if any) inhibited the implementation of the e-textbook supported PBL intervention?	Hard-scaffolding has its limitations, and e-textbook design should facilitate soft-scaffolding. The application of soft-scaffolding needs to cover both content and group-work. Students need to be aware of the function of the e-textbook and not expect it to fulfil the role of a traditional one. The nature of the interaction between students regarding argumentation is important and requires further development. PBL is a relatively new teaching methodology for secondary school students and, as such, must deal with differing expectations of themselves and the teacher. This novelty of PBL is another scaffolding issue.	Develop soft-scaffolding protocols for the next iteration in terms of content and group-work as far as possible. Explicitly state the function of the e-textbook at the start of each iteration. Develop soft-scaffolding protocols regarding PBL for the next iteration as far as possible.
2. What design features of the e-textbook supported PBL intervention most influenced student learning?	The hands-on nature of the PBL was enjoyed by students and is an important component of the experience. The self-pacing of the learning experience was also an important component. The multimodal nature of the presentation of the information to students was beneficial. Feedback on how students are developing their understanding of the concepts is also important. Group-work is still a popular feature of the PBL experience.	Continue to provide hands-on experiences for the students and develop them further. Ensure that the iteration continues to be self-paced. Further, develop the multimodal approach using VARK. Further develop feedback to students. Develop group-work skills through soft-scaffolding.
3. What was the overall impact of the e-textbook supported PBL intervention	Development of the students' content knowledge is still a concern and needs further improvement. In certain cases, misconceptions need identification and correction. Students still need support in organising specific searches for information rather than a general approach to seeking information.	Provide more lead-in information for students. Develop soft-scaffolding protocols for the next iteration in terms of information seeking to clarify misconceptions as far as possible.

5.6 Summary

The completion of the second cycle has provided information for the ongoing refinement of the e-textbooks and their use to support PBL in science classrooms. The use of evaluation tools, interviews and observations have provided information that allows for some targeted re-design of e-textbooks and their use in PBL. These implications concern scaffolding problem-solving and group-work, providing feedback on progress, engendering a greater appreciation of PBL and sourcing and evaluating information.