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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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The Design and Development of E-textbooks to Support Problem-based Learning in Secondary School Science Classrooms

Nigel Stewart

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DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other institution.

To the best of my knowledge and belief this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signed: Nigel Stewart

Date: 11/04/2018

ABSTRACT

Problem-based Learning (PBL) is widely used in education and extensive research has been conducted into the use of PBL to improve student learning. E-textbooks are a relatively recent development and represent the next stage of evolution of print media with improvements in the presentation of information. They also offer the possibility of being used as a learning tool rather than just as a store of knowledge. This thesis attempts to develop a set of design principles that allow the development of e-textbooks to promote PBL in secondary school science students.

This research presents the results of a four-year study, between 2013 and 2016 with different classes, that aimed to investigate the development and use of e-textbooks to facilitate PBL in secondary school science classrooms. It involved identification of constraints that limit the implementation of PBL and measurement of their effect on learning through PBL. These included learning, pedagogical and technical constraints. An investigation was conducted into the use of e-textbooks to augment PBL and ameliorate these constraints. Through a process of Design-based Research, a set of principles was established that might promote the successful use of PBL and e-textbooks in secondary science contexts.

A review of the research literature revealed that PBL can have a powerful impact as an educational tool if the learning environment is well managed. However, certain constraints to using PBL, especially in secondary schools, require investigation. E-textbooks may also be able to improve student learning using PBL while ameliorating some of these constraints. The three research questions developed for this research aimed to identify such constraints and identify factors that could increase the impact of PBL on student learning using e-textbooks.

This study used a qualitative approach to investigate the use of e-textbooks to support PBL in secondary school science classrooms with some quantitative data used to support one aspect of the study (student knowledge). Data collected from a PBL Evaluation Tool before and after each intervention were used to measure student knowledge, planning, monitoring and evaluation and student engagement. In addition, data were collected through focus group interviews and observations of students in class. The four-year time span of the study allowed the collection of a large amount of data that provided opportunities for triangulation.

The three research questions guided the development of a set of design principles that will be useful in the future development of e-textbooks that support PBL. The results of the study were several design principles that could be used by teachers and schools to develop e-textbooks to support a PBL program. These principles are presented using a road map analogy that illustrates the journey undertaken in this research. The design principles involve the pedagogy of the teacher, the design of the e-textbook and the facilitation of the students in the PBL environment.

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GLOSSARY

ACARA

Australian Curriculum and Reporting Authority (ACARA) is a body established by an act of parliament, which is responsible for development of the national curriculum, assessment and reporting within Australia.

Cycle

The completion of two iterations within one year of a Problem-based Learning (PBL) program in a class or classes with different topics.

E-textbook

The result of integrating classical book structure …with features that can be provided within an electronic environment is referred to as an electronic book (or e-book), which is intended as an interactive document that can be composed and read on a computer. (Landoni, 2003, p. 168)

FGI

Focus group interviews conducted at the researcher's school by the researcher's supervisors using students randomly selected from classes in which the iterations took place. Five to six students participated in each interview.

Gaming

A term used to describe playing digital games on a computer.

ICO

Informal classroom observations made by the researcher during each lesson in each iteration regarding students group work, teacher student interaction and general impressions of the lesson.

ICSEA

Index of Community Socio-Educational Advantage is used specifically to enable fair comparisons of National Assessment Program – Literacy and Numeracy (NAPLAN) test achievement by students in schools across Australia. A value on the index corresponds to the average level of educational advantage of the school's student population relative to those of other schools (ACARA, 2015b).

ICT

Information and communication technologies have been defined as "a diverse set of technological tools and resources used to communicate and to create, disseminate, store, and manage information" (Blurton, 1999, p. 46). Skryabin, Zhang, Liu, and Zhang (2015, p. 50) noted that "a broad definition of ICT includes computers, the Internet, telephones, personal digital assistants (PDAs) and mobile phones, television, radio and audio-visual equipment."

Independent school

A school in Australia that derives most of its funding from private sources rather than from the government.

Iteration

A single learning event in which students are presented with a problem and work towards a solution and then complete a pre- and post-iteration evaluation. The iterations were: Newton's Laws (cycles one to three, abbreviated to NL1, NL2 and NL3 respectively), Chemical reactions (cycles one and three, abbreviated to CR1 and CR3) and Compression and Tension (cycle two, abbreviated to CT2). Where student responses from focus group interviews are included from each iteration, they are identified in the following way: (FGI Iteration topic Student number). For example, '(FGI NL1 S1)' means a response from Student 1 in the first iteration of Newton's Laws.

Secondary school

A high school educating students from Year Seven (13 years of age) to Year 12 (18 years of age).

STEM

Science, technology, engineering and mathematics "refers to teaching and learning in the fields of science, technology, engineering, and mathematics; typically including educational activities across all grade levels, from pre-school to post-doctorate, and in both formal and informal classroom settings" (Kennedy & Odell, 2014, pp. 246–247).

VMWare Horizons

A platform that allows a user to emulate a computer operating system and applications on another device without using the hardware of the physical device they are using.

Chapter One: Introduction

1.1 Introduction

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

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

1.2 Overview

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

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

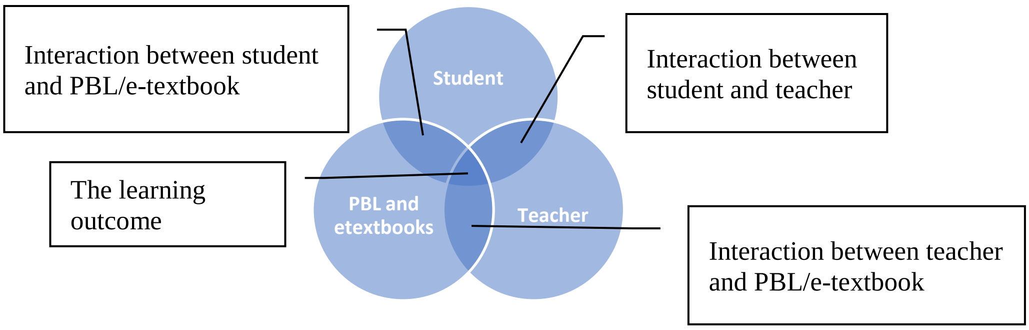


Figure 1.1. Interconnection between students, PBL/e-textbook and teacher (Macnish, Bate, & Stewart, 2017).

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

1.3 Framework and Research Questions

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

1.3.1 The Purpose of the Study

Over recent years newspaper headlines have been replete with stories regarding declining numbers of students choosing science and mathematics courses. Kennedy, Lyons, and Quinn (2014) noted that declines in Year 12 student enrolments occurred in all but one of the sciences between 1992 and 2012. Lyons (2006) noted that students in various countries found that students felt science courses were didactic, lacking context and excessively hard. This study proposes that PBL supported by e-textbooks can help overcome some of these issues.

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

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

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

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

The soft-scaffolds, which Saye and Brush (2002, p. 82) stated "are dynamic and situational … require[ing] teachers to continuously diagnose the understandings of learners and provide timely support based on student responses." It is not possible to quantify soft-scaffolding with any degree of specificity because it is highly variable and context dependent. For the purposes of this study, the role of the teacher was to provide students with hard-scaffolding incorporated into the problems presented to them in e-textbooks. Soft-scaffolding then became the responses the teacher provided to immediate student needs while they worked on the problems.

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

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

While PBL is attractive as a pedagogical approach, its implementation in schools is not without problems. Ertmer and Simons (2006) noted that the change in the roles of the participants and the time required for implementation are areas of concern. Another area of concern is the ability of teachers to support learners in a PBL environment (Simons & Klein, 2007). This study investigates whether ICT, in the form of e-textbooks, could help overcome, or at least mitigate, some of these concerns. Liu, Wivagg, et al. (2012), noted that while such technological tools are not essential, they can help with some of the issues inherent in implementing PBL in a classroom.

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

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

The use of technology, such as e-textbooks, should not be considered separately from the pedagogical framework a teacher may choose to use. Mishra and Koehler (2006) described the evolution of what constitutes teacher knowledge from its origins in an emphasis on content, through content and pedagogy, to content, pedagogy and technology (TPACK). It is the interconnectedness of the three entities that are important (Mishra & Koehler, 2006; Mishra, Koehler, & Kereluik, 2009). The TPACK model "emphasizes the role of teachers as decision makers who design their own educational technology environments as needed, in real time" (Mishra et al., 2009, p. 52). This emphasis is important for this study where development of e-textbooks is interwoven with a pedagogical approach, PBL, to teach particular content knowledge. This has been termed a digital pedagogy where "digital technologies change the way we teach and promote learning" (Maor, 2017, p. 72).

1.3.2 Conceptualisation of the problems

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

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

1.3.3 Development of a solution

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

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

3. What was the overall impact of the e-textbook supported PBL intervention in terms of students':

   - content knowledge;
   - problem-solving skills;
   - transfer of problem-solving skills to other topics.

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

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

1.4 Significance of the Research

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

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

PBL research gaps:

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

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

E-textbook research gaps:

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

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

1.5 Organisation of the Study

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

Chapter Two: Literature Review

2.1 Introduction

This review examines two central constructs that form the basis of the study: Problem-based Learning (PBL) and e-textbooks. It is, therefore, appropriate to examine the literature concerning their development, deployment, utilisation and evaluation in educational settings. This review considers the goals of PBL and its history, in particular, the work of Howard Barrows. It next provides a more focused review of PBL in secondary school classrooms. A review of the challenges of introducing PBL in secondary school classrooms follows, and the role of the facilitator and scaffolding is considered. The nature of problems in PBL and its use in science education are then considered. Next, this review defines an e-textbook and examines their use in learning using PBL. The VARK model's application to the design of e-textbooks is reviewed to provide a basis for producing a deliverable e-textbook package to students using PBL.

PBL is a large and varied topic that includes, but is not limited to, the design of problems, role of the facilitator, assessment of the student and environment in which it occurs. The use of PBL occurs in a variety of educational environments, including secondary schools and undergraduate and postgraduate institutions. Furthermore, the areas in which PBL is in use continue to expand (Savery, 2015) and as such, it needs to evolve and adapt (Barrows, 2003).

E-textbooks are textbooks in a digital form, which may include various augmentations that increase their readers' interaction with the content (Landoni, 2003). E-textbooks exist in a variety of formats with varying degrees of interactivity and the inclusion of different quantities and types of media, including text, video and graphics. E-textbooks, like PBL, are evolving as an important area in education, particularly regarding their design and utilisation and, therefore, also warrant careful consideration to inform this thesis.

2.2 Problem-based Learning

PBL is one of a suite of techniques that utilise “anchored instruction and project-based science” (Hmelo-Silver, 2004, p. 237). However, a clear definition of what constitutes PBL is elusive (Davis & Harden, 1999; De Graaf & Kolmos, 2003; Gijbels, Dochy, et al., 2005; Lloyd-Jones et al., 1998; Newman, 2005; Ravitz & Blazevski, 2010). A perusal of the literature reveals many references to Howard Barrows as the developer of PBL in its modern form (Chin & Chia, 2008; Frey et al., 2009; Gijbels, Dochy, et al., 2005; Liu, Wivagg, et al., 2012; Ravitz, 2009; Savery, 2006; Wong & Day, 2009). It is from the work of Barrows that this thesis will seek to start to develop a meaningful definition of PBL.

2.2.1 Goals of PBL

A perusal of the literature revealed some different goals for PBL and Table 2.1 presents them. These goals are extensive and can encompass PBL environments at postgraduate, undergraduate and secondary school classroom levels. However, it is possible to draw out some common themes from these goals, and they include the ability of students to work collaboratively on problems, acquire content knowledge, communicate effectively and be motivated to learn. Underpinning these themes is the constructivist approach to learning. Pecore (2012, p. 9) stated that “PBL provides one of the best examples of a constructivist learning environment by adhering to the theoretical principles of constructivism.” Within the context of this study, the ability of students to be motivated to work collaboratively on problems to acquire new content knowledge is a reasonable goal. These goals represent a starting point for customising a PBL program in a secondary school and embody the basic ideas of PBL. More ambitious goals, including learning beyond the current program by developing higher-level cognitive reasoning, may occur as the study progresses.

Table 2.1
The Various Goals of PBL Reported in the Literature

Goal	Description	Reference(s)
Enhancing acquisition, retention and use of knowledge	Help students learn information, skills and dispositions necessary for success in the information age.	(Gallagher, 1997, pp. 334, 356)
Developing self-directed, lifelong learning skills	Decide on a course (or courses) of action to reach these goals. As they implement their plan, learners must be able to monitor and evaluate whether or not their goals have been attained.	(Hmelo-Silver, 2004, p. 241)
Problem-solving	Perform less routine tasks requiring problem-solving skills.	(Gijbels, Van de Watering, Dochy, & Van den Bossche, 2005, p. 329)
Gaining a deeper understanding of content	Incorporate more systematic ways of helping students make the connection between their inquiry activities and the content.	(Ertmer & Simons, 2006, p. 47)
Preparing students for future learning	Develop problem-solving, reasoning and self-directed learning skills to help prepare students for future learning.	(Hmelo-Silver, Duncan, & Clark, 2007, p. 103)
Developing an extensive and flexible knowledge base	Integrate information across multiple domains so that it can be fluently retrieved and applied under varying and appropriate circumstances.	(Ge et al., 2010, p. 32; Hmelo-Silver, 2004, p. 240)
Developing the 'inquiry' or 'problem-solving' skills of an expert	Imitate students thinking processes. Working on a problem is seen as a simulation of what the… [expert] …does, particularly in its emphasis on data gathering and interpretation.	(Schmidt et al., 2011, p. 802)
Enhancing students' intrinsic motivation to study	The interest level of problems in PBL was positively associated with intrinsic motivation.	(Wijnia, 2014, p. 31)
Developing higher-order thinking skills, as well as communication and collaboration skills	Engaging in self-directed learning, students work on filling those gaps, and they conclude the process of learning by sharing their newly acquired knowledge and collaboratively finalising and presenting the solution.	(Wilder, 2015, p. 415)

2.2.2 The work of Howard Barrows

Barrows (1986) acknowledged that PBL encompasses a broad range of approaches to the task of educating students with problems presented to them as the shared quality between these approaches. The problems themselves are also quite variable (Barrows, 1986). Consequently, it is necessary to identify the key features of a PBL experience that is relevant to this investigation.

Barrows and Tamblyn (1980, p. 18) defined PBL as "the learning that results from the process of working toward the understanding or resolution of a problem." Savin-Baden and Major (2004, p. 4) described the definition provided by Barrows and Tamblyn (1980) and equated this definition to the "classic model" containing the following features:

- Complex, real world situations that have no one 'right' answer are the organizing focus for learning;
- Students work in teams to confront the problem, to identify learning gaps, and to develop viable solutions;
- Students gain new information though [*sic*] self-directed learning;
- Staff act as facilitators; and,
- Problems lead to the development of clinical problem-solving capabilities.

(Savin-Baden & Major, 2004, p. 4)

The classic model was developed in response to a perceived need to provide medical students with the ability to apply large amounts of knowledge learnt about medical science to the care of patients. It required students to learn both relevant content knowledge and its application to the problem at hand. Research by Barrows between 1980 and 1996 showed that there was remarkably little change in the initial PBL model described by him. The learning style and role of the teacher remained consistent as does the notion of group-work and team skills. Learning is held to be student-centred and reasoning skills defined as hypothetico-deductive, scientific or clinical, but all imply the same idea. Their nature describes problems (Barrows, 1986; Barrows & Kelson, 1993; Barrows & Tamblyn, 1980), their purpose (Barrows, 1996) and their role developing problem-solving competences (Barrows, 1986, 1996;

Barrows & Kelson, 1993; Barrows & Tamblyn, 1980). The problem provides motivation for the students who engage in some form of self-evaluation (Barrows, 1986; Barrows & Kelson, 1993; Barrows & Tamblyn, 1980). The nature of the knowledge produced by PBL does evolve through the various versions of PBL, starting with the application of knowledge (Barrows & Tamblyn, 1980), then structuring knowledge (Barrows, 1986) and finally, integration of knowledge (Barrows, 1996; Barrows & Kelson, 1993).

Barrow's ideas have been presented in this study as a concept map, as shown in Figure 2.1. In this map, PBL is a black box, where the internal operations are unknown, that will produce a measurable outcome (integrated applicable knowledge) from a known input (constructed problems). This system consists of the processes that develop in the students as they work on the problem using PBL. The processes themselves are measurable and provide some insight into how students use Barrow's PBL. It is a system regarding the interactions between the different components that produce structured and integrated knowledge. It is a black box regarding how these interactions produce this integrated knowledge since the literature provides no description.

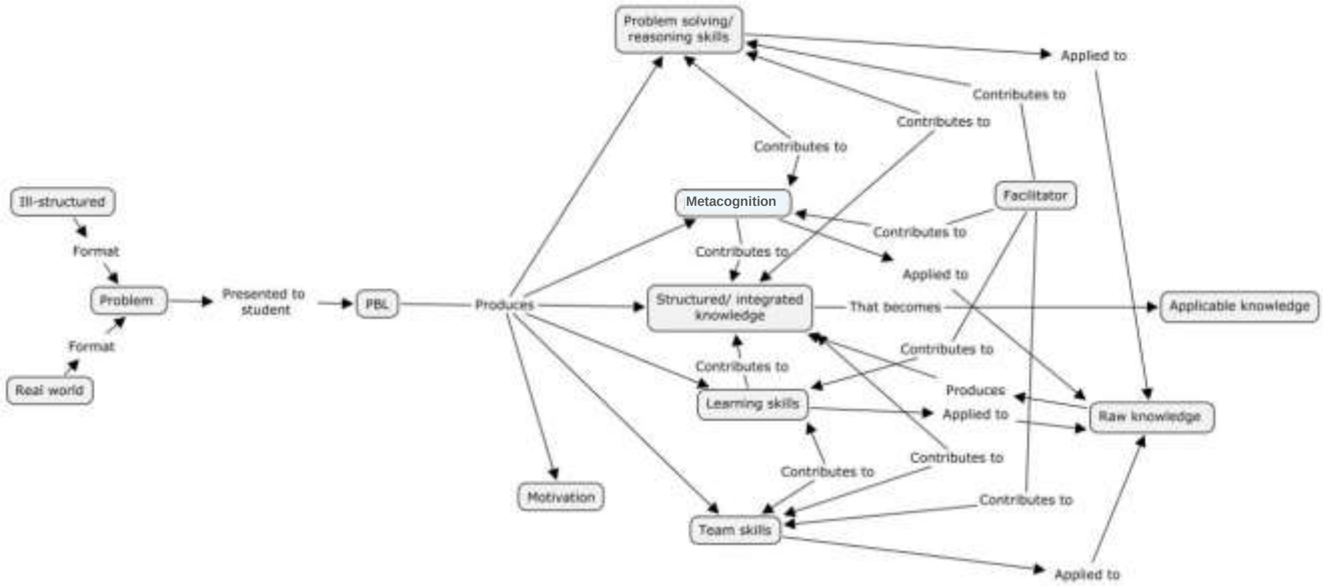


Figure 2.1. A concept map used to illustrate Barrows model of PBL.

PBL has changed over time and in undergoing an evolutionary process from its ancestral form as it responded to a variety of pressures, which have helped shape and develop it as an educational methodology. Barrows (2003) was critical of many of these “poorly conceived problem-based learning approaches” (p. 255), and in response to criticisms levelled at PBL by Glew (2003), Barrows sought to redefine PBL as “authentic PBL” where its design and methods remain faithful to its original principles (Barrows, 2003, p. 255). However, doing so does not address the issues raised by Glew (2003), who was concerned about the lack of knowledge of fundamental scientific ideas in medical students. The lack of knowledge stemmed from issues with the employment of personnel who were not equipped to do so to deliver the PBL program to students and the numerous competing demands on their time reducing contact with students (Glew, 2003). These concerns have more to do with budget concerns in faculties and perceptions of PBL by people within the departments implementing PBL in university medical schools (Glew, 2003). Furthermore, it is unrealistic to expect PBL not to evolve in response to the myriad of factors that can and do affect its implementation since a “one size fits all” PBL program does not exist (Goodnough & Cashion, 2006). The transition of PBL from university medical schools to secondary schools is just one example of the changing forces with which it contends. The differences between medical students and secondary school students are numerous, such as motivation, background knowledge, maturity and academic ability. One cannot simply transplant PBL from one to the other without the very real prospect of failure (Goodnough & Cashion, 2006).

2.2.3 PBL in a secondary school classroom

PBL has been used successfully in secondary school classrooms. This success has been in the areas of improved motivation (Pedersen, 2003), problem-solving skills (Wilder, 2015) and self-efficacy (Cerezo, 2004). Specifically, in secondary science classrooms, PBL is associated with improved conceptual development (Tandogan & Akinoglu, 2007), attitudes towards science (Ferreira & Trudel, 2012) and academic achievement (Tandogan & Akinoglu, 2007). Furthermore “it is believed that PBL is a [*sic*] student-centred, which prepares learners to relate scientific concepts to real life situations” (Aidoo, Boateng, Kissi, & Ofori, 2016, p. 107). Hattie (2009, p. 211) noted that PBL was associated with improved “application and principles underlying … knowledge” in a meta-analysis of influences on achievement. In the area of science education, specifically science, PBL has many advantages (Asghar, Ellington, Rice, Johnson, & Prime, 2012; Dischino, DeLaura, Donnelly, Massa, & Hanes, 2011; Goodnough & Cashion, 2006).

Implementation of PBL in secondary school classrooms is a challenging undertaking (Belland, Kim, & Hannafin, 2013; Ertmer & Simons, 2006; Liu, Hsieh, Cho, & Schallert, 2006; Liu, Wivagg, et al., 2012; Veletsianos & Doering, 2010; Yeo & Tan, 2014). For PBL to be successful in a secondary school classroom, it is necessary to identify these challenges (Table 2.2) and, as far as possible, moderate them. The process by which these challenges are controlled assist in the provision of a model for PBL implementation into secondary science classes.

Table 2.2
Summary of the Challenges to Using PBL in Secondary School Classrooms

Challenges	Focus	Author
Students lacking self-direction	Secondary School Gifted	Gallagher (1997)
Using PBL in secondary school classrooms requires access to rich knowledge bases and cognitive tools	Secondary School	Liu, Williams, and Pedersen (2002, p. 255)
Young learners of average ability may lack the skills to identify pertinent learning needs and the resources that can meet them. They may have less developed planning skills and be less able to reflect upon their efforts and change them when necessary	6^{th} Graders	
Insufficient time available for activities	6^{th} Graders	Simons, Klein, and Brush (2004)
Creating a culture of collaboration and interdependence Adjusting to changing roles Scaffolding student learning and performance	Secondary School	Ertmer and Simons (2006, p. 40)
Ineffective ways to present the central problem through oral or written means and large investment in time and effort to develop PBL units	Middle school	Liu et al. (2006, p. 227)
Scarce research on PBL in secondary school contexts	Secondary School	Veletsianos and Doering (2010, p. 281)
Students maintain superficial and minimum work to appear active in the learning process Inadequate time devoted to searching literature and information … and superficial synthesis of the investigation of the problem in the final reports	Secondary School[a]	Hung (2011, p. 539)
Solving complex problems, however, proves to be especially challenging for young learners	6^{th} Graders	Liu, Horton, et al. (2012, p. 113)
Lack of research describing ‘how to’ in implementing PBL in classrooms	Secondary School	Liu, Wivagg, et al. (2012, p. 47)

(continued)

Challenges	Focus	Author
Poor connectedness among groupmates Poor elicitation and maintenance of interest	Secondary School	Belland et al. (2013, p. 243)
Difficulties balancing between helping students to learn content prescribed in the formal curricula in school and developing thinking and problem-solving skills that are preferred by the PBL approach	Secondary School	Yeo and Tan (2014, p. 747)

[a] While relating mainly to medical school programs, extrapolations are made to secondary school classrooms.

The ability to work effectively in groups is an important, if not vital, component of any PBL undertaking (Dolmans et al., 2005). However, it is not a given that groups will naturally work productively (Belland et al., 2013; Hung, 2011). Given the former and requiring the latter means that group dynamics are an important consideration in any PBL undertaking. Achieving effective group dynamics is usually the role of the facilitator (Wood, 2004), who must balance several considerations, including the personality, behaviour and individual circumstances of group members. However, as Liu, Wivagg, et al. (2012) and Veletsianos and Doering (2010) noted, a 'go to' manual for implementing PBL is unavailable and, by definition, the facilitator's role is unique to each circumstance in which they operate.

How then can the challenge of group dynamics be addressed? Ertmer and Simons (2006) suggested a staged approach to PBL implementation where students can develop their group-work skills in a series of small problems before encountering larger ones. Given the issues identified regarding group functioning in PBL environments, the idea of using a process of gradual inculcation to familiarise students with the method has merit. Where possible, the PBL model would need to include a series of problem encounters that allow students to develop their group-work skills gradually. Student collaboration is an integral part of PBL since it allows them to work together to develop a solution to the problem presented to them (Ertmer & Simons, 2006), but it requires careful support to achieve it (Saye & Brush, 2001). Collaboration should not be viewed as students talking, and facilitation of collaboration by computers is not simply allowing them to talk. It is the nature of these student interactions that is of critical importance and simply allowing them to communicate is to miss the point entirely. The role of technology in the form of e-textbooks, in this case, is to develop and support productive student discourse in the form of argumentation. Many different viewpoints exist about the definition of argumentation even within the scope of science (Bricker & Bell, 2008). Nonetheless, a more empirical definition of "discussions that present and provide support for claims" (Belland, Glazewski, & Richardson, 2008, p. 402) is sufficient. However, argumentation does not spontaneously arise in secondary school classrooms (Belland, French, & Ertmer, 2009). Failure results from several factors involving the student's inability for:

- Adequately representing the central problem;
- Determining and obtaining the most relevant evidence;
- Synthesizing the information gathered; and,
- Construct[ing] a sound argument.

(Belland, Glazewski, & Richardson, 2011, p. 668)

Initially, these issues arise because the students "participating in PBL units often represent the problem to themselves based on the surface-level details in the initial description of the problem that they received" (Belland et al., 2008, p. 406), which will limit further progress towards a solution. The initial representation of the problem is the starting point for any support that will facilitate effective student collaboration leading to argumentation. Provision of this support is by scaffolding delivered by a resource available to the student which allows them to engage in argumentation when they are unable to do so alone (Belland et al., 2008). The support would include delineating the problem for the students to provide them with a means to represent the problem effectively, making available access to appropriate resources and allowing for recording of information and supporting their formulation of a reasoned solution.

While the importance of collaborative group-work is paramount, it should not supplant consideration of the individual within the group. Gallagher (1997) noted that while students develop self-direction in PBL, the level of self-direction is variable and dependent on their developmental stage:

> Medical school students grow to the point where they virtually take over class planning; they set up a schedule, lead class discussion, share self-assessments and critique each others' performance … [but] successfully going and returning from the library may be impressively self-directed for younger students. (p. 355)

Gallagher (1997) made this observation in the context of using PBL with high-ability students. The ability of students in the general population regarding the level of self-directedness may vary considerably. Ertmer and Glazewski (2015, p. 94) noted that "learners have difficulty during the initial stages of inquiry" and steps aimed at "enlisting learners' interests and presenting the requirements of the task" to students are necessary. The engagement needs to occur at the level of the individual rather than the group lest the attempt becomes diluted through the group with resultant superficial group behaviours. If each individual is interested and knows how to achieve the requirements of the task, then each such individual is more likely to be self-directed, which, in turn, will reinforce self-direction in the group.

2.2.4 The role of technology in PBL

In using computers to promote PBL, Liu et al. (2002) harnessed cognitive tools to overcome some of the challenges that they identified in teaching science using PBL. Cognitive tools are devices, including glossaries, notebooks, animations, chemical formulae and equation writing. These tools can be used to assist students working with complex and challenging problems (Liu, Horton, et al., 2012). These "cognitive tools are instruments that assist learners in accomplishing complex cognitive tasks" (Liu et al., 2002, p. 258). Lajoie (1993) described four roles for cognitive tools:

- Support cognitive processes, such as, memory and metacognitive processes;
- Share the cognitive load by providing support for lower level cognitive skills so that resources are left over for higher order thinking skills;
- Allow the learners to engage in cognitive activities that would be out of their reach otherwise (Pea, 1985; Olson, 1988); and,
- Allow learners to generate and test hypotheses in the context of problem solving. (p. 261)

However, the present study utilised two of these roles: support memory and metacognitive processes and provide support for lower level cognitive skills. These were the most relevant in that they helped to alleviate the challenge of large class sizes and large numbers of groups. These two roles also helped the different ability levels of students working independently from the teacher.

While problems are central to the idea of PBL, what is not so clear is how to present these problems to students in an effective way. Hoffmann and Ritchie (1997) noted that "sole reliance on written cases or verbal vignettes, as Bransford and others (1989) have noted, may have dysfunctional consequences for the learner" (p. 100). Liu et al. (2006) suggested that technology can be used to remedy the issue of presenting problems to students. Specifically, these tools can present problems to students in an engaging way that allows students to develop the problem-solving skills. However, designing problems to present to students can be a time-consuming process (Simons et al., 2004) and time is a precious commodity in secondary school science classrooms. The need to provide several staged problems rather than a single one exacerbates the lack of time. Furthermore, traditional means of presenting problems (oral or printed) may prove ineffectual (Hoffmann & Ritchie, 1997), necessitating a more engaging mode of presentation. By presenting problems in a multimedia format with interactivity, it was possible to engage students in the PBL process and use limited time more effectively.

In any school system, there will be specific content that students need to know to achieve a particular grade as decided by test results (Meier, Hovde, & Meier, 1996). The need to ensure student achievement often sets teachers at odds with the PBL process, which, while valued, is considered too difficult to reconcile with the demands of the curriculum (Lee & Bae, 2008; Yeo & Tan, 2014). While the two approaches may be incompatible, it is more useful to think of the issue regarding how students learn the content rather than just considering what they need to learn. Yeo and Tan (2014) noted that "developing problem-solving competencies and content learning need not be disparate activities … we can harness the interdependency of these two activities to achieve dual goals in learning" (p. 747). Thus, the content and process of learning are not incompatible, but complementary.

2.2.5 The role of the facilitator in PBL

A clear distinction exists between the role of a teacher and that of a facilitator. In the former role, it is the transmission of knowledge that takes precedence, whereas in the later, the role changes to encouraging students to gain knowledge for themselves. Ertmer and Glazewski (2015) noted that this requires a "willingness and ability of teachers to change the way they control the class"(p. 92). Grant and Hill (2006, p. 26) asserted that "moving to a facilitator also shifts what the teacher teaches." Furthermore, Ertmer and Glazewski (2015) did not specifically describe how teachers can achieve this transition stating that the process was "unclear"(p. 92).

As a result, considerable emphasis is placed on the role of the students in PBL as a constructor of their knowledge while working, as a group, on a problem presented to them in what English and Kitsantas (2013) termed "self-regulated learning" (p. 129) or SRL. Such learning does not imply that the students should be locked in a room and left entirely to themselves to develop the requisite knowledge that the problem requires. Students, especially those in the secondary school environment, will require support in their endeavours while working on the problems set before them. Hung (2011) noted that PBL research focused on outcomes rather than implementation, and yet, this is an area that is deserving of investigation since successful implementation should lead to successful outcomes. In implementing PBL, the provision of support by facilitators is vitally important (Hmelo-Silver, 2004; Marcangelo & Gibbon, 2009). However, the expectations of these facilitators in PBL is enormous. Scott (2014, Facilitator Effectiveness, para. 1) emphasised questioning skills to develop "reflection, metacognitive skill development, and collaborative knowledge… and scaffolding problem-solving and learning strategies by modeling effective behaviors." The facilitator is expected to work with each individual group to promote collaboration and assist them to acquire problem-solving skills through reflection by representing appropriate processes to the group. (Hmelo-Silver, 2004) described the facilitator as one who “guides the development of higher order thinking skills by encouraging students to justify their thinking and … externalizes self-reflection by directing appropriate questions to individuals” (p. 245). The facilitator is responsible for developing in the student’s argumentation, which is necessary for students to engage in PBL. Haith-Cooper (2000, p. 268) stated that the “facilitator is to ‘use all means available’, intervening with questions, suggestions and information to stimulate discussion.” The facilitator is seen here as someone who is closely involved with the group and takes a more hands-on approach to the workings within the group.

Two important issues are to be considered here regarding the role of facilitators: first, the diverse nature of what they must provide to several groups in a secondary school classroom and second, how to effectively facilitate these roles post-problem presentation. How can a facilitator fulfil all of these roles identified by Scott (2014) within a classroom of diverse learners at different stages of social and intellectual development after the students encounter the problem? English and Kitsantas (2013, p. 133) proposed a model that links the role of the facilitator with student knowledge development through three phases of development during PBL, as shown in Figure 2.2.

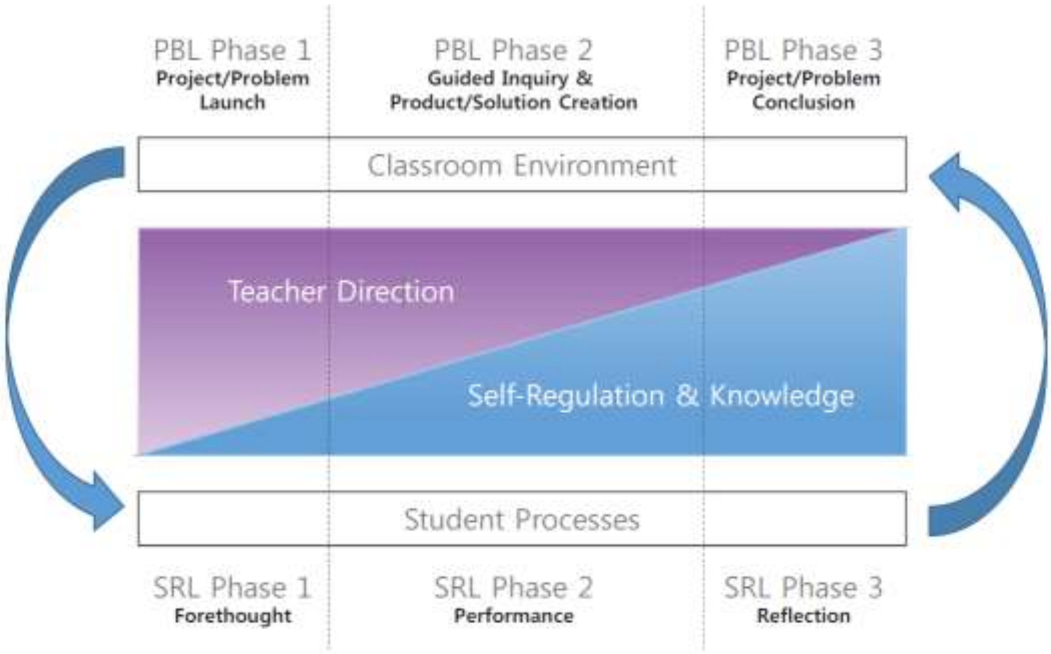


Figure 2.2. A model depicting the relationships among the phases of PBL and SRL (English & Kitsantas, 2013, p. 133).

However, this model may be deficient if it fails to address the large initial load placed on the facilitator, for example, establishing positive group behaviour. This situation does not allow for any preliminary work before the students encounter the problem, but this model could provide the basis for one that does address these needs if it is modified to include the use of technology.

For this study, the model in Figure 2.2 was revised to take into account the use of technology to provide hard-scaffolding to students (see Figure 2.3). As a result, there was a commensurate reduction in both the requirements placed on the facilitator and the need to pre-position students before engaging in PBL. In such a model, e-textbooks can provide the hard-scaffolding required (Makrakis & Kostoulas-Makrakis, 2017) during each phase of the PBL/SRL process, and in doing so, replace the role of the facilitator to some degree (Saye & Brush, 1999), allowing the facilitator to concentrate on areas of specific need within each group rather than classroom issues. By pre-positioning students for group-work, they do not go into the problem without any ideas regarding their role but can now engage with the problem more effectively.

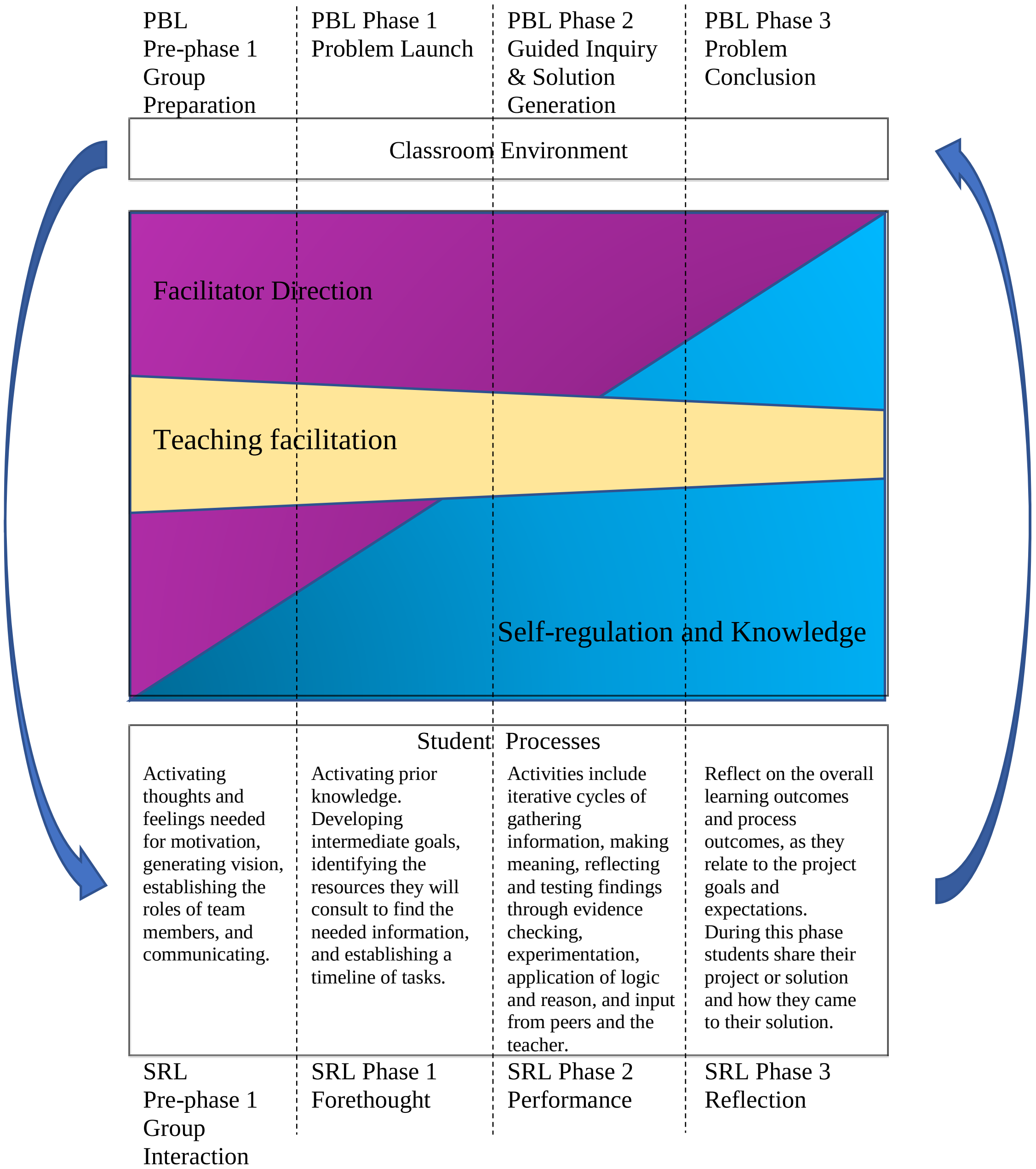


Figure 2.3. A revision of the model by English and Kitsantas (2013, p. 133), which shows the relationship between the phases of PBL and SRL, taking into account a pre-problem phase, inclusion of student processes and the use of technology.

2.2.6 Scaffolding in PBL

There is ample evidence to suggest the need for scaffolding in any PBL environment (Belland, 2010; Belland et al., 2011; Bogard, Liu, & Chiang, 2013; Kim & Hannafin, 2011; Liu, Horton, et al., 2012; Liu, Wivagg, et al., 2012; Schmidt et al., 2011). Two main types of scaffolding are used in PBL: hard-scaffolding and soft-scaffolding (Ertmer & Simons, 2006). Hard-scaffolds are hardwired into the PBL environment and are based on the students' support requirements that are predicted from either previous research or exposure (Belland et al., 2008). Provision of soft-scaffolds by the teacher are more responsive to the immediate requirements of students (Simons & Klein, 2007).

While scaffolding is important, questions remain about its use in PBL. Belland et al. (2011, p. 669) noted that "few studies on science scaffolding investigate the differential impact of scaffolds on students of differing ability levels." Furthermore, students and classes are not static over the course of a student's academic career in secondary school, and so, the types and amounts of scaffolding need to be varied to accommodate differing student needs (Liu, Wivagg, et al., 2012). Scaffolding is dynamic in nature and dependent upon many factors that themselves can vary considerably.

Technology can go some way to providing appropriate scaffolding to students in PBL (Makrakis & Kostoulas-Makrakis, 2017). The use of e-textbooks that incorporate hard-scaffolds can provide support to students, and this support can be varied from year to year and class to class, if necessary. However, as Saye and Brush (2002, p. 94) stated "there are clearly limits to the gains that can be achieved by hard-scaffolding improvements" and as such, soft-scaffolding will always be required and will need to be responsive to a wide variety of students.

2.2.7 The nature of the problem in PBL

Jonassen (2000) listed just two essential features of problems: they are unknown, and they have value. However, Dolmans et al. (2005, p. 735) cautioned that developing successful problems is difficult and asserted that "In order to stimulate students towards constructive and contextual learning more complex, realistic, open-ended, and ill-structured problems are needed that fit with students' prior knowledge." Davis and Harden (1999, p. 136) noted that "The problem scenario should present basic science concepts … to encourage integration of knowledge" and "The problem scenario should contain cues to guide the student and … encourage students to elaborate and to search for explanations." Jonassen (2000, p. 66) described three attributes of problems that can be used to categorise them into various types: structuredness, complexity and abstractness.

However, complexity is considered too variable to be useful (Jonassen, 2000). Jonassen (2000) defined 11 different problem types and discussed their suitability to problem solving, which provided a useful basis to consider the types of problems used in this study. Within this study, four of the problem types were given consideration: story problems, rule-using problems, decision-making problems and design-problems (Jonassen, 2000, pp. 74–75). The problems at each end of Jonassen's (2000) scale were excluded because, as Walker and Leary (2009, p. 16) noted, "problem types at both ends of the loose continuum are likely to be inappropriate for PBL." Furthermore, Hung et al. (2008) cautioned that PBL had its genesis in medical education where students would be intellectually capable and self-motivated enough to engage in PBL, and this was not necessarily true for secondary school students. It is therefore important to ensure that while the problems designed hold true to the ideals of PBL, ill-structured, authentic and valued, it was also crucial that secondary school students complete them.

The development of suitable problems in a secondary school PBL required the careful balancing of various competing factors. These factors included the prescribed curriculum, the current level of student familiarity with PBL, the student's ability level and the student's previous knowledge (Merritt, Lee, Rillero, & Kinach, 2017). In designing appropriate problems for secondary school students, familiarity with the problem enables them to engage with it more effectively in a collaborative setting (Scott, 2014). Furthermore, they should be ill-structured in that they require further research to arrive at a solution that may be one of many possible solutions (Gallagher, Sher, Stepien, & Workman, 1995). Finally, problems will need to be "imaginatively assembled for an educational context [and] created to fit particular needs" (Allchin, 2013, p. 368). However, in doing so, it is important that they not be considered too contrived by students (Allchin, 2013).

2.2.8 PBL and science education

Since this thesis is concerned with the use of PBL in science classrooms, it is appropriate to review the literature pertaining to its use in science education in secondary school settings. Goodnough and Cashion (2006) raised several questions about the use of PBL in secondary school science education, including what models are most suitable for students, and stressed the importance of preparing them to take part in PBL. Leite, Dourado, and Esteves (2010) added to this need to prepare students by emphasising the importance of students' preferred learning styles when encountering PBL. Horak and Galluzzo (2017) reported that at least in the case of gifted middle school students, PBL students performed better on academic achievement tests compared with those experiencing a more didactic method of teaching. Goodnough (2008) described that the difficulties experienced by teachers who adopt PBL to teach science was that teachers found it difficult to provide the appropriate amount of structure during PBL and were uncertain about how students would cope with the experience.

While it would not be unexpected for teachers embarking on PBL to have concerns, it was important to document such unease so that mitigation strategies could be adopted to ameliorate their effects. Asghar et al. (2012, p. 109) noted that there are “individual and institutional barriers confronted by many science and mathematics teachers while learning and employing the integrative STEM-PBL modules in their practice” that need addressing. While institutional barriers are less tractable, amelioration of individual concerns through continued practice and reflection is possible.

In attempting to address poor performance by secondary school students in science subjects (Brush & Saye, 2017) noted that PBL provided a means to engage students in science content as well as “higher–order thinking skills” (p. 165). Argaw, Haile, Ayalew, and Kuma (2017) reported that PBL improved secondary student’s results in physics and was a “more effective method of instruction” (p. 866). While PBL may be considered a useful tool to engage students in science it was also necessary to consider how this approach may be implemented in secondary schools. Balim, Inel-Ekici, and Özcan (2016) investigated the use of concept cartoons to facilitate PBL in science classrooms. However, while they found PBL improvement by the students on an inquiry skills perception scale using PBL, there was no improvement between the concept cartoon PBL group and the PBL alone group. Concept cartoons alone may not be sufficient to engage science students in PBL and more dynamic support in the form of e-textbooks could be more useful.

2.3 The Definition and Role of E-textbooks

This section considers the definition of an e-textbook as well as its role in learning in general and supporting PBL in particular. A perusal of the literature about the definition of what constitutes an e-textbook does not yield a universally accepted classification. Armstrong (2008) noted that "Over recent years there has been considerable confusion over the use of the term 'e-book'" (p. 193) while Vassiliou and Rowley (2008) went further in stating that "there is no consensus on the definition of the term e-book" (p. 355) and this lack of agreement extends to the users of the e-book as well (Briddon et al., 2009).

2.3.1 The definition of an e-textbook

Although a universally accepted definition of an e-book is lacking, some authors have attempted to provide one. Armstrong, Edwards, and Lonsdale (2002) emphasised the device used in defining an e-book as "any piece of electronic text regardless of size or composition (a digital object) … made available electronically (or optically) for any device (handheld or desk-bound) that includes a screen" (p. 217). Landoni (2003) concentrated on its structure, defining an e-book as:

> The result of integrating classical book structure …with features that can be provided within an electronic environment is referred to as an electronic book (or e-book), which is intended as an interactive document that can be composed and read on a computer. (p. 168)

E-books provide extra functionality to the user. Armstrong (2008) noted that "the integration of …audio and visual clips, moving images, still images, tables and graphs – or extensive added functionality does not detract from the book-ness." (p. 197). Maynard and Cheyne (2005) extend the e-book definition to e-textbooks by stating that "An electronic textbook (or e-textbook) has similar content and could be seen as a subset of the more generic concept of an electronic book" (p. 104). For the purposes of this study, an e-textbook will be considered using the definition proposed by Vassiliou and Rowley (2008):

> An e-book is a digital object with textual and/or other content, which arises as a result of integrating the familiar concept of a book with features provided in an electronic environment.
>
> E-books, typically have in-use features such search and cross-reference functions, hypertext links, bookmarks, annotations, highlights, multimedia objects and interactive tools. (p. 363)

2.3.2 E-textbooks and learning

The use of technology in support of PBL has received considerable attention in the literature by Beaumont, Norton, and Tawfik (2011); Belland (2010); Ertmer and Ottenbreit-Leftwich (2013); Ge et al. (2010); and Rongbutsri, Khalid, and Ryberg (2011). However, no mention seems to have been made of the use of technology in the form of an e-textbook. Nevertheless, e-textbooks could be used effectively for PBL given their effective use in other areas of education (Dennis et al., 2015; Embong, Noor, Hashim, Ali, & Shaari, 2012; Hamedi & Ezaleila, 2015; Sun et al., 2012).

Given the value of linking technology and PBL cited above, it is necessary to establish how e-textbooks can improve learning in a PBL program. Certain features can be easily incorporated into e-textbooks that allow for their use as a tool in PBL. The e-textbook allows the presentation of the problem to students using a variety of formats, including video and audio. However, e-textbooks go further in providing “complex annotation strategies” (Dennis et al., 2015), that “allow students to learn content that can be tailored to their abilities” (Hamedi & Ezaleila, 2015, p. 254), give feedback to students (Embong et al., 2012), “provide a platform for initiative and collaborative learning for students” (Sun et al., 2012, p. 74), and allow for taking of notes (Chen, Gong, Yang, Yang, & Huang, 2013).

These features are readily adaptable to PBL and hence allow for e-textbooks to be used effectively in such a program. However, the problem of e-textbook acceptance by students remains. A review of the literature reveals contradictory opinions about e-textbook acceptance (Gu, Wu, & Xu, 2015; Lau, 2008; Nicholas & Lewis, 2009). The relatively recent arrival of e-textbooks on the educational scene has created this ambiguity. Nevertheless, it is possible to identify factors that promote e-textbook uptake by students. Chen et al. (2013) noted that e-textbooks should be similar in design to paper books, but with additional features peculiar to the e-textbook format. Lau (2008) observed a preference by younger (secondary school) students for e-textbooks, and Sun et al. (2012) reported that use of e-textbooks in class improved student perception of the usefulness of the e-textbook. All of these factors are considerations in producing an e-textbook for use in a secondary school PBL program.

2.3.3 E-textbooks and PBL

The decision to use e-textbooks in this study resulted from the need to create a learning environment that allowed students to work with laboratory equipment in the real world, as opposed to a virtual one. Furthermore it is desirable to have a theoretical base from which to use the technology of e-textbooks to avoid what Bennett and Oliver (2011) described as a lack of educational theory in the design of learning technologies. PBL provides the theoretical background to the design of the e-textbook. By using a combination of e-textbooks and laboratory equipment in a science laboratory, students develop PBL skills as well as hands-on proficiencies. De Jong, Linn, and Zacharia (2013, p. 308) reported that “combinations of virtual and physical laboratories offer advantages that neither one can fully achieve by itself” and this was the approach taken in this study. Furthermore, there is the issue of students immersed in the virtual world to the point where they “ran out of time to complete the more important activities, such as finding and analysing data or sharing and discussing the data with their teammates” (Dunleavy, Dede, & Mitchell, 2009, p. 14). To minimise these problems, students work in both the physical and virtual worlds.

The design of e-textbooks has focused “on the interface and the technical aspects to improve user acceptance. Instructional principles and strategies for e-textbooks are not widely and systematically evaluated” (Gu et al., 2015, p. 37). As such, there is a lack of literature on the use of e-textbooks to support PBL. An internet search of the literature using the Summon library tool and Google Scholar with the keywords of ‘PBL’, ‘e-textbook’, and ‘secondary school science’ produced no relevant responses. In some cases, for example, Španović (2010, p. 467), there is a desire to see e-textbooks expedite student learning through “didactics instructions … to help students reach the goal in easier and faster manner.” The utilisation of e-textbooks in this way would be the antithesis of PBL.

2.3.4 E-textbooks and the VARK model

E-textbook's advantages over traditional textbooks include the facility to incorporate additional features, such as multimedia, simulations and interactivity. The VARK model (Fleming, 1995) describes four ways learners can receive information, namely, visual, aural, reading/writing and kinesthetic (Malik & Sharma, 2016). The design of an e-textbook can incorporate these learning styles. Table 2.3 shows the application of e-textbook design features to multimedia learning systems using the VARK model. The relative amounts of each learning style required are unique to each learner (Malik & Sharma, 2016), but they are presented with all of them and can use them as they deem appropriate.

Table 2.3
Linking Multimedia Learning Systems, the VARK Model and E-textbook Design Features. Adapted from Malik and Sharma (2016, p. 99)

Multimedia learning systems in 21st century	Fleming's VARK learning system	E-textbook design feature
Do	Kinaesthetic	Practicals/experiments/investigations
Observe	Reading & Writing	Note-taking/reading text
Watch	Visual	Simulations/demonstrations
Hear	Aural	Simulations/demonstrations

By presenting information to students using the VARK model as a guide, it is possible for e-textbooks as "multimedia applications in education to address these varying styles" (Zhang & Bonk, 2008, VARK). Bolliger and Supanakorn (2011) found that in online tutorials, different learning styles did not have a significant impact on student responses. However, they attributed this result to the fact that all learning styles are incorporated into online tutorials and therefore accommodate the style preferences of the students. The incorporation of the different learning styles is the approach taken in the current study. All learning styles are presented to the student, rather than assessing student learning style preferences.

2.3.5 Combining e-textbooks and PBL into a deliverable package

Thus far, PBL and e-textbooks have been considered separate, but related entities. For the development of e-textbooks to provide a platform for PBL, it is necessary to combine the two entities into a single deliverable package. However, to do so without considering the challenges posed by PBL in a secondary school classroom situation would be unhelpful. Table 2.4 links the goals and challenges of implementing PBL to initial design solutions for the e-textbook. These initial solutions were arrived at by considering how an e-textbook could be designed to achieve each goal by overcoming the identified challenges. The achievement of some or all these goals will provide an indicator as to the success of the e-textbook intervention.

Table 2.4

Initial e-textbook Design Responses to the Challenges of Implementing PBL in a Secondary School Environment as They Relate to PBL Goals.

Goal	Challenge	Design response
Enhancing acquisition, retention and use of knowledge	Students maintaining superficial and minimum work to appear active in the learning process. Inadequate time devoted to searching literature and information … and superficial synthesis of the investigation of the problem in the final reports.	Problem design Scaffolding/facilitation
Developing self-directed, lifelong learning skills	Young learners of average ability may lack the skills to identify pertinent learning needs and the resources that can meet them. They may have less developed planning skills and be less able to reflect upon their efforts and change them when necessary.	Scaffolding/facilitation
Problem-solving	Lack of research describing 'how to' in implementing PBL in classrooms.	Ongoing review and refinement of the e-textbooks
	Scarce research on PBL in secondary school contexts.	Scaffolding/facilitation
Gaining a deeper understanding of content	Time available for activities.	Provide access to relevant information and cognitive tools
Preparing students for future learning	Creating a culture of collaboration and interdependence.	Ongoing result of PBL
Developing an extensive and flexible knowledge base	Using PBL in secondary school classrooms is challenging and requires access to rich knowledge bases and cognitive tools.	Provide access to relevant information and cognitive tools
Developing the 'inquiry' or 'problem-solving' skills of an expert	Solving complex problems, however, proves to be especially challenging for young learners.	Incorporate problem-solving skills into e-textbook Scaffolding/facilitation
Enhancing students' intrinsic motivation to study	Self-direction	Scaffolding/facilitation
Developing higher-order thinking skills, as well as communication and collaboration skills	Difficulties balancing between helping students to learn content prescribed in the formal curricula in school and developing thinking and problem-solving skills that are preferred by the PBL approach.	Working in small groups Scaffolding/facilitation

2.4 Mapping of Conceptual Ideas to the Study's Research Questions

This chapter presented a review of the literature as it pertains to the use of e-textbooks in PBL science education. It proposes several frameworks to answer the research questions presented in this thesis and shows them mapped to these questions in Table 2.5. This research aims to provide an informed and improved understanding of how e-textbooks can be used to support PBL in secondary school science classrooms.

Table 2.5
Mapping of Conceptual Ideas to the Study's Research Questions

Research question	Conceptual ideas	Reference in chapter
1. What constraints (if any) inhibits the implementation of e-textbook supported PBL intervention?	Use of ICT (Beaumont et al., 2011; Ertmer & Ottenbreit-Leftwich, 2013; Rongbutsri et al., 2011)	Table 2.2 Figure 2.3
	Group interaction (Dolmans et al., 2005)	Table 2.1
	E-textbook design (Chen et al., 2013; Dennis et al., 2015; Embong et al., 2012; Hamedi & Ezaleila, 2015; Sun et al., 2012)	Figure 2.3
2. What design features of the e-textbook supported PBL intervention most influence student learning?	Constructivism (Pecore, 2012)	Table 2.1
	Scaffolding (Belland, 2010; Belland et al., 2008, 2011; Bogard et al., 2013; Ertmer & Simons, 2006; Kim & Hannafin, 2011; Liu, Horton, et al., 2012; Liu, Wivagg, et al., 2012; Schmidt et al., 2011; Simons & Klein, 2007)	Figure 2.3
	PBL goals	Table 2.4
	E-textbook design (Chen et al., 2013; Dennis et al., 2015; Embong et al., 2012; Hamedi & Ezaleila, 2015; Sun et al., 2012)	Figure 2.3 Table 2.4
3. What was the overall impact of the e-textbook supported PBL intervention?	Knowledge creation (Ertmer & Simons, 2006; Gallagher, 1997; Ge et al., 2010)	Table 2.1
	Student engagement (Wijnia, 2014)	Table 2.1
	Problem-solving skills	Table 2.4

2.5 Summary

The literature has been both informative and limited regarding the use of e-textbooks to support PBL in secondary school science classrooms. An acknowledgement has been made of PBL as a constructivist teaching methodology that supports student-centred learning. There are also examples of the use of PBL in science classrooms and the need to incorporate scaffolding into the program. The crucial role and evolving role of the facilitator were considered together with the development of appropriate problems for students. Finally, there was consideration given to the goals of PBL, some of which are attainable in the short term and others that are more long term in nature.

The role of e-textbooks in PBL was less clear from a review of the literature and has left questions unanswered. While a working definition of e-textbooks was available and their role in general education covered, there was a lack of information regarding their use in PBL. The decision to use e-textbooks as a vehicle for PBL in science classrooms was a deliberate one designed to provide students with both a virtual and physical learning environment. The next chapter presents the methodology supporting this research.

Chapter Three: Methodology

3.1 Introduction

In this chapter, the Design-based Research (DBR) method is discussed together with the tools used to facilitate data collection and analysis. The chapter considers the design of the problems used in this study and the epistemological approach. The chapter also includes a discussion of the methods for analysing the data, the limitations of the study and its ethical implications.

The purpose of this study was to investigate a set of targeted iterations, at a single secondary school site, which facilitated Problem-based Learning (PBL) in secondary school science classrooms. A key feature of these iterations was that they employed e-textbooks. Thus, the research had two complementary objectives. The first was to examine the extent to which PBL was a useful pedagogical approach in a secondary school science context. This objective necessarily entailed considering whether PBL stimulated a greater breadth and depth of student learning, and also whether any incidental learning (e.g., problem-solving, communication, teamwork skills) occurred. The second objective was to discern the extent to which the e-textbook contributed to the pedagogical approach of PBL and produced incidental learning outcomes (e.g., digital literacy skills). Three research questions were formulated to achieve these objectives:

- What constraints (if any) inhibited the implementation of e-textbook supported PBL intervention?
- What design features of the e-textbook supported PBL intervention most influence student learning?
- What was the overall impact of the e-textbook supported PBL intervention?

Using a DBR method enabled these three research questions to be answered.

3.2 The Underlying Epistemological Approach

Observations and reflection are important attributes for an educational researcher because they allow for the formation of a particular epistemological belief that would guide and inform their practice. The researcher in this study has evolved into a pragmatist. Pragmatism is defined as “action or policy dictated by consideration of the immediate practical consequences rather than by theory or dogma” (Pragmatism, 2012, p. 1559). While acknowledging the value of social constructivism in science education where “meaningful learning occurs when individuals are engaged in social activities such as interaction and collaboration” (Amineh & Asl, 2015, p. 13), real constraints exist in educational institutions. These constraints are owing to factors such as available teaching time and syllabus requirements and they determine that at least initial, basic facts are better taught to students so that they may become more fully involved in later learning experiences using social constructivism when encountering more complex tasks. An example will illustrate this point. While a constructivist approach could be used to help students learn the periodic table, it is more efficient to teach them the structure of the periodic table and then have them use this knowledge as an enabler to engage in learning about chemical formulae and reactions, which are more complex tasks.

The choice of methodology in the current study was not separable from the chosen “theoretical perspective and epistemology” (Case & Light, 2011, p. 188). Mackenzie and Knipe (2006) described four different research paradigms: postpositivist (and positivist), interpretivist/constructivist, transformative and pragmatic. The use of DBR in the current study indicated that a pragmatic paradigm was the best fit for the research undertaken "using data collection and analysis methods…most likely to provide insights into the question with no philosophical loyalty to any alternative paradigm" (Mackenzie & Knipe, 2006, p. 197). Furthermore, with a pragmatic approach "knowledge claims arise out of actions, situations, and consequences rather than antecedent conditions (as in postpositivism). There is also a concern with applications –'what works'- and solutions to problems" (Creswell, 2003, p. 11). The development of general principles for the use of e-textbooks to support PBL based on the iterative approach of DBR, which was what the current study involved, fits well with this approach.

3.3 Design-based Research

DBR is a relatively recent research method that emerged at the start of the 21st century (Anderson & Shattuck, 2012). Given the large number of methodologies available to researchers (Cohen, Manion, & Morrison, 2011), it is important to explain the use of the DBR method in the current study. DBR, which has also been called design research and development research (Anderson & Shattuck, 2012), has been defined by McKenney and Reeves (2012, p. 7) as "a genre of research in which the iterative development of solutions to practical and complex problems … yield[ing] theoretical understanding that can inform the work of others." This methodology also uses "the close study of a single learning environment … as it occurs in naturalistic contexts, to develop new theories, artefacts and practices that can be generalised" (Barab, 2006, p. 153). The Design-Based Research Collective (2003) reported that "design-based research methods can compose a coherent methodology that bridges theoretical research and educational practice" (p. 8). Bridging the gap between theory and practice is crucial to the current study, which sought to work within the naturalistic settings of secondary school science classrooms to develop ways of implementing PBL using e-textbooks. A small, but growing, literature base attests to the value of DBR, particularly in considering the use of technology (Barab & Squire, 2004; Herrington & Reeves, 2011; Juuti & Lavonen, 2006; McKenney & Reeves, 2013).

As the study progressed, there was a constant need to reflect on educational practices. The process fitted well with the DBR process, which has a cycle of reviewing the design of a procedure or artefact based on results obtained during the study, with the purpose of improving those procedures or artefacts (Barab & Squire, 2004). This characteristic of DBR allowed the development of solutions "that speak directly to the problems of practice" (The Design-Based Research Collective, 2003, p. 5), which were inherent in the research questions. It also required that the study use design principles that did not just satisfy the exigencies of the immediate environment but also contributed to the broader educational community (Anderson & Shattuck, 2012; Barab & Squire, 2004). Developing design principles served to confirm or refute the utility of the intervention at the local level as well as the wider sphere of science education.

3.3.1 The DBR process

DBR consists of a series of phases (Reeves, 2006) shown in Figure 3.1. This particular model of DBR is implemented in this study. Herrington and Reeves (2011) described the essential requirements of each step:

- The problem is explored intensively … from the perspective of the people who deal with the problem on a day-to-day basis;
- The second phase of educational design-based research focuses on a solution to the problem that can be implemented in the educational setting, such as a classroom or online learning environment;
- The implementation and evaluation cycles of a mature product provide further opportunities to refine design principles;
- Design principles can be ‘captured’ to comprise the sharable, published output from the research to inform future development and implementation decisions. (pp. 297–298)

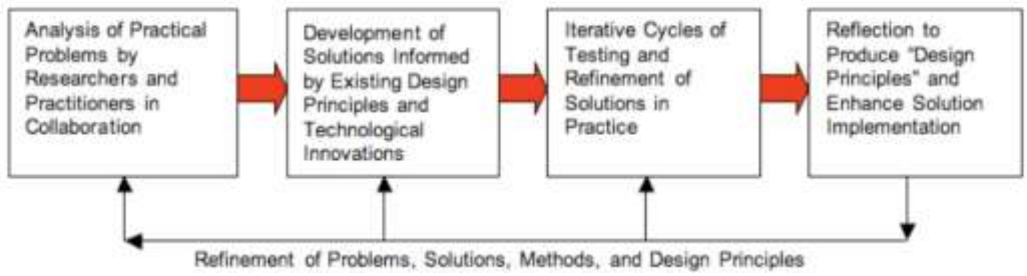


Figure 3.1. The Reeves model of DBR (Herrington & Reeves, 2011, p. 596).

In the current study, all research questions (problems in DBR) needed examination from the viewpoint of the teacher (the researcher in this instance) in the naturalistic setting of the classrooms where the study took place. Doing so allowed possible solutions to the problems to be developed and evaluated. Repetition of the process occurred until a solution was evident that was used to form guiding principles. These guiding principles would allow for the broader application of the solutions developed through the cycles.

3.3.2 Trustworthiness in the DBR process

At a basic level, DBR seeks to improve practice through a process of testing and refinement in a naturalistic setting and to derive from this process of refining practices, design principles that can be used by others in their settings. Therefore, it is essential that those who wish to use these design principles have a high degree of trust in the current research. Thomas and Magilvy (2011, p. 152) listed four aspects of trustworthiness: "(a) truth–value (credibility); (b) applicability (transferability); (c) consistency (dependability); and (d) neutrality (confirmability)." These are discussed below and summarised in Table 3.1.

Table 3.1
Rules of Conduct for the Investigation to Ensure Trustworthiness

Aspect of study	Tool/technique	Explanation
Data Collection	PBL Evaluation Tools	Administered by the researcher not used for assessment reporting. They were de-identified.
	Observations	Conducted by Head of Department and Laboratory Technician which the researcher would not be able to influence.
	Focus group interviews with students	Conducted by researcher's supervisors.
Credibility	Focus group interviews with students	Focus group interviews were conducted by the researcher's supervisors to minimise any potential dependent or unequal relationship.
	Sustained interaction with participants	The researcher is conscious of the importance of the need to be aware of any potential bias while working with the participants. Using a systematic approach that is fundamental to DBR regarding data collection and providing full details of its analysis reduces bias (Morrow, 2005).
	Member checking (Merriam, 1998)	The researcher transcribed the focus group interviews for review by the supervisors. The researcher also provided the participants with a transcript and asked for confirmation of transcript accuracy.
	Eidetic Bracketing (Gearing, 2004; Morrow, 2005; Tufford & Newman, 2012)	The researcher acknowledges the post-positivist point of view that the background and values of the researcher can affect observations. The researcher attempted to identify and set aside any biases that were identified and tried to approach the study in an unbiased way by, for example, reviewing literature that is both favourable and unfavourable to the theoretical framework for this study. The researcher examined and reviewed the data collected to ensure that any preconceptions or biases were made explicit.
	Triangulation	Data from different sources were collected using different individuals from the researcher's school and the University of Notre Dame Australia. The sources of data included the PBL Evaluation Tool results, observations and focus group interviews.

(continued)

Aspect of study	Tool/technique	Explanation
Transferability	Selection	The researcher provided a detailed description of the sample selected and the context of the study to allow the reader to decide how transferable the results are to other situations (Shenton, 2004).
Dependability		The methodology, including data collection methods and analysis, was described in such detail as to allow another researcher to repeat the study.
Confirmability	Audit trail	An audit trail shows how the data were collected and analysed during the study (Shenton, 2004).

3.3.2.1 Credibility

To be credible, a study must describe and explain all of the events in the study and the participants in that study would be in agreement with those descriptions and explanations (Krefting, 1991). In the current study, member checking and triangulation were used to ensure credibility. Thomas and Magilvy (2011) noted that comparing data from different sources and checking for consistency is a persuasive means of ensuring credibility. Member checking involves the participants in a study reviewing the data collected and (analysing) the interpretations of that data to ensure it reflects their own experiences (Krefting, 1991; Porter, 2007; Thomas & Magilvy, 2011) accurately. During this study, participants were given the opportunity during class to review responses made in the PBL Evaluation Tool and the focus group interviews. There was a review of the observations made during the lesson after each round of observations recorded. Triangulation was achieved by using data from different sources, collected using different individuals from the researcher's school and the University of Notre Dame Australia. The sources of data included the PBL Evaluation Tool results, observations and focus group interviews.

Validity in predominately qualitative studies is an area of considerable debate. Golafshani (2003, p. 602) noted that “this concept [validity] is not a single, fixed or universal concept” in qualitative studies. Creswell and Miller (2000, p. 125) opined that “qualitative inquirers bring to their studies a different lens toward validity than that brought to traditional, quantitative studies.” To establish validity in a qualitative study Creswell and Miller (2000) linked validity to the methods used to show credibility of the data collected. These methods can include “member checking, triangulation, thick description, peer reviews, and external audits” (Creswell & Miller, 2000, p. 124). Member checking and triangulation were used in the current study.

3.3.2.2 Applicability

Applicability or transferability is “the ability to transfer research findings or methods from one group to another” (Thomas & Magilvy, 2011, p. 153). Both Krefting (1991) and Thomas and Magilvy (2011) noted the importance of providing a rich description of all aspects of the study so that others may replicate it in their unique situations. The current study provided such a rich description by specifying details of the methodology and analysis of the results.

3.3.2.3 Consistency

Consistency is a measure of how well the steps followed by the researcher could be tracked and understood by another person (Thomas & Magilvy, 2011) and “provides information as to how repeatable the study might be or how unique the situation” (Krefting, 1991, p. 221). Thomas and Magilvy (2011) noted that specifying the exact methodology of the research can show consistency and Krefting (1991) asserted that triangulation also contributes to consistency. This study used both processes. The procedure followed is outlined in this paper to ensure it can be replicated by other researchers and data were collected from different tools including the PBL Evaluation Tool results, observations and focus group interviews.

A consideration of reliability within qualitative research requires an alternate view of how to establish it in such a context. Noble and Smith (2015) assert that reliability in qualitative studies can be related to consistency and neutrality. Golafshani (2003) links reliability in quantitative research to consistency in qualitative research.

3.3.2.4 Neutrality

Neutrality is "the degree to which the findings of an inquiry are a function solely of respondents and the conditions of the inquiry and not of the biases, motivations, interests, perspectives, and so on, of the inquirer" (Guba & Lincoln, 1982, p. 246). Sale and Brazil (2004, p. 360) listed several strategies to achieve neutrality, including "Bracketing (Secker et al., 1995; Burns, 1989; Patton, 1999), statement of researcher's assumptions (Marshall, 1990; Elliott et al.,1999) or statement of researcher's perspective (Greenhalgh and Taylor, 1997)." Bracketing involves researchers in a process "whereby they recognize and set aside (but do not abandon) their a priori knowledge and assumptions, with the analytic goal of attending to the participants' accounts with an open mind" (Starks & Brown Trinidad, 2007, p. 1376). Bracketing was made use of during the study by the researcher attempting to remain unbiased and seeking a neutral approach to reviewing the data collected in the study.

3.3.3 The role of the teacher/researcher in DBR

In this study, the teacher was also the researcher. Juuti and Lavonen (2006) stressed the importance of close collaboration and interaction between the researcher and the practitioner. The achievement of collaboration and interaction in this study occurred owing to the practitioner being the researcher. Cobb, Confrey, Lehrer, and Schauble (2003) accepted that a teacher might also be a researcher. Kelly (2003, p. 3) goes further by stating that DBR "is directed primarily at understanding learning and teaching processes when the researcher is active as an educator." Furthermore, Barab (2006, p. 153) stated that DBR "is used to study learning environments which are designed and systematically changed by the researcher." The teacher was in an appropriate position to effect such change in this study. This reinforced the dynamic nature of teaching where teachers constantly review their practice and modify it according to evidence collected.

3.3.4 Criticism of the DBR approach

To provide a balanced view of the DBR methodology, criticisms of the approach are considered and addressed. Kelly (2004, p. 116) stated that DBR needs to "develop design studies from a loose set of methods into a rigorous methodology" intimating that such a rigorous methodology does not currently exist. The assertion in this thesis is that Reeves' (2006) model mentioned earlier in this chapter addresses this concern. It is interesting to note that while McKenney and Reeves (2014, p. 133) stated that DBR "is not a methodology" nevertheless it is "held to the same standards as other scientific work." Another of Kelly's (2004, p. 119) claims was that DBR lacks an "argumentative grammar" which would be used, for example, to substantiate the collection of data and its subsequent use to develop credible theories. This lack of "argumentative grammar" is especially important given DBR's capacity to produce "unmanageable (and almost unstorable [*sic*]) amount(s) of data" (Dede, 2004, p. 107). Kelly (2004) also noted that "a simple assertion that design studies use 'grounded theory' or 'thick description'… does not constitute an acceptable basis for according design studies the status of a methodology.” (p. 119). While the current study produced large amounts of data, these data were in no way unmanageable or un-storable. Furthermore, in the current study, the use of the constant comparative method of qualitative analysis (Glaser, 1965) and eidetic bracketing (Gearing, 2004; Morrow, 2005; Tufford & Newman, 2012) addressed the concerns of a lack of argumentative grammar. However, The Design-Based Research Collective (2003) noted that when the intervention is in a naturalistic setting where the designer makes a large number of design decisions, it proves problematic to determine which ones are efficacious in bringing about any observed change. Such uncertainty leads to what has been termed the “Bartlett Effect” (Brown, 1992, p. 162) where only the data reported support the researcher’s claims. To provide an objective as possible interpretation of the data, the data were considered through the process of eidetic bracketing, where the “researcher [has] to set aside his or her personal assumptions” (Gearing, 2004, p. 1439). This was achieved in part by using external interviewers for the focus group interviews and independent observers for the Strobe Protocol to provide a data source to which the researchers own data could be compared. The statistical analysis of the quantitative data provided a means by which the researchers results could be validated dispassionately.

Some scepticism regarding the achievement of DBR’s goal of providing guiding principles applicable beyond the local context in which the study took place has been voiced by McKenney and Reeves (2013). However, they did acknowledge that the evidence for this scepticism may be a product of the assessment of this achievement, the lack of available data and the relatively recent arrival of DBR as a research methodology. The more studies conducted, the more data will be available, and a better judgement made of how DBR achieves its goal of providing guiding principles.

A final consideration was the Hawthorne Effect where changes in outcomes are owing to the subjects being studied rather than the intervention artefacts themselves (Merrett, 2006). However, Brown (1992) was quite dismissive of this effect where specific, rather than general, improvements were being investigated. Specific developments were the case in the current study where improvements in students' content knowledge and problem-solving ability in chemistry and physics were the focus.

3.3.5 The relevance of the DBR method

What does DBR have to offer that makes it an appropriate choice for the current study? In the current study, technology, in the form of e-textbooks, had a significant role in the creation of a PBL environment in the classroom. However, there has been a criticism of some research into the use of technology in educational settings including that it is "pseudoscientific and socially irresponsible" (Reeves, 2006, p. 52), lacking in a clear characterisation of the achievement of any reported gains. Furthermore, the design of technologies used in education is not based on research and may be "based on a designer's own experiences, and beliefs of effective learning or [the] design is purely technology driven" (Juuti & Lavonen, 2006, p. 55), which may adversely affect its adoption by educators.

DBR provides an effective means of investigating the use of technology in education because it involves a thorough investigation over a period of years from which derivation of principles for use in other situations occurs (Herrington, McKenney, Reeves, & Oliver, 2007). Juuti and Lavonen (2006, p. 54) noted that

DBR “bridge[s] the gap between educational research and praxis. It combines the designing of an educational artefact and research concerning the learning in the designed settings.” As such, it could reduce the reluctance of educators to adopt new educational technologies, such as e-textbooks, since testing occurs in the naturalistic settings of a classroom. Finally, the use of DBR in doctoral research investigations (Bakker, 2004; Bower, 2008; Javed, 2008; Kazakoff, 2009; Kinnear, 2013; Nordin, 2012; Yeh, 2007) is indicative of its usefulness as an emerging research methodology.

3.4 Sample Population Selection

The school participating in the study is an independent day school situated in the City of Mandurah, located 70 km south of Perth. It is a secondary school and draws its students from both Mandurah and the surrounding districts. The school has an Index of Community Socio-Educational Advantage (ICSEA) rating slightly above average with most students in the middle quarters (Table 3.2). The school places a strong emphasis on academic success and students from the school consistently perform well in the Western Australian Certificate of Education examinations each year. The school has specialist computer laboratories, an ICT service department and a 1:1 laptop ratio in years nine to twelve.

Table 3.2
Statistical Data for the School Where the Study Took Place (ACARA, 2012)

Student background	
Index of Community Socio-Educational Advantage (ICSEA)	
School ICSEA value	1070
Average ICSEA value	1000
Data source	Parent information

Distribution of students [2]

	Bottom quarter	Middle quarters		Top quarter
School Distribution	5%	29%	37%	29%
Australian Distribution	25%	25%	25%	25%

Percentages are rounded and may not add to 100

Students	
Total enrolments	1291
Girls	681
Boys	610
Full-time equivalent enrolments ?	1291
Indigenous students	1%
Language background other than English	6%
Student attendance rate	95%

School facts	
School sector	Non-government
School type	Combined
Year range	U, PP-12
Location	Provincial

The school determined the classes and subjects taught by the researcher. The Year 10 classes typically numbered from 25 to 30 students who complete six periods of Science per week. These periods were usually 40 minutes long and consisted of two double periods and two single periods. Each class was heterogeneous in semester one, but streaming occurred in semester two with the top 45% of students being placed together in an accelerated program. The remainder, which was the group used in this study, completed a general science course. The streaming policy changed in 2015 with all Year 10 classes remaining heterogeneous.

3.5 Conduct of the Cycles

There were three cycles conducted over three years, 2013, 2015 and 2016. The first cycle was used to gain a sense of the educational environment, including determining any logistical problems with regard to the use of the e-textbook technology and the students' interactions with it. The cycles outlined in Table 3.3 were used to trial new strategies and techniques based on a review of the preceding iterations.

Table 3.3
Students Involved in the Current Study

Cycles	Iteration topics	Topic length (weeks)	Class size		
			Number of students	Number of groups	Number of students who permitted results to be used in this study and participated in focus group interviews
Cycle one (2 classes)	Iteration 1 Newton's Laws Iteration 2 Chemical Reactions	5 6	20 and 25	5 and 6	7 and 17
Cycle two	Iteration 1 Newton's Laws Iteration 2 Compression and Tension	6 5	28	6	12
Cycle three	Iteration 1 Newton's Laws Iteration 2 Chemical Reactions	6 6	19	5	11

3.5.1 Cycle one

The first cycle was conducted in the second semester of 2013 with two Year 10 classes participating in two iterations. The two Year 10 classes were heterogeneous groupings of middle ability students. The Year 10 classes studied two subjects using e-textbook and PBL: physics and chemistry. The physics unit covered Newton's Laws of Motion and sought to apply those laws to the design of a model rocket. The chemistry unit covered different types of reactions and the factors that affect the rate of reactions. The researcher designed the e-textbook using Adobe InDesign™. The design of the e-textbook was changed slightly in the second iteration, the Chemical Reactions topic, in response to some difficulties experienced by the students with the first e-textbook. Specifically, the problem was broken down into a series of smaller problems with one large problem at the end.

3.5.2 Cycle two

Cycle two was conducted in 2015 in semesters one and two with two iterations. The Year 10 class was a heterogeneous grouping of students with varying ability levels. The Year 10 class studied two subjects using e-textbook and PBL: physics and structures. The physics unit covered Newton's three laws of motion in a series of problems and then sought to apply those laws to the design of a model rocket as the final problem. The structures unit covered compression and tension. The design of the e-textbook changed in the second cycle in response to difficulties experienced with the first e-textbook. The changes involved using a new platform to produce the e-textbook and improve the presentation of the problems to the students.

3.5.3 Cycle three

Cycle three was conducted in 2016 in semester one and two with two iterations. The Year 10 class was a heterogeneous grouping of students with varying ability levels. The Year 10 class studied two subjects using e-textbook and PBL: physics and chemistry. The physics unit covered Newton's three laws of motion in a series of problems and then sought to apply those laws to the design of a model rocket as the final problem. The chemistry unit covered different types of reactions and the factors that affect the rate of reactions. The design of the e-textbook changed in the third cycle in response to some difficulties experienced by the students with the previous e-textbook. In particular, students received more support and problem presentation and navigation improved.

3.6 The Instruments Used in the Study

The study was predominately qualitative, which is defined as a type of research that Malterud (2001, p. 483)noted "involve[s] the systematic collection, organisation, and interpretation of textual material derived from talk or observation." Curry, Nembhard, and Bradley (2009, p. 1442)added that "they are often exploratory in nature and seek to generate novel insights using inductive … approaches." Wang and Hannafin (2005, p. 17) noted that "qualitative documentation methods are often especially useful in design-based research." The qualitative aspects of this study included observations of classes, focus group interviews and three pre- and post-PBL Evaluation Tools. Quantitative aspects of this study were pre- and post-knowledge tests for each topic in the PBL Evaluation Tool. The use of some quantitative data with qualitative data "can achieve various aims, including corroborating findings, generating more complete data, and using results from 1 method to enhance insights attained with the complementary method" (Curry et al., 2009, p. 1442). Table 3.4 details the relationship between the data collection methods and the research questions.

Table 3.4
The Relationship Between the Research Questions and the Data Collection Method with Possible Interpretations Made from the Data

Research question	Data collection instruments	Data interpretation	Collection dates
1. What constraints (if any) inhibited the implementation of the e-textbook supported PBL intervention?	Weekly observation during problem-solving tasks conducted by independent observers Focus group interview at the conclusion of each iteration	Observation data can determine: (i) if most students are on task; (ii) what individual students are doing; (iii) what groups of students are doing; (iv) what the teacher is doing.	2013 (Cycle 1) 2015 (Cycle 2) 2016 (Cycle 3)
2. What design features of the e-textbook supported PBL intervention most influenced student learning?	Weekly observation during problem-solving tasks conducted by independent observers Focus group interview at the conclusion of each iteration	From this, identification of factors constraining the e-textbook supported PBL intervention, and design features of this intervention that most influenced student learning.	2013 (Cycle 1) 2015 (Cycle 2) 2016 (Cycle 3)
3. What was the overall impact of the e-textbook supported PBL intervention in terms of students': - content knowledge; - problem-solving skills; - transfer of content knowledge to other topics.	Pre- and post- PBL Evaluation Tools Focus group interview at the conclusion of each iteration	The tools help to determine if there has been an improvement in student achievement by comparing student results before each iteration to those after each iteration.	2013 (Cycle 1) 2015 (Cycle 2) 2016 (Cycle 3)

3.6.1 PBL Evaluation Tool

The main focus of this study was the use of e-textbooks to facilitate PBL in secondary school science students. The PBL Evaluation Tool (Pre and Post) was used to consider if there was an improvement in the students learning when using e-textbooks to support PBL (Appendix five). The instruments described in Table 3.4 provided useful data upon which to consider any improvement in the students' learning when using e-textbooks to support PBL.

While not the only aspect of PBL environment, solving problems is an important component of the process (Anderson & Lawton, 2014; DeWaters & Powers, 2011; Jonassen, 2011; Schmidt et al., 2011; Yeo & Tan, 2014). Gijbels, Dochy, et al. (2005, pp. 34–35) distilled two characteristics of expert problem solvers from cognitive psychological research:

> Experts possess coherent knowledge. They have command of a well-structured network of concepts and principles in the domain that accurately represents key phenomena and their relationships;
> Experts know how to use the relevant elements of knowledge in a flexible way to describe and solve novel problems. (p. 30)

These characteristics provide a benchmark to compare against students engaged in problem-solving using the eight tasks described by Newman (2005):

- Explore the problem: clarify terms and concepts that are not understandable, create hypotheses, identify issues;
- Identify what you know already that is pertinent;
- Identify what you do not know;
- As a group, prioritize the learning needs, set learning goals and objectives, allocate resources; members identify which task they will do;
- Engage in a self-directed search for knowledge;
- Return to the group and share your new knowledge effectively so that all group members learn the information;
- Apply the knowledge; try to integrate the knowledge acquired into a comprehensive explanation and;
- Reflect on what has been learned and the process of learning. (p. 15)

Several criteria may be used to assess problem-solving in relation to evaluating knowledge structure. Sugrue (1994) and Gijbels, Dochy, et al. (2005, pp. 34–35) identified three criteria: understanding of concepts, understanding of principles and application of those concepts and principles. Gijbels, Dochy, et al. (2005) provided a useful matrix, based on the first part of Sugrue's (1995) own matrix for assessing knowledge structure. Importantly Gijbels, Dochy, et al. (2005, p. 35) noted that the type of assessment, multiple choice, open-ended or hands-on format, was not as important as measuring "the extent to which the student's knowledge structure is organized around key concepts and principles that are linked to conditions and procedures for application." In this study, Sugrue's (1994) original matrix was useful for assessing problem-solving, which included metacognition and motivation since these are important attributes of a problem solver.

A number of metacognitive strategies are available within the context of using e-textbooks to facilitate PBL in students. These strategies are described broadly by Nett, Goetz, Hall, and Frenzel (2012, p. 1) and Sugrue (1995, p. 30) as "planning", "monitoring" and "evaluation." The aspects of motivation relevant in this study were described by Green et al. (2012, p. 1113) and Sugrue (1995, p. 30) as self-efficacy, by Lai (2011, p. 7) as task difficulty and as task attractiveness by Pintrich and De Groot (1990, p. 33), Sugrue (1995, p. 30) and Wigfield and Eccles (2000, p. 68).

The final question to be answered was how to apply these measurements to Newman's (2005) eight PBL tasks. A new matrix was developed to include the tasks, where appropriate, in Table 3.5 to achieve this. It was not possible to find a complete correlation between all of the items in Sugrue's matrix (1994) and Newman's (2005) tasks. However, the inclusion of all of the tasks occurred at least once. Pre- and post-evaluation was used to determine changes in students' problem-solving ability. The first two research questions: What constraints (if any) inhibited the implementation of the e-textbook supported PBL intervention? and What design features of the e-textbook supported PBL intervention most influenced student learning? were to be answered through the DBR iterative process.

Table 3.5

A Design Matrix Incorporating the Criteria of Gijbels, Dochy, et al. (2005); (Newman, 2005; Sugrue, 1995) to Assess Learning in a PBL Environment

	Elements of knowledge structure, metacognitive function and motivation	Method					
		Selection		Generation		Explanation	
		(Sugrue, 1995) and (Gijbels, Dochy, et al., 2005)	(Newman, 2005)	(Sugrue, 1995) and (Gijbels, Dochy, et al., 2005)	(Newman, 2005)	(Sugrue, 1995) and (Gijbels, Dochy, et al., 2005)	(Newman, 2005)
Knowledge structure	Concepts	Select examples		Generate examples	Identify what you know already that is pertinent. Identify what you do not know.	Explain why examples reflect concept attributes. Select live examples.	Explore the problem: clarify terms and concepts that are not understandable, create hypotheses and identify issues.
Knowledge structure	Principles	Select best prediction Select best explanation	Explore the problem: identify issues	Generate predictions or solutions. Explain an event		Explain predictions or solutions	
Knowledge structure	Application conditions and procedures	Select correct procedure for identifying instances. Select most appropriate procedure to change the state of a concept by manipulating another concept.	Identify what you know already that is pertinent. Identify what you do not know.	Perform task specific procedures. Generate (describe) a procedure.	As a group, prioritise the learning needs, set learning goals and objectives and allocate resources; members identify which task they will do.	Explain how to perform a procedure	Return to the group and share your new knowledge effectively so that all group members learn the information. Apply the knowledge: try to integrate the knowledge acquired into a comprehensive explanation.
Metacognitive function	Planning	Select or rate items that represent amount and type of planning engaged in during the activity	As a group, prioritise the learning needs, set learning goals and objectives and allocate resources; members identify which task they will do.	Engage in behaviours indicative of planning during the activity.	Engage in a self-directed search for knowledge.	Describe amount and type of planning engaged in during activities.	

(continued)

	Elements of knowledge structure, metacognitive function and motivation	Method					
		Selection		Generation		Explanation	
		(Sugrue, 1995) and (Gijbels, Dochy, et al., 2005)	(Newman, 2005)	(Sugrue, 1995) and (Gijbels, Dochy, et al., 2005)	(Newman, 2005)	(Sugrue, 1995) and (Gijbels, Dochy, et al., 2005)	(Newman, 2005)
	Monitoring	Select or rate items that represent amount and type of monitoring engaged in during the activity.		Engage in behaviours indicative of monitoring during the activity.		Describe amount and type of monitoring engaged in during activities.	Reflect on what has been learned and the process of learning.
	Perceived self-efficacy	Select or rate items that represent level of confidence in ability to do well on different activities.		Engage in behaviours indicative of effort and persistence during the activity.	Set learning goals and objectives and allocate resources; members identify which task they will do.	Describe one's perception of one's ability to do well on different activities.	Reflect on what has been learned and the process of learning.
Motivation	Perceived task difficulty	Select or rate items that represent perceived relative difficulty of different activities.		Engage in behaviours indicative of effort and persistence during the activity.	Engage in a self-directed search for knowledge.	Describe one's perception of the relative difficulty of different activities.	Reflect on what has been learned and the process of learning.
	Perceived task attraction	Select or rate items that represent perceived relative attraction of different activities.		Engage in behaviours indicative of effort and persistence during the activity.		Describe one's perception of the relative attraction of different activities.	Reflect on what has been learned and the process of learning.

3.6.2 Strobe observations

Applying assessment items to each of the criteria in Table 3.5 informed the third research question: What was the overall impact of the e-textbook supported PBL intervention. Observation is considered a useful tool for providing information about the activities of others or their response to various experiences (Jones & Somekh, 2005; McMurray, Scott, & Pace, 2004). Natural observation, with observations made in realistic environments, are useful in collecting information about group behaviour (McMurray et al., 2004), which was the focus of the current study. The PBL groups were observed via the Strobe Protocol described by Kelly et al. (2005). The Strobe Protocol was initially developed by O'Malley et al. (2003) to provide a means of documenting student engagement during a lesson although an antecedent of the protocol was described by Marchant (1989).

The Strobe Protocol was chosen for the current study because it provided a large amount of information about what was occurring in the classroom, including the: level of student engagement, type of student work and teacher interactions in a relatively unobtrusive way. O'Malley et al. (2003, p. 100) found that the Strobe Protocol provides "a practical, reliable, and valid instrument" for measuring the behaviour of students. The Strobe Protocol has been used successfully in undergraduate studies (D'Souza, Isac, Venkatesaperumal, Nairy, & Amirtharaj, 2013; Hurford & Hamilton, 2008; Ofstad & Brunner, 2013) and secondary school courses (Seaton & Carr, 2005), which demonstrates its usefulness. McMurray et al. (2004) listed, among other considerations, three important steps when using observation as a data gathering tool:

- Decide how many observations to make;
- Decide how long to observe;
- Decide what to observe. (p. 194)

In the current study, a reporting sheet modified from Fermilab (2013) took into account these three considerations of how many observations, how long and what to observe. The recording sheet for the Strobe Protocol was modified to make it easier for the observer to make and record observations with minimal training. Appendix three details the modified Strobe Protocol recording sheet.

3.6.3 Informal classroom observations

Observation refers to “the purposeful examination of teaching and/or learning events through systematic processes of data collection and analysis” (Bailey, 2001, p. 114). Tilstone (2012, p. 23) described observation as “the systematic, and as accurate as possible, collection of usually visual evidence, leading to informed judgements and necessary changes to accepted practices.” This study used a qualitative approach to informal classroom observation. O'Leary (2014) listed three types of qualitative observations:

- Completely unstructured, ‘stream of consciousness’ type where the observer is given a blank canvas to record their notes as a ‘running log’ of events;
- Semi-structured type where what the observer records is shaped by a set of pre-established categories; and,
- Highly structured type, which shares many of the features of the previous type but divides assessment of the lesson into individual performance indicators. (p. 54)

The first type of observation provided to the observer, in this case, the researcher, no guidance as to what to observe, which had the advantage of not prejudicing the observer to produce a particular outcome. Wragg (1999) noted that while quantitative methods allow observations to focus on particular events according to predetermined criteria, it is less adaptable regarding recording what is happening in the classroom. The current study used this running log model to make observations because it was the most flexible.

The researcher entered observations into a journal at the end of each lesson. The entries reflected on how the lesson progressed and noted any difficulties and successes of individual students, groups and the use of the e-textbook. The interactions between the teacher/observer and the students were also noted.

In this study, the qualitative informal classroom observations were complemented by the Strobe Protocol. The Strobe Protocol provided a quantitative comparison made by independent observers, the school laboratory technician and the head of the Science Department, to the qualitative informal classroom observations. Wragg (1999, p. 20) noted that "quantitative and qualitative approaches need not be seen as polar opposites, as they can often complement each other."

3.6.4 Focus group interviews

At the conclusion of each PBL activity, a focus group of volunteers from each class convened. Onwuegbuzie, Leech, and Collins (2010, p. 711) defined focus groups "as a method of collecting data, in a safe environment, from more than one individual at a time, regarding a specified area of interrogation." Onwuegbuzie, Dickinson, Leech, and Zoran (2009) described some advantages in using focus groups, including efficiency and increased data generation through social interaction. The questions were developed from observations made during the PBL task and follow guidelines proposed by McMurray et al. (2004), who suggested that there should be "opening questions", "framing questions", "focal questions" and "concluding questions" (p. 204). Opening questions were covered informally by the facilitators asking the names of the students. Questions followed that framed the topic, which was PBL and the use of e-textbooks. The remaining questions focused on specific aspects of the students' experiences. To conclude, the interviewer asked students if they had any further comments or questions. Appendix four details the focus questions asked. Each class provided volunteers for the focus group interviews with the final selection of those to be involved based on having a range of students from groups that performed well on the task as well as those who performed adequately and poorly, based on observations during the iteration. The size of the groups ranged between five and six people.

3.7 Development of Problems

Table 3.6 details the specific problems used in the current study. In selecting the problems in Table 3.6, a range of factors needed consideration: context, structuredness and abstractness. Each problem type is presented against the factors that describe it.

Table 3.6
Aspects of the Problems Used in the Current Study Incorporating Jonassen's Criteria (Jonassen, 2000)

Problem type	Problem example	Australian curriculum link	Inputs	Success criteria	Context	Structuredness	Abstractness
Rule using	Compression and Tension	ACTDEK043	Application of compression and tension to building structures	Correct application of the rules to a novel situation	Real world	Multiple solution paths. Defined purpose	Problem situated
Troubleshooting	Reaction rates	ACSSU187	Inefficient production of chemical product owing to poor setup	Fault identified and rectified	Real world	Limited faults and outcomes	Problem situated
Design	Newton's Laws	ACSSU229	Goal: improve design of rocket Constraints: Max altitude 75 m; payload 100 g; available materials Structure: initial rocket design	Improved rocket performance	Complex Real world	Ill-structured	Problem situated

The context within which a problem exists is important since the skill set that a student will use to solve a particular problem is specific to the context of the problem (Jonassen, 2000). Context is also important in representing the problem to the intended audience, in this case, secondary school students. Walker and Leary (2009) noted that the importance of context varies with the degree of structuredness in the problem, with the context in ill-structured problems being vitally important. However, Jonassen (2000) stated that exceptions exist to this rule of context varying with structuredness. Jonassen (2000), differentiated between the type of strategies that are used to solve these problems, asserting that, in general, structured problems require only “domain-general strategies (weak methods)” (p. 68). This study asserts that most secondary school problems within the science area, in fact, require specific problem-solving strategies that would be context dependent, and therefore, context is important. Therefore, it was important to establish a clear context for each problem in the current study so that students could learn and use a specific skill set to effect a solution.

The structuredness of a problem relates to how many elements are known, the number of possible solutions, how identifiable the solutions are and whether value judgements need to be made (Jonassen, 2000). These decisions are not discrete, but rather, exist along a continuum. The continuum in Figure 3.2 represents the structuredness of a problem.

Figure 3.2. A continuum of problem structuredness based on Jonassen’s criteria (Jonassen, 2000).

In deciding how much structure to put into a problem, Hung (2006) noted the importance of the problem-solving ability of the learning as a determining factor, with students less able to problem solve requiring more structure. In the current study, students were assumed to have limited problem-solving ability at the start of the year owing to the minimal exposure they have had to PBL environments, and so, initially, the problems were quite structured. However, the level of structuredness reduced as the year progressed and students became more familiar with PBL environments. As mentioned earlier, most secondary school problems are considered abstract, given that they have no situational context (Jonassen, 2000). However, within science PBL environments it is argued, in the current study, that these problems do require a context to allow for the application of specific skills and as such are not abstract.

3.8 Methods of Data Analysis

Pre- and post-PBL Evaluation Tool data were compared by determining mean scores for each criterion and calculating standard deviations. A Wilcoxon signed-rank test was used to determine if there was a significant change in the scores since the sample is small and may not be normally distributed. Qualitative data were analysed using NVivo™ to code the student responses to the intervention tools and the focus group interviews. In each case student responses were reviewed, and broad categories developed into which their responses were coded. Descriptions of each category were included in the NVivo™ program which allowed for consistency of coding over the study period. The constant comparative method of qualitative analysis (Glaser, 1965) was used to code the qualitative data. This method is "a central data collection method in the grounded theory methodology…[and] provides a clear step by step outline of a process for analysing qualitative data" (Case & Light, 2011, p. 193). Strauss and Corbin (1994) noted that grounded theory allows for the development of a theory from the data rather than relying on the data to support the theory. The theory was congruent with the DBR methodology, which developed applicable theories at the end of the process rather than affirm theories at the start.

Table 3.1 summarises the procedures used to ensure the integrity of the data collected.

3.9 Software

The software used to produce the e-textbooks in this study was InDesign CS6™, Flash™ and Mediator 9™. InDesign CS6™ was used to produce the first e-textbook since it provided a way of combining various features, including video and text, into a single presentation for students to use. However, there were limitations to the use of InDesign CS6™ that made it unsuitable for future cycles. In cycles two and three, Flash™ and Mediator 9™ were used. Mediator 9™ was used as the platform to construct the e-textbook because it provided a way of combining most of the interactive features required for this study in one package. It was augmented by Flash™ to provide extra animation when required.

3.10 Limitations

There were limitations to this study that included the sample size, the subject and topics covered and the length of the intervention. Limitations of sample size and subject were owing to the allocation, by the school, of classes to the teacher. Teachers can only teach in their area of expertise and only to classes assigned by the Head of Department in the School. The Australian National Curriculum limited the number and length (five to six weeks) of topics in the study. However, it was possible to view some of those limitations as strengths of the study rather than weaknesses since they fit well with the DBR process of researching natural environments. Juuti and Lavonen (2006) described the complex milieu that is the science classroom and noted that it does not readily lend itself to standard scientific investigation but does suit a DBR process. Nevertheless, the study occurred in only one school, which will limit any generalisations.

3.11 Ethical Considerations

The researcher attempted to be dispassionate, unbiased and open-minded about the study and was committed to objectively reporting the findings. Triangulation through using data from different sources collected using different individuals from the researcher's school and the University supervisors were used to ensure this objectivity. The sources of data included the PBL Evaluation Tool results, observations and focus group interviews. Table 3.1 highlights the rules of conduct that were used to ensure researcher bias was minimised while also improving the study's trustworthiness, namely credibility, transferability, dependability and confirmability (Guba & Lincoln, 1982, p. 246).

Consideration also needs to be given to the power differential between the teacher/researcher and the students in the classroom. The latter were given the option to withdraw from the study at any time without prejudice. This option was included in the letter of consent they signed. Therefore, the students had the power to remove themselves from the study if they felt pressured or uncomfortable at any stage.

3.12 Summary

The use of predominately qualitative instruments was consistent with the pragmatist paradigm that was most suited to the current study. A DBR methodology with three cycles, each consisting of two iterations, reviewed through a lens of pragmatism provided a suitable research setting. The sample for the current study consisted of four Year 10 classes (2025 students per class) sourced from the researcher's school. Data collection was in the form of observations, focus group interviews and evaluation tools. The data were analysed using a Wilcoxon signed-rank test and NVivo 10™ software to code student responses.

A variety of instruments were used in this study to evaluate the students' learning of the content presented in the e-textbook and included PBL Evaluation Tool, focus group interviews, informal classroom observations and structured observations. These instruments were used to provide some different sources to answer the research questions. It was not the intention to determine definitive answers, but rather, to provide information that would allow for the refinement and further development of the e-textbooks for the second and third cycles.

The PBL Evaluation Tool was designed to capture information regarding the students' content knowledge of the subject, their metacognitive abilities and their motivation to complete the task at hand. The PBL Evaluation Tool was administered immediately before each iteration and again at its conclusion. While the need to assess changes in student content knowledge was self-evident and the methodology well established, the other two aspects of the PBL Evaluation Tool required further elaboration.

The focus group interviews were designed to provide the students' perspective on each iteration to the researcher. The students' responses were used to determine the effectiveness of the intervention regarding the design of e-textbooks, the e-textbooks effect on their learning and difficulties experienced by students using the e-textbooks. This information could then be used to inform future developments of the e-textbooks and extrapolated to introducing PBL in a wider setting. Informal classroom and structured observations were performed by the researcher and by an independent observer respectively. They intended to identify implementation difficulties during the PBL intervention, levels of student engagement with the tasks and, in the long term, the implications for a wider use of PBL in the classroom.

The analysis of these various instruments included a Wilcoxon Signed Rank two-tail test for paired samples and Spearman–Brown split-half reliability coefficient. Student responses' in the PBL Evaluation Tools and focus group interviews were coded into categories using NVivo 10™ based on the students' answers to the questions posed. Transcription of informal classroom observations occurred at the end of each lesson.

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 (α = .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 rSB1 = 0.74 and the completing question had an rSB1 = 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 rSB1 = 0.71 and the post-intervention results had an rSB1 = 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 rSB1 = 0.86 and the completing question had an rSB1 = 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?	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. 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. 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.	Develop more hard-scaffolding within the e-textbook including how to work in groups. Explicitly state the function of PBL to students. Reduce and simplify questions. Review role of facilitator.
2. What design features of the e-textbook supported PBL intervention most influenced student learning?	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. 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.	Improve feedback so that it targets specific issues identified through formative testing of students. Use new platform that controls students progress, limits gaming and automatically saves students work. See strategies for Research Question 1.
3. What was the overall impact of the e-textbook supported PBL intervention	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. Students need support in organising specific searches for information rather than a general approach to seeking information.	Add a glossary to provide definitions of key terms. Provide targeted feedback on concepts covered in each problem. Add note taking facility. Add hard-scaffolding for research techniques

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?	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.	Improve glossary to provide definitions of key terms.
	Students need more support than was provided, regarding hard-scaffolding, to achieve a better understanding how to use equipment in science.	Add hard-scaffolding showing how equipment can be used to investigate science problems.
	Students require more hard-scaffolding to understand what is happening at the molecular level during chemical reactions.	Add hard-scaffolding to help students understand what is happening at the molecular level during chemical reactions.
	Students need more support from the e-textbook to develop their problem-solving skills.	Soft-scaffold on a need's basis.
	Students need support to learn from their practical work, and this is especially so when recording results and analysing those results. They also need support to plan, search and evaluate information and monitor progress.	Add hard-scaffolding showing how to plan, search and evaluate information and monitor progress.
2. What design features of the e-textbook supported PBL intervention most influenced student learning?	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.	Soft-scaffold on a need's basis. Provide feedback to students after each problem.
3. What was the overall impact of the e-textbook supported PBL intervention	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.	Improve hard-scaffolding of PBL in e-textbook. Improve feedback on student progress.

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.

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.

Chapter Six: Cycle Three—Results, Review and Implications

6.1 Introduction

"It is good to have an end to journey toward; but it is the journey that matters, in the end" (Le Giun, 1969, p. 220). Cycle three was the final 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 and, in doing so, finding a destination by reflecting on the journey. These questions related to e-textbook supported PBL iterations and are concerned with their design features, their impact on students and the constraints in using them in secondary schools. This chapter will recapitulate the analysis of cycle two and then present the results and analysis of cycle three.

6.2 A Recapitulation of Cycle Two

The completion of the second cycle provided a basis for the further refinement of the e-textbooks and their use to support PBL in science classrooms. Evaluation tools, interviews and observations were used to acquire information 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 helping students see the value of problem-solving.

6.3 The Cycle Three Environment

Cycle three involved one Year 10 Science class and covered two topics: Newton's Laws and Chemical Reactions. Eighteen students comprised the class of which 10 participated in the study with the permission of their parents. Each topic lasted five weeks, and each was a topic covered by Year 10 students as part of the Australian National Science Curriculum. The 18 students in the class were part of the mainstream cohort that 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% were moved to other classes since this was the policy of the Science Department at the School at the time of this third cycle. 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.

6.4 Themes Arising from the Analysis of the Data

The analysis of the data from the two iterations of cycle three revealed 15 different themes related to the research questions that this study attempted to answer. Table 6.1 presents the research questions, the data and the themes that arose from the data's analysis. There follows an analysis of each theme in relation to each research question.

Table 6.1

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?	Function of e-textbook	FGI NL3	Questions 1 & 7
	Functionality of e-textbook	FGI NL3	Question 7
		ICO	17/08
	Technology infrastructure	FGI NL3	Questions 3, 6 & 7
		FGI CR3	Question 1
		ICO	17/5, 13/06 & 15/08
	Understanding PBL	FGI NL3	Question 1
	Note-taking	FGI NL3	Questions 7 & 9
		FGI CR3	Question 4
2. What design features of the e-textbook supported PBL intervention most influenced student learning?	Multimodal	FGI NL3	Questions 7 & 8
		FGI CR3	Question 7
		ICO	All
	Group-work	FGI NL3	Question 6
		FGI CR3	Questions 2, 3 & 6
	Enjoyment	ICO	All
		PBLETSE	Table A1.16 & Table A1.38
	PBL	FGI NL3	Questions 2 & 4
		FGI CR3	Questions 1 & 4
		ICO	All
	Hands-on	FGI CR3	Questions 1, 3 & 4
		PBLETSE	Table A1.16 & Table A1.38
	Argumentation	ICO	26/05, 30/05, 31/05, 9/08, 11/08, 18/08 & 24/08

(continued)

Research question	Themes	Data collection component	Data source in appendix A1.1 and A1.2
3. What was the overall impact of the e-textbook supported PBL intervention?	Content knowledge and its application	FGI NL3	Questions 3 & 4
		PBLETK	Figure A1.3, Figure A1.17, Table A1.1, Table A1.2, Table A1.3, Table A1.4, Table A1.6, Table A1.24, Table A1.25, Table A1.26, Table A1.27, Table A1.28 & Table A1.30
	Misconceptions	FGIETK	Table A1.1, Table A1.2, Table A1.4, Table A1.6, Table A1.24, Table A1.25 & Table A1.28
	Planning, monitoring & evaluation	FGI NL3	Question 2
		FGI CR3	Question 6
		PBLETK	Table A1.5
		PBLETMPE	Table A1.9, Table A1.11, Table A1.12, Table A1.34 & Table A1.33
	Student engagement	PBLETSE	Table A1.11, Table A1.13, Table A1.14, Table A1.15, Table A1.16 , Table A1.7. Table A1.35, Table A1.36, Table A1.37, Table A1.38 & Table A1.39
	Hard-scaffolding	SPO	Table A1.23 & Table A1.42
		FGI NL3	Question 2

Note. FGI NL3 refers to focus group interview—Newton's Laws, FGI CR3 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.

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

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

- function of e-textbook
- functionality of e-textbook
- technology infrastructure
- understanding PBL
- note-taking.

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

6.4.1.1 Learning constraints

This category included 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 various reasons. There was only one factor that related to learning constraints in this iteration. Table 6.2 details these categories.

Table 6.2
Themes Contained in Each Category for Research Question One

Categories	Themes
Learning constraints	Function of e-textbook
Pedagogical constraints	Understanding PBL
Technical constraints	Technology infrastructure Functionality of e-textbook Note-taking

6.4.1.1.1 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 they use in science. This mismatch created a disequilibrium in the students using the e-textbook. When asked in the focus group interview about the e-textbook, one student stated that "it's a lot easier to have a physical textbook that you can flick through the pages and often there is a lot more information there" (FGI NL3 S3). The lack of information in the e-textbook was commented on by two other students in the interview in response to the same question. When asked about learning the content regarding Newton's Laws, one student noted that "I just think like overall I liked the e-book but if it was more in-depth" (FGI NL3 S5). The students had a preconceived idea that the 'textbook' should provide all the answers to a problem without them having to do any extra work. This issue did appear in the Chemical Reactions iteration, but to a lesser extent, perhaps because the students were now used to the idea that the e-textbook was not there to provide them with the answers. However, one student did comment in the Chemical Reactions focus group interview that:

> I do like the normal textbook a lot because like you have the-the topics like the chemistry topic. And then let's say we're talking about co-covalent bonds or something, there's a topic of that in that chapter and you—everything that you need to know about it is there with the diagrams and everything. (FGI CR3 S1)

Thus, while the issue of the e-textbook not providing all the information to students has abated somewhat, it was still extant in some students' minds. However, it was possible to postulate that further exposure to the e-textbook PBL format would continue to have a positive impact on students' expectations of it. In particular, they would more likely became better accustomed to the PBL process.

6.4.1.2 Pedagogical constraints

Pedagogical constraints were outside the direct sphere of influence of students 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. There was only one factor that related to pedagogical constraints in this iteration.

6.4.1.2.1 Understanding PBL

The student responses in the focus group interview conducted after the Newton's Laws iteration highlighted the issues around not understanding the purpose of PBL. When asked what they liked or disliked about the topic, one student noted that:

> I disliked how the experiments we did the results we got from them were difficult to get accurate because of how the tests were set-up. Like we had one where you had to attach a balloon to a string and run the balloon down the string as to test I think the force of the balloon but the problem with that is the balloon has a variable weight depending on how much air is left in it so you can't get an immediately accurate result so I think it would be better if the experiments we did we could gain a lot more exact results that are easier to understand rather than running an experiment and getting more rough results from that. (FGI NL3 S3)

This response highlighted a few issues regarding PBL in this iteration. The problems were deliberately ill structured, and the concerns the student was raising are ones that they needed to solve this problem. The student was aware of the issues, but not able to go to the next step of trying to resolve them. The student wanted more exact results but did not try to develop a means of achieving those results. Another student's response was more direct in delineating one of the issues:

> I thought that it was hard to understand what to do for the experiments coz [*sic*] obviously, we had to design them ourselves, but most of us were stuck

> on like how to start off – like we got the materials, but we couldn't figure it out. (FGI NL3 S1)

In this case, the student was not able to start working on the problem without some help and so would take longer to appreciate the most intricate issues in the problem. For example, obtaining reliable results while considering several factors that could affect those results.

However, this sentiment was not universal among the students in the focus group interview. Another student stated that "I kind of liked how like not knowing because it makes you feel like more independent. I just liked that bit." (FGI NL3 S4). The preference for independent problem-solving carried over into the Chemical Reactions iteration where the students did not express the same issues with working on the problems. One student in the Chemical Reactions focus group interview noted that:

> It felt more worthwhile learning it than rather than just taking down some notes and going Oh, I've learned this for a test. When you're actually doing it, you go I've actually learned something now, like you now apply it. (FGI CR3 S5)

There was a realisation among the students of the purpose of PBL, and thus, there was less resistance to working on ill-structured problems for which they had no immediate solution. There was also a perception that it was possible to learn while working on a problem and that solving the problem was a part of the learning process. This perception was evident from the informal classroom observations (Table A1.41) and the Strobe observations (Table A1.42) where students were on-task in working with the problem and the facilitator was interacting with subgroups about specific issues related to the problems.

6.4.1.3 Technical constraints

Technical constraints were also outside the students' sphere of influence and control. However, their source and therefore the measures needed to mitigate them were different. As such, they needed to be considered separately from the pedagogical constraints. Three technical constraints occurred in this cycle.

6.4.1.3.1 Technology infrastructure

The issues centred around accessing the e-textbook during the lesson. In the focus group interview for Newton's Laws, students expressed their frustration:

> I thought it was worse coz [*sic*] the process of having to open a laptop and connect to VMWare, a lot of people take a lot of time doing that and then having the program open some people had to go to IT multiple times to get it to work properly. (FGI NL3 S3)
>
> It was really good like I really liked it except the fact that logging onto it took a lot of time, like if it was a book you would just open it and get on with it. (FGI NL3 S2)
>
> I think that is the schools Wi-Fi though coz [*sic*] the schools Wi-Fi kind of affected that a lot. (FGI NL3 S5)

There were clearly issues with the technology infrastructure, and this had a significant impact on how the students were able to access and interact with the e-textbook. This issue repeated itself in the Chemical Reactions iteration focus group interviews where students again raised issues concerning access to their e-textbooks:

> The only thing I could see that I didn't like about it would be just the, uh, multiple IT problems we were having… Like it wasn't the eBook itself; it was just the computers. (FGI CR3 S2)
>
> It's just the school Internet, it's just when you had to use the eBook on the school Internet it just made it more difficult. (FGI CR3 S4)

Installing the software on the students' computers remedied the issue in some cases. However, the program was not compatible with MacOS and most of the students use

Apple MacBook's running MacOS. Fixing the infrastructure issues was beyond the scope of this study, and given the importance of network access to education, it was not unreasonable to believe the network should support the program.

6.4.1.3.2 Functionality of the e-textbook

New issues arose in this iteration regarding the functionality of the e-textbook. Since this was a continuing cycle of development and refinement, such issues were to be expected and commented on further. The main issue was the user interface (UI), which one student commented on in the Newton's Laws focus group interview noting that "it is difficult to use, it's a lot easier to have a physical textbook that you can flick through the pages" (FGI NL3 S3). The UI had been designed to prevent students from moving through the e-textbook (flicking through) without interacting with the information on the pages. However, in the Newton's Laws iteration, this also prevented students from going back and reviewing previous pages. Modification of the e-textbook in the Chemical Reactions iteration allowed students to move backwards, and they did not raise this issue.

However, a separate issue did occur in the Chemical Reactions iteration with the e-textbook. More hard-scaffolding was included in the e-textbook to assist students with chemical formulae and chemical equation writing by using cognitive tools. Taskin and Bernholt (2014) noted that chemical formulae writing, and chemical equation balancing are two areas that students find difficult. A formulae generator and chemical reaction generator were included to assist students with these tasks. However, some small errors developed in both scaffolds that caused some confusion among students, although they were able to identify the issue and work around it. For example, the chemical reaction generator had one set of reactions missing; however, their observed confidence in writing equations remained high (Table A1.41).

6.4.1.3.3 Note-taking

Students are accustomed to taking notes in class from the teacher, a textbook or another source of information, such as the internet, and this practice is a common aspect of any academic routine (DeZure, Kaplan, & Deerman, 2001). However, the use of computers (laptops) for this task is more controversial. Mueller and Oppenheimer (2014) reported that students using laptops for note-taking performed poorly in recall and application tests. This problem is related to the fact that "if the notes are taken indiscriminately or by mindlessly transcribing content, as is more likely the case on a laptop than when notes are taken longhand, the benefit disappears" (Mueller & Oppenheimer, 2014, p. 8). The students were directed to take specific notes on their laptops that related to the problems they were trying to solve and any research they conducted to prevent indiscriminate note-taking. However, students had an aversion to using their laptops for note-taking, preferring instead to use pen and paper. In the Newton's Laws iteration focus group interview, two students noted that:

> If you had to like write it in your book because writing it you also remember it better if you had to write something in your book I think you'd be better remembering it and it would help or if you had a book that went with the e-book as well. (FGI NL3 S5)
>
> I reckon maybe instead of after like getting information from the e-book and writing it in like the next following page Mr Stewart should maybe print off like a booklet. (FGI NL3 S1)

Another student noted that:

> I thought that there was too much technology used. I think he could have balanced it more with a textbook coz [*sic*] some things weren't needed

> taking notes. There I found it much more like useful writing in books and also having a test at the end, so you know that you are going to have a test at the end you need to know the correct information and the other thing is I thought there was a lot of context there. (FGI NL3 S2)

These responses were unexpected since students had often shown a preference in class for writing notes using their laptops in previous topics. It was possible that this resistance to writing notes in the e-textbook stemmed from the issues raised about the technology infrastructure. That is, students found it difficult to begin using their e-textbooks and were wary of losing the notes they had taken. The issue of note-taking became more problematic in the Chemical Reactions iteration where one student noted that "we didn't really make notes coz [*sic*] just students can't be bothered" (FGI CR3 S4). However, it was interesting that the same student then noted that when it came to write up the practicals, which was the final part of each problem:

> The entire write-up and what we were going to do had to be made up. And that also made us make sure that everything we'd also learned it really confirmed - it was like coz [*sic*] - so, when we have to write up our own practical it means that we really have to know it. (FGI CR3 S4)

In this case, the students needed specific reasons to take notes and researching the topic was, in itself, not sufficient. The students may need more direction on the reasons for taking notes in the form of hard-scaffolding in the e-textbook, especially regarding research notes.

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

Cycle three 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:

- multimodal
- group work
- enjoyment
- Attitude of student to PBL
- hands-on
- argumentation.

It was possible to group these themes into three broad categories that could be considered together owing to the similar underlying characteristics. Table 6.3 details these categories.

Table 6.3
Themes Contained in Each Category for Research Question Two

Categories	Themes
Facilitation features	Multimodal Hands-on Argumentation Attitude of student to PBL
Interaction features	Group-work
Enjoyment	Enjoyment

6.4.2.1 Facilitation

The inclusion of a feature in the facilitation category meant that it assisted students in learning from the problems presented to them in the iterations. The hands-on nature of the problems together with argumentation were features that students found helped them. The multimodal presentation of the problems to students also facilitated their learning as did the process of PBL itself. A discussion of these two facilitation features occurs below.

6.4.2.1.1 Multimodal

The multimodal design of the e-textbook was continued and improved from the previous cycle and included visual (diagrams and graphs), aural (speaking), reading (text) and kinaesthetic (simulations) aspects. One student noted in the focus group interviews for the Newton's Laws iteration that "it's a better way to describe with an e-book coz [*sic*] you can see what's happening whereas the book just tells you and you have to like accept it even if you don't get it" (FGI NL3 S5). Students also commented on the incorporation of some of the multimodal aspects into videos embedded into the e-textbook:

> better explained because it had videos and things. (FGI NL3 S5)
>
> I think it helped just the understanding from the videos I liked those yeah. (FGI NL3 S4)
>
> I liked the video the most like that's the bit I liked the most having the videos there. (FGI NL3 S2)

The students found the videos and the animations useful in providing information about the problems they were encountering and how to start to work out a solution to those problems. In the Chemical Reactions iteration, which also used videos and animations, the animations could simulate and visualise for students' certain phenomena that may not normally be perceived. Two students mentioned the videos and animations in the focus group interview:

> Watching the videos, I still found myself more engaged … because the eBook's interesting and you learn some basic knowledge. (FGI CR3 S4)

> You can actually like watch animations and get involved, and it’s interactive. (FGI CR3 S5)

Therefore, the use of multimedia to present information to students regarding the problem was beneficial.

6.4.2.1.2 Hands-on

The problems presented to the students in both iterations were, to a large extent, practical in nature with an underlying theoretical basis. As such, there was considerable scope for a hands-on approach, which the students liked. In the Chemical Reactions focus group interview, one student noted that “we actually want to do it. When you can see reactions and that sort of stuff it makes you look forward to it” (FGI CR3 S1). Another student noted that “personally I preferred it because it, it is more hands-on” (FGI CR3 S2). A third student provided further explanation noting that “so we had the practicals, but then we also, to understand them, had to read through as well so we got more information and knowledge through that too” (FGI CR3 S5). Therefore, it was not just performing hands-on work for the sake of it, but rather seeing a purpose in the hands-on work they perform as they work through the problem. The positive response to hands-on activities showed in the students’ responses to the PBL Evaluation Tool regarding enjoyment of the topic. In the Newton’s Laws iteration (Table A1.16), 14% of those students who said they would enjoy the activity indicated it was because it was a hands-on activity, pre-iteration, and this increased to 44%, post-iteration. This preference increased in the Chemical Reactions iteration (Table A1.38) where 40%, pre-iteration, and 100%, post-iteration, of students who responded that the task was enjoyable indicated it was because it was hands-on.

6.4.2.1.3 Argumentation

Argumentation was a constraint in the previous cycle. However, in this cycle, considerable argumentation within the groups was observed in both iterations and across most groups. In the Newton's Laws iteration, the main topics of discussion were how to demonstrate each of Newton's Laws with the materials provided and how to meet the design criteria for the rocket. In the Chemical Reactions iteration, discussions concerned interpreting the results of each set of reactions and how to measure a rate of a reaction while changing only one variable.

6.4.2.1.4 Attitudes of students to PBL

In previous cycles, students had not embraced the process of PBL as fully as was hoped. However, in this cycle, there was a discernible change in the students' attitudes. When asked about problem-solving in the Newton's Laws iteration, one student noted that "I think it helped like thinking more creatively" (FGI NL3 S5). This point was picked up by another student who described the process in more detail:

> Yeah first you have to discuss with your team, and I think they do show that in the online thing. It shows you how to discuss and then assign tasks. That was good I learned a lot from that. (FGI NL3 S1)

Then, when asked if they learned more or less using this method (PBL), another student stated that:

> Through the experiment I actually understood. Usually I read something and I just have to remember what it says, but I actually understood the process better by doing this. (FGI NL3 S2)

There was an appreciation by the students of the value of working through a problem to find a solution and in doing so learn about the topic they were covering.

There was a similar response in the Chemical Reactions focus group interview. When asked what they liked or disliked about the topic, one student noted that:

> It was also easier to grasp the topics when you'd just done an experiment or a practical or a problem on when you've done the work and then you can - it's so much easier to also then also understand the practical once you've also worked out what the problem actually is and how to explain it. (FGI CR3 S4)

Another student explained the advantage of working on a problem further, when asked if they learned more using this (PBL) method by stating that:

> It's like when you're writing down notes you - sometimes you don't really register what you're writing, you just do it. But when you're given a practical you have to actually think about it and figure out what you're doing. (FGI CR3 S5)
>
> At the end of the eBook there was a problem where we also had to go into our textbook, so we had the practicals, but then we also, to understand them, had to read through as well, so we got more information and knowledge through that too. (FGI CR3 S5)

Over both the iterations, there was an appreciation by the students of the value of learning by problem-solving. This appreciation was evident in the Informal Classroom Observations as well as with students actively engaging with the problems in their groups (Table A1.20 and A1.41).

6.4.2.2 Interaction

Interaction is taken to mean any feature that involved students communicating with each other or the e-textbook. The students were involved in interacting and supporting each other in groups. The interaction between students involved discussing the problems and working on solutions, which included interacting with the e-textbook (Table A1.20 and A1.41).

6.4.2.2.1 Group-work

The level of interaction and support within groups in the Newton's Laws iteration was remarkable both for its sophistication and endurance. The students constantly worked with and supported each other by discussing the problems and working on possible solutions. When asked during the focus group interview for Newton's Laws, one student noted that "Yeah our team was like had different like everyone had like different like opinions and ability" (FGI NL3 S4). Another student commented that "It kinda [*sic*] pushes you …you're expected to do something it's like if you were by yourself, it's like if you don't do it it's your fault but if you're in a group you kind of have to" (FGI NL3 S2). There was both an appreciation of the value of working in a group by sharing ideas and opinions and a sense of commitment by the members of each group to the other members.

In the Chemical Reactions focus group interview, students again responded positively about group-work. When asked about group-work in PBL, one student noted that "So, it wasn't just the one person; it wasn't just you trying to understand the thing, like you had to - and that way the entire group had to have an understanding" (FGI CR3 S4). When asked if they preferred this style of teaching (PBL), the same student said that "it's also just a whole lot more appealing to be able to walk into science and get to work in a group and not just as a single student in a classroom" (FGI CR3 S4). Thus, this student not only just enjoyed working in a group but saw value in doing so. Further questioning about whether students learned more using PBL confirmed the value they placed on using PBL. The same student stated that "your group actually had to work together to design the practical, so you needed to have an understanding before you could even think about doing the practical" (FGI CR3 S4). Therefore, there was an appreciation of the importance of working together on a problem. While this was only one student, other students in the interview agreed with the idea of requiring an understanding of the purpose of the practical (problem) before carrying it out.

6.4.2.3 Enjoyment

In the Newton's Laws iteration (Table A1.16), 42% of students, pre-iteration, and 64%, post-iteration, found the activity enjoyable in some respect. In the Chemical Reactions iteration (Table A1.38), there was no change in the level of enjoyment pre-iteration and post-iteration with the level remaining at 56%. Informal Classroom Observations also showed the students enjoying the process of PBL in their groups as they were observed to be working together on-task during the cycle.

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

The instruments used in this study also gathered data on the overall impact of the e-textbook supported PBL intervention on the students, and analysis of the data identified five key themes:

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

The Newton's Laws iteration affected students' knowledge with significant improvement post-iteration. Figure A1.3 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 a significant difference between the pre- and post-iteration scores (α = .05 and p = .023). There was also an 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 A1.6). Students understood more about most terms post-iteration with only one term recording a decline post-iteration.

Questions relating to describing and applying Newton's Laws (see Table 6.4) indicated substantial improvement post-iteration in most areas, the exception being explaining an application of Newton's Laws, which showed only a slight improvement. This anomaly was owing to students not providing enough detail in their answers. Post-iteration students were able to apply the concepts of Newton's Laws correctly in general as well as specifically to the design of a rocket.

Table 6.4
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	12.5	44
Explaining an application of Newton's Laws	Table A1.2	70	80
Applying Newton's Laws to rocket design	Table A1.3	60	100
Applying Newton's Laws to rocket efficiency	Table A1.4	22	67

In the Chemical Reactions iteration, there was a similar result with significant improvement in students' content knowledge post-iteration. Figure A1.17 shows the percentage of correct choices for each question. A Wilcoxon Signed Rank two-tail test for paired samples performed on this data showed a significant difference between the pre- and post-iteration scores (α = .05, p = .026).

When asked questions that related specifically to the topic of reaction rates, the results were positive (Table 6.5). Similarly, when asked about kinetic theory, increasing reaction rate and factors affecting reaction rates, there was a substantial improvement in students' knowledge. However, when asked to explain how a factor increased a reaction rate, there was no great improvement in the student's understanding with students either restating the question or using loose terminology (e.g., increasing just one factor will increase the rate at which the reactants react together). The result would indicate a deficit in student learning in this area. Nevertheless, overall the results indicated an improvement in the students understanding of reaction rates.

Table 6.5
Percentage of Correct Student Answers to Questions Regarding Rates of Reaction Pre-iteration and Post-iteration

Topic	Source	Percentage correct	
		Pre-iteration	Post-iteration
Apply kinetic theory	Table A1.24	30	50
Describe how to increase reaction rate	Table A1.25	60	80
State factors affecting reaction rates	Table A1.26	90	100
Explain how a factor increases reaction rate	Table A1.28	25	44
Measuring reaction rate	Table A1.29	0	34

6.4.3.1 Misconceptions

Table 6.6 shows student misconceptions regarding various concepts involving Newton's Laws as a percentage of total responses. In most of the topics in the Newton's Laws iteration, the percentage of misconceptions present in student responses decreased post-iteration. In the explaining of Newton's Laws, there were no misconceptions pre-iteration or post-iteration.

Table 6.6

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	25	0
Explaining an application of Newton's Laws	Table A1.2	0	0
Applying Newton's Laws to rocket efficiency	Table A1.4	44	11
Explain how you increased the efficiency of your rocket	Table A1.6	20	12.5

In the Chemical Reactions iteration (see Table 6.7), two of the topics showed a reduction in the percentage of misconceptions post-iteration. However, when asked about how a factor may increase the rate of a chemical reaction, there was a small increase post-iteration. Overall, the level of misconceptions shown by the students was small and for the most part, trended downwards. The iteration seemed to prevent many misconceptions forming and helped remove those misconceptions that did form.

Table 6.7

Percentage of Responses Containing Misconceptions Regarding Chemical Reactions Pre-iteration and Post-iteration

Topic	Source	Percentage of responses containing misconceptions	
		Pre-iteration	Post-iteration
Explaining kinetic theory	Table A1.24	20	10
Describing increasing a chemical reaction	Table A1.25	20	10
Explaining how a factor increases a chemical reaction	Table A1.28	0	11

6.4.3.2 Planning, monitoring and evaluation

Students were asked to rate, using a Likert scale, the importance of five aspects of planning and completing a problem relating to the design and construction of a rocket. 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 = -.240 and the completing question had an rSB1 = .573. These results showed no and little 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 the planning question and completing question had an rSB1 = .339 and the post-iteration results had an rSB1 = .941. This result would indicate that the students did not see a significant difference between these aspects of planning and completing a problem, post-iteration, but did so, pre-iteration.

When asked the same questions in the Chemical Reactions iteration, the results were different. The planning question pre- and post-iteration had an rSB1 = .786 and the completing question had an rSB1 = .702. These results showed a greater level of equivalency between the pre- and post-iteration responses compared with the Newton's Laws iteration in 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 = .634 and the post-iteration results had an rSB1 = .800. There was a decrease in the pre-iteration value comparing the planning and completion of the problem, but it was not a significant one and there was an increase post-iteration.

When asked about evaluating their performance on the problems in the Newton’s Laws iteration, 70% of students indicated that they would do so by looking at the progress they made, pre-iteration, compared with 90%, post-iteration. The other response was communicating, which 30% of students indicated, pre-iteration, and 10%, post-iteration. When asked to consider how they would evaluate each step 29% of students indicated they would compare with another group member, pre-iteration, which decreased to 12.5%, post-iteration. The number of responses indicating trial and error increased from 0%, pre-iteration, to 37.5%, post-iteration and the number of responses indicating post consideration decreased from 57% to 0%. (Table A1.12 and A1.10).

In the Chemical Reactions iteration, there was a difference in the responses to how students would evaluate their performance with 22% indicating they would use the end result, pre-iteration, and this declined to 0%, post-iteration. The other response was progress made, which 70% of students indicated, pre-iteration, and 100%, post-iteration. When asked to consider how they would evaluate each step, 62.5% of students indicated they would compare with another group member, pre-iteration, which decreased to 11%, post-iteration. The number of responses indicating testing at each step increased from 12.5%, pre-iteration, to 44%, post-iteration, and the number of responses indicating post consideration increased from 25% to 44% (Table A1.34 and A1.33).

When asked how they would search for information in the Newton’s Laws iteration, students considered using multiple sources of information with the internet being the most common, pre-iteration, at 67%, and post-iteration, at 55% each. In some cases, the searches were specific in nature and did specify a particular piece of information—for example, "we looked up best rocket designs, based on their weight and aerodynamic design"—that they would search for using resources available. When asked about assessing the information found, the most common student response was to compare it with other members of their group: 71% pre-iteration and 62.5% post-iteration (Table A1.11 and A1.13).

In the Chemical Reactions iteration, students searching for information mainly focused on the use of the internet with 64% indicating they would use the internet, pre-iteration and post-iteration (Table A1.35). One hundred percent of responses post-iteration were general searches rather than specific ones. However, in class, they were observed using more specific search terms (Table A1.41). In assessing information, the most common response, pre-iteration, was comparing it with other group members at 57%. However, this declined to 50%, post-iteration, with increases in relevance and testing accounting for the difference (Table A1.36). The result was not unexpected since the students focused on the outcomes of their investigations into the problem.

6.4.3.3 Student engagement

The PBL Evaluation Tool used two Likert scales to assess student engagement. They 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 A1.15 shows the results of the first Likert test. Pre- and post-iteration differences tested for using a Wilcoxon Signed Rank two-tail test for paired samples. There was no significant difference between the pre- and post-iteration scores ($\alpha = .05$, $p = .83$). The second Likert scale asked students to rate how useful they thought the task would be to them. Figure A1.12 shows the results of the second

Likert scale. There was no significant difference between the pre- and post-iteration scores ($\alpha = .05$, $p = .681$) using a Wilcoxon Signed Rank two-tail test for paired samples.

The first Likert scale showed only small gains in student confidence post-iteration with increases in confidence at the upper (more confident) end of the scale. There was no quantum lift in student confidence. The second Likert scale showed that there was a wider range of opinions among students about the usefulness of the topic post-iteration. This result was not unexpected given the student's response to the next question (see Table A1.14) where 66% of students, post-iteration, indicated that the end result or supporting the team was the motivation for working on the task. The students saw the iteration as being entire unto itself with no application beyond the iteration. Historically, the students were taught discrete topics in science with a test at the end of each topic. There was no incentive for them to look beyond the completion of each unit of work.

When asked whether the task would be easy or difficult (see Table A1.17), the students' results showed that 11% of students, pre-iteration, and 30%, post-iteration, found it easy. When asked whether the task would be enjoyable (see Table A1.16), 42% of students, pre-iteration, found it enjoyable and 64%, post-iteration, thought that it would be enjoyable. In the Newton's Laws iteration, students found the task to be more enjoyable despite a majority still finding it difficult post-iteration.

The Chemical Reactions iteration also assessed student engagement 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 A1.23 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 differences. There was no significant difference between the pre- and post-iteration scores ($\alpha = .05$ and $p = .776$). The second Likert scale asked students to rate how useful they thought the task would be to them as students. Figure A1.21 shows the results of the second Likert scale. There was no significant difference between the pre- and post-iteration scores ($\alpha = .05$ and $p = .205$) using a Wilcoxon Signed Rank two-tail test for paired samples.

The first Likert scale showed a greater spread of student confidence responses post-iteration. As in the previous iteration, there was no major lift in student confidence. The second Likert scale showed that students considered the iteration more useful to themselves post-iteration. When asked what their motivation was for working on the task (see Table A1.37), 0% of students, post-iteration, indicated that their grades were a major concern. Only 11% indicated that a good end result was a major motivation and 67% indicated that timing was the motivation for working on the task post-iteration. In this iteration, the main focus of the students was on working to a deadline rather than their grades.

In terms of task difficulty, 11% of students, pre-iteration, and 57%, post-iteration, indicated that they found the tasks easy (Table A1.39). When asked whether the task would be enjoyable (Table A1.38), 56% of students' pre-iteration and post-iteration, found it enjoyable. Thus, they found the task less difficult than expected and a majority found it to be enjoyable.

6.4.3.4 Hard-scaffolding

The students were almost always engaged in some way during both iterations as indicated by the Strobe Protocol Observations (Table A1.23 and A1.42). The hard-scaffolding in the e-textbook guided the students on how to work in groups, and this seemed to have helped groups work cooperatively. In the focus group interview for Newton's Laws, when asked about problem-solving, the students mentioned the group-work scaffolding in the e-textbook:

> First, you have to discuss with your team, and I think they do show that in the online thing. It shows you how to discuss and then assign tasks and stuff. That was good I learned a lot from that. (FGI NL3 S5)
>
> In the introduction where it told you how to, the people sitting on the table, include people, that was really helpful. (FGI NL3 S4)
>
> Yeah, I agree with them and yeah. (FGI NL3 S2)
>
> I think it like helped like thinking more creatively. (FGI NL3 S5)

The hard-scaffolding provided in the e-textbook had made a substantial impact on the students' approach to group-work.

6.5 Summary

The journey has concluded, but a reflection on that journey has revealed much to consider and review. Refinement and modification of the e-textbook occurred over the course of the longitudinal study and a large amount of data produced by the students who took part. These results enable consideration of the implications for the introduction of e-textbook supported PBL in secondary school contexts in the next chapter.

Chapter Seven: Discussion

7.1 Introduction

The English historian Henry Buckle in commenting on the history of civilisation in England noted:

> The great enemy of knowledge is not error, but inertness. All that we want is discussion, and then we are sure to do well, no matter what our blunders may be. One error conflicts with another; each destroys its opponent, and truth is evolved. (Buckle, 1861, p. 518)

The purpose of this discussion is to review the data collected and then commence a dialogue that might provide insight into the use of e-textbooks to facilitate Problem-Based Learning (PBL) in secondary school science. The discussion focuses on answering the three research questions stated in the first chapter. Table 7.1 provides a summary of the key themes that emerged from the three research questions using the results presented in the three preceding chapters.

Table 7.1
A Summary of the Key Themes that Emerged from the Research Questions

Research question	Themes
Research question 1: What constraints (if any) inhibited the implementation of the e-textbook supported PBL intervention?	Learning constraints Pedagogical constraints Technical constraints
Research question 2: What design features of the e-textbook supported PBL intervention most influenced student learning?	Facilitation features Interaction features Enjoyment
Research question 3: What was the overall impact of the e-textbook supported PBL intervention on students?	Knowledge Problem-solving transfer Engagement

7.1.1 The road model used to illustrate the development of the e-textbook to facilitate PBL in secondary school science

This study intended to develop a learning resource in the form of an e-textbook produced by an in-house teacher that would enable science students in a secondary school to effectively use PBL to learn specific scientific concepts and skills. The development of these e-textbooks was evolutionary with refinements occurring to improve the e-textbook to the point where it was an effective tool used in PBL. However, the development of a series of e-textbooks in one school was only a starting point, an embryonic project that has the potential for growth, development and wider application. In viewing this bigger picture, it was valuable to reflect on the design process to highlight areas that future developers could consider in developing the next generation of e-textbooks for PBL.

In reviewing the development of the e-textbooks, it was useful to have a model as the basis for guiding the review process. A road was used as the model since it is metaphorically descriptive of the developmental process of producing e-textbooks for students. A road has a starting and finishing point, and in this case, the starting point was the initial e-textbook and the finishing point was the final e-textbook used by the students (Figure 7.1). The road itself was the pathway followed, with all its obstructions and hazards, to develop the final e-textbook. There was a temporal as well as a spatial aspect of this model, which required a second pathway in the model to reflect changes that occurred (Figure 7.16).

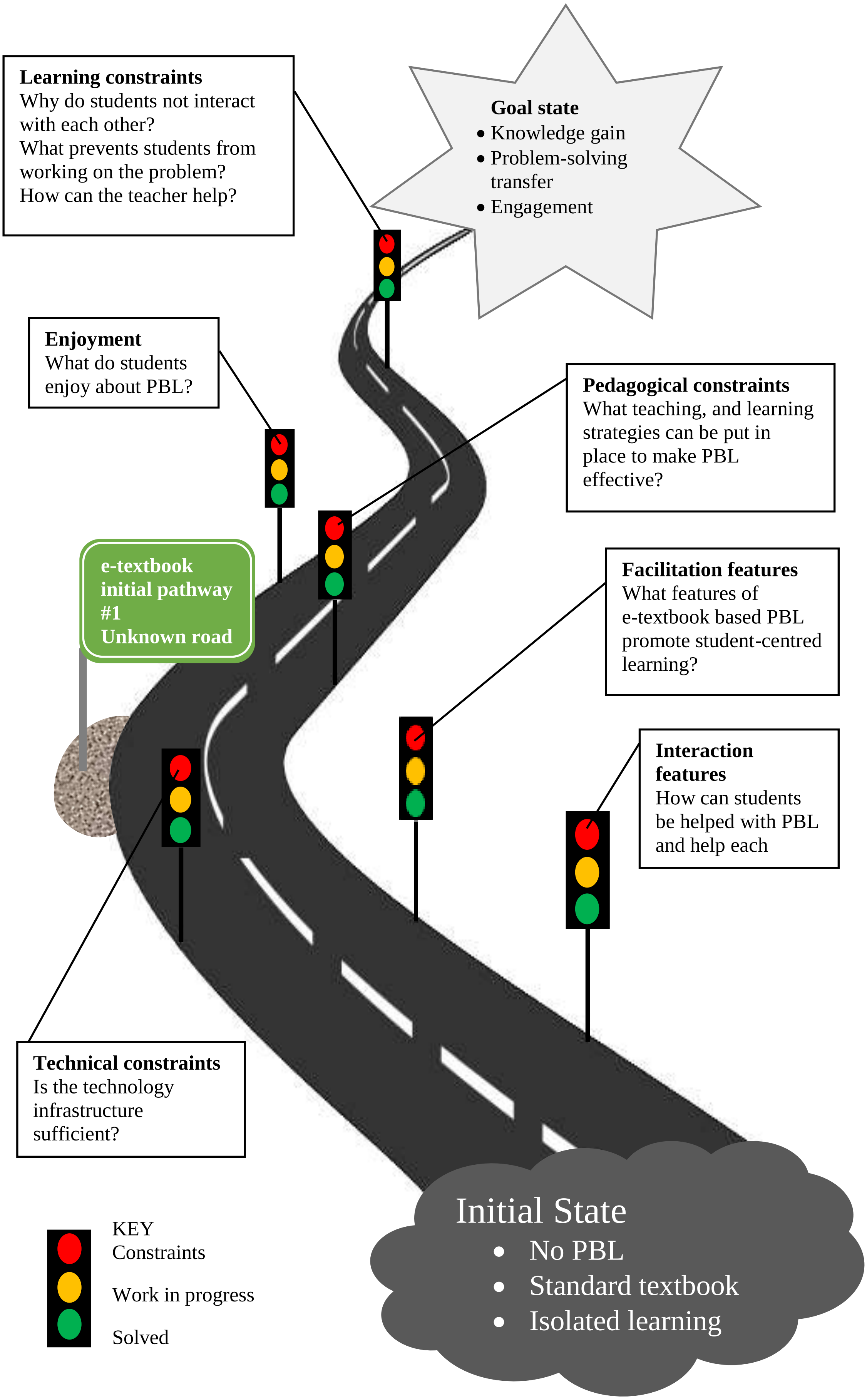


Figure 7.1. The initial road model describing the development of the PBL e-textbook.

Roads are never perfectly straight, free of control points or obstacles and are undergoing construction—so it was in the model used in this study. While the attainment of the goal state was significant, it was the journey along this road with all its control points and construction sites that was the main consideration since this journey provided insights into the design process of the e-textbook. This road model is considered again at the end of this chapter and a determination made regarding the attenuation, or otherwise, of the obstacles and control points in light of this study.

7.2 Research Question One: What Constraints (if any) Inhibited the Implementation of the E-textbook Supported PBL Intervention?

This first research question concerned the constraints that impeded the putting into practice of the e-textbooks to support a PBL environment in a secondary school science classroom. Therefore, it was necessary to consider the various factors that hindered the use of e-textbooks to promote PBL. These factors were distilled from the analysis of the data and consisted of learning, pedagogical and technical constraints. The subsequent remediation of these factors provided some insight into the implementation of PBL into secondary school science classrooms.

7.2.1 Learning constraints to the use of e-textbooks to promote PBL

Learning constraints covered several different categories, including group dysfunction, distraction, copying, the function of the e-textbooks, prior knowledge, the nature of the topic and student expectations of the teacher. Broadly speaking, these categories could be coalesced into five main ideas regarding student interaction: interaction with each other, the technology, the problem, teacher and the institution. The number of constraints decreased as the study progressed.

7.2.1.1 Student interaction with each other that was incompatible with PBL

The literature has documented the importance of interaction between students (Aziz & Hossain, 2010; Chapman, Meuter, Toy, & Wright, 2010; Johnson & Johnson, 1982; Okebukola, 1985; Sharan, 1980; Webb, 1982). Sharan (1980) described the cooperative learning environment as one consisting of small groups that engender cooperative interaction to study a specific area under consideration. He further noted that these groups "become the social unit in which learning is pursued, instead of the class as a whole or the individual pupil" (Sharan, 1980, p. 242). The individual student in such a situation is less able to 'hide in the crowd' and so is more likely to be called upon to contribute to the group. However, the requirement of individuals to contribute to the group led to group dysfunction where students displayed a variety of behaviours incompatible with successful PBL group-work. Chin and Chia (2004) identified some of these behaviours, including how to proceed as a group, what information was relevant and allocation of tasks to group members. As PBL is a group-based learning tool, effective group dynamics are important (Savin-Baden & Major, 2004) and dysfunctional groups can hinder achievement of its goals (Dolmans et al., 2005). Other observed behaviours were described by Wood (2004, p. 3) as the flight, fight and pairing responses. In these situations, students would withhold information from other group members (fight), not take part in group discussions (flight) or work with only part of the group (pairing).

By Year 10, and with two years of secondary school experience that would have involved some group-work, the observed students' inability to work with a group from the start was surprising. Therefore, it was necessary to explore this observation further. The type of group-work required of the students in the first cycle was different from the standard work in a group format that students participate in at school. In working in a science class group format, students typically are given a task (not a problem) and told what to do and how to do it. The only requirement then is for the students to adopt groups and carry out the task. Activities such as this require minimum interaction between the students so that, effectively, they work on small individual tasks. In the case of PBL, the situation is markedly different. The students needed to collaborate to solve a problem that does not have an immediate answer and are required to do more than just completing a set task (Scott, 2014). Students found it difficult to adjust to this paradigm of group-work, which was different from their established perceptions of working in a group. A comment from one student illustrated the issue:

> 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)

Students were not able to work collaboratively towards a common goal.

The level of collaboration improved in the second iteration owing to two factors. First, the students became used to working in PBL groups, and second, and almost counter-intuitively, they responded better to random group placement. In the focus group interview at the conclusion of the first Chemical Reactions iteration, a student commented that "So you [indicating another group member] could sort of focus on something and I could focus on something then we could just collaborate and it would be a lot more efficient way of learning" (FGI CR1 S2). All of the other students agreed with the comment made by this student. The improvement because of familiarity with working in PBL groups was not unexpected, since students had some experience in working as a group, albeit with different ground rules. The students had expressed that they had experienced a paradigm shift regarding what group-work involved, and so, they could function more effectively owing to their previous exposure to PBL group-work. The types of interactions that occurred in the groups explained the second observation. In friendship groups, there was competition between non-productive social interaction and productive social interaction. The non-productive social interactions would involve collaborations that did not relate to the problem, but rather to off-task socialising, including gaming (e.g., playing Minecraft ™), noted during observations of the class. The latter refers to on-task interaction related to the problem. In random groups, there was less opportunity for students to engage in non-productive social interaction. Typically, this was due to students trying to find common ground for communication. Friendship was not an option, and therefore, they had two choices: interact with each other about the problem or not at all. While it was possible for students to disengage, this did not occur since a new dynamic evolved in the group. As one student noted in the same focus group interview, "we aren't really close friends outside but the group-work may have brought us a bit more closer" and "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" (FGI CR1 S4). This evolution of a different interaction within the group may not have arisen spontaneously, and it was necessary to develop productive group interaction.

There was a change in the e-textbook design to facilitate group-work to achieve better group interaction. Figure A2.2 shows the modification to the PBL introduction for students. The modification aimed to improve student interaction and PBL skills rather than relying on the students acquiring the skills. However, there was no noted improvement in the student's initial interaction, and so, the decision was made to modify the e-textbook further. Students received feedback after they had completed the assessment regarding their PBL skills (Figure A2.3) about what they did incorrectly and how to improve in each aspect of the PBL skills (Figure A2.4). The feedback made very little difference to student interactions within groups, and there were numerous occasions when the groups were dysfunctional. If the group perceived the problem to be too difficult, it no longer functioned to support its members and became dysfunctional. Individuals could not cope with their specific tasks, and so, these reverted to the group, which then failed to work cooperatively. This was exemplified in the focus group interview for the Newton's Laws (cycle two) by a student that commented "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). The comment highlighted the issue with PBL in students who expect all the information at the start of the problem. In the same focus group interview, another student commented that "but other people don't get it … like understand what we had to do coz [*sic*] it wasn't really straight forward" and "but we should have had a little bit more information on what we were supposed to be doing" (FGI NL2 S6), which illustrated a lack of understanding about the principles of PBL.

Students' expectations expressed in the focus group interviews necessitated further changes to the presentation of the information to them about PBL, including how to work in a group. The presentation information on group-work was in two parts (Figure A2.5) with part one serving as a general introduction and part two dealing with specifics, including group-work. It was decided to include an assessment of how the students understood PBL (Figure A2.6) and to provide specific feedback about how they could improve in areas where they had not fully understood the concepts covered (Figure A2.7). The feedback strategy was implemented not because of how the students were performing as a group, but rather from a concern about their understanding of the PBL process, stemming from student comments about not being given sufficient information at the start. The presentation regarding PBL now also required the students to work through the sections on group-work rather than allowing them to skip through the section. That the students had to engage with the presentation caused them to stop and think about the information in the e-textbook. There was mostly positive on-task interaction between group members. Students worked cooperatively in groups in both iterations as indicated in the Strobe observations (Table A1.23 and A1.42) and informal classroom observations (Table A1.20 and A1.41).

In classes where students use laptops as a tool for learning, there is the possibility of multitasking occurring where they engage in activities not related to their studies (Fried, 2008; Junco, 2012; Sana, Weston, & Cepeda, 2013). One such activity is playing games (Bate et al., 2014), which can distract students from the educational purpose of using their laptops when the game is not part of the educational experience, as was the case in this study. In the first two cycles of this study, game playing was an issue mentioned in the focus group interviews. The ease with which students could switch between the required task and playing a game was a factor contributing to this concern. Students created the impression of working on the task they were supposed to while spending some of their time off-task.

The time spent in game playing declined over the course of the study, and it was important to determine why there was a difference between the level of gaming from the start of the study to its conclusion. The nature of the learning experience regarding its structuredness can have an impact on student use of technology in environments where such technology is freely available (Kay & Lauricella, 2011; Mohammadi-Aragh & Williams, 2013). This structuredness relates to how technology integration into the students' learning experience occurs. In an unstructured learning experience, the technology is present, but not incorporated in any way whereas in a structured learning experience, the technology has specific integral purposeful uses (Mohammadi-Aragh & Williams, 2013). However, these are two extremes, and perhaps greater insight lies somewhere in the middle. Indeed Mohammadi-Aragh and Williams (2013) noted the existence of situations where no clear distinction between structured and unstructured occurred. A similar situation existed in this study, albeit for a different reason, which is the very nature of the e-textbook. The problems presented to the students were all similar. However, the presentation of the problems was different (Figure A2.8, A2.9 and A2.10).

Initially, there was very little structure regarding how to work through the problems presented in the e-textbook. Information provided to the students was largely text based with questions used to focus their attention on the salient facts they needed to work through the problem. There was no attempt to inculcate in the students an ethos of collaborative group-work and minimal experimentation for them to work on as a group. Feedback to the students was also minimal and restricted to corrections to incorrect responses to multiple-choice questions (Figure A2.8). Thus, the structure of the learning experience was loose; the students had their laptop and the e-textbook and were expected to use them effectively. Support regarding hard-scaffolding was minimal, and so, there was a heavy reliance on soft-scaffolding. In relying heavily on soft-scaffolding, distraction was more likely to occur because the facilitator must spend more time with each group with the result that other groups could go off task.

As the study progressed, the design of the e-textbook was modified to attempt and provide a more interactive and scaffolded learning environment for the students. The modifications included animation to illustrate how PBL worked, including working in groups, Newton's Laws and rocket design. When students' results indicated an insufficient level of understanding, the level of feedback and remediation provided to students was increased. A review of each problem was conducted for the students, and they received assistance with producing their report. Thus, there was more hard-scaffolding in addition to the soft-scaffolding (Figure A2.9). Despite these changes, there was still distraction especially in the form of socialising and game playing.

Further modifications to the e-textbook largely concerned the functionality of the e-textbook and are discussed later in this chapter. However, improvements were made to the presentation of the experiments by moving them from a whiteboard to a table in the lab scene and information presented to the students on each page was reduced (Figure A2.10). Students had more structure through the provision of soft-scaffolding, and the level of distraction decreased substantially. In the focus group interviews for cycle three for Chemical Reactions and Newton's Laws, no mention of gaming was made by students, whereas in previous interviews, they openly commented about gaming. There was less off-task behaviour noted in the classroom observations. The use of soft-scaffolding to respond to student's specific needs on an as-required basis worked to reduce the problem of distraction.

Ryu and Sandoval (2015, p. 337) noted that students working in groups must deal with a variety of issues, including “differences in experience, values, and goals during collaboration” in addition to working on the problem they are attempting to solve. Gillies and Haynes (2011, p. 351) noted that “it is only when students have been taught how to communicate that the benefits attributed to this approach to learning are realised.” The intervention should include “not only the skills of learning to communicate effectively through listening, explaining, and sharing ideas but also those skills needed to plan and organise their work” (Gillies & Haynes, 2011, p. 351). This study found that some of this upskilling could occur in the e-textbook to reduce the demands placed on the teacher to provide basic group-working skills including communicating. Such upskilling does not replace the teacher, who must be prepared to intervene on an as-needed basis in response to specific issues that are difficult to plan for in advance.

Copying was a major issue in the initial stages of the study. Copying can have many causes that include:

- Academic self-efficacy;
- Academic interest;
- Academic level;
- Task importance;
- Task clarity and relevance; and,
- Peer pressure.

(Cheung, Wu, & Huang, 2016, pp. 248–249).

Only a few of these factors were at play during the course of the study. A student’s belief in their abilities will affect their attitude towards cheating with those having a higher self-efficacy less likely to engage in such behaviours as plagiarism (Marsden, Carroll, & Neill, 2005). Academic interest relates to students’ goals regarding mastery (high interest) or performance (low interest) (Cheung et al., 2016) with those in the latter group more likely to cheat (Anderman & Midgley, 2004). Academic performance (level) is a factor in determining the level of cheating by students, but cheating by low-ability students can be mitigated by strongly identifying with the school they attend (Finn & Frone, 2004). Ashworth, Bannister, and Thorne (1997) noted that the importance students attribute to a task was a determiner of the level of cheating with higher levels occurring when they perceived the task to be less important. The significance and level of ambiguity are also determiners of the likelihood of cheating with less cheating occurring when tasks are unambiguous and considered valuable by the student (Anderman, 2007). Finally, the impact of peers can affect the level of cheating with such behaviour correlating with the attitude of a student's peers to cheating (McCabe & Trevino, 1997).

The self-efficacy of the students in this study was not an issue with students confident in their ability to complete the task and an increase in this belief post-intervention (Figure A1.13, A1.14 and A1.15). Further, the majority of students, with the exception of those of Newton's Laws, cycle two, felt that the task they were working on was useful to at least some extent, and so, disinterest, relevance and lack of importance are not relevant. Initially, the students were part of a lower achieving group (as identified by their school test and exam scores), and so, this is a possible contributing factor to the copying observed. The clarity of the task was an area that proved to be a justifiable cause for the copying that students engaged in during the intervention. The tasks were designed to be vague since PBL requires problems that have no immediate solution, and the students found it difficult to work with the problem effectively. Peer pressure was another factor that influenced students with one student commenting in focus group interviews that they copied work from each other within the group because others were also copying.

In the latter stages of the study, copying was no longer an issue. Possible explanations for this observation include the following. First, the students were now a heterogeneous mix of ability levels with each group consisting of members at various levels of academic ability. Second, there was more soft-scaffolding to ameliorate the need for students to copy each other's work, which Anderman (2007) noted as a factor in preventing cheating.

Productive work does not automatically result from students working in groups despite many students preferring to do so. It was more productive to construct groups that were not friendship-based but heterogeneous. The data collected over the course of this study support the idea that groups composed of students of differing abilities randomly assigned to their group and provided with appropriate scaffolding were the most successful. Williams (2011) noted that friendship grouping was more productive; however, in the present study, such grouping provided opportunities for non-productive interaction of a more social nature rather than working collectively to develop a solution to the problem. Grouping students of similar ability did not produce the level of sophistication in their interactions that was required. When the students were in mixed ability groups, they could interact and support each other. They would listen and respond to each other, allocate tasks (sometimes as a group) and research information when required. The actual grouping of students was not a function of the e-textbook but one that a facilitator in a PBL environment using e-textbooks should be aware of when setting up the groups.

7.2.1.2 Student unrealised expectations of the e-textbook technology

The issue of the extent to which students interact with the e-textbook here is not one of a technical nature, such as accessing the network, but rather one of an expectation of what a textbook should do for the student. The e-textbook did not provide all the necessary information for the students which was a clear difference between it (Figure A2.9) and the traditional textbook. There was no specific information about the problem, but only about how the students may go about working through the problem in their group. The fact that the students had used the traditional textbook in a previous topic exacerbated this issue. The disconnect between what the students expected from a textbook and what the e-textbook provided caused them to regard the e-textbook unfavourably, since they considered it to be lacking in essential information. Student comments in the focus group interview for the cycle one Chemical Reactions topic exemplified this disconnect:

> I don't feel it contained enough information to guide me in what we were doing, a lot if it I had to ask or research it myself, so I felt it did not contain enough information. (FGI CR1 S3)
>
> 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. (FGI CR1 S3)
>
> Normal textbooks have a broader range which is quite useful in understanding the overall topic. (FGI CR1 S1)

This issue continued despite the purpose of the e-textbook being explained to the students at the start of each iteration so that their expectations of what the e-textbook would and would not provide were delineated. There appeared to be an ingrained belief in students that a textbook should provide 'the answers' and given that throughout most of their schooling this is the case, it is a difficult belief to change.

Songer and Linn (1991, p. 772) noted that students who approach science textbooks have fixed beliefs about the nature of science "often believ[ing] that all scientific principles in textbooks will always be true, and they view science as best learned by memorizing facts rather than attempting to understand complicated material.” Therefore, denying these students facts to be learned and requiring them instead to research information and apply it to a problem created confusion. The students came to the textbook expecting it to provide all the information they needed to remember. This issue was exacerbated by “textbooks and exercises in them often emphasiz[ing] procedural skill” (Kollöffel & Jong, 2013, p. 377) that Rittle-Johnson, Siegler, and Alibali (2001, p. 346) describe as “the ability to execute action sequences to solve problems, and the reproduction of facts and definitions.” Thus, students expected that the textbook would tell them how to solve the problem with a set of procedures rather than requiring them to develop their own procedures to solve a problem. However, Mayer, Bove, Bryman, Mars, and Tapangco (1996) reported that students provided with a detailed explanation of a particular phenomenon are still unable to transfer the information to a related problem. So, simply providing the students with all of the information needed is not a solution to help them engage effectively in PBL. Mayer (2003) found that using multimodal presentations supports students’ learning and application of various concepts using different, but complementary, media. This media may include text, simulations, animations and audio. Sobhanian (2016) cited numerous examples of improvement in student learning when using multimedia programs, especially in science and mathematics.

In this study, the facilitation of the student’s interaction with the e-textbook occurred in several different ways. The VARK model, discussed in the Literature Review, was used to present ideas to students to accommodate the different learning styles they used. While the VARK model has been criticised, especially regarding its treatment of learning styles, it is still a common model, and students tend to identify with one or more of the learning styles (Ganesh & Ratnakar, 2014). The e-textbook assessed student understanding of various concepts and provided feedback and targeted support when needed. The e-textbook had note-taking facilities and students also had access to glossaries in later cycles. The students had specific support tools that they could use to, for example, write chemical formulae and balance chemical equations. Improvement to such tools occurred in each successive cycle during this study. In this way, the e-textbook was superior to a standard textbook in its ability to support students in a PBL environment by providing a greater range of presentation media and targeted scaffolding when required. The issue of student expectations becomes a hurdle to overcome rather than an obstruction per se, and they require continual reinforcement regarding the purpose of PBL.

7.2.1.3 Difficulty with students' interaction with the problem

To interact with the problems presented to them, students required a certain amount of assumed prior knowledge. A lack of such knowledge would be detrimental to the students in their attempt to work with the problem. The amount of required prior knowledge varied depending on the topic, with no prior knowledge needed to work on Newton's Laws because it was a topic discrete of previous physics topics. However, the Chemical Reactions topic did require some previous knowledge that many of the students lacked and which hindered progress through the problem. Ideally, the students would recognise this deficiency in their chemistry knowledge and work to resolve it. However, initially, the students were not able to do so since they found the problem overwhelming and it was necessary to address these knowledge deficits by having a mix of abilities in both the class and in their groups. As such, each group had students with sufficient background in chemistry to work with the topic as a group and issues with prior knowledge did not develop. Three quotes from the Chemical Reactions focus group interviews illustrate the change in the way the students worked with the problems:

> Once we got into it, we were very good like we would share our opinions and ask each other questions, so that definitely helped. (FGI CR1 S3)

> I think we all worked well in the team as well with the experiments we all knew what our strengths and weaknesses were and we played to those. (FGI CR1 S1)

> If someone didn't have a complete understanding you could then help them, like that group with just that person rather than the teacher having to go around to every person and having to explain it. (FGI CR3 S4)

A second issue concerned the problem presented to the students. Initially, a major focus of the Newton's Laws topic was the design and building of a model rocket taking into account Newton's three laws of motion. These laws were covered briefly in the e-textbook, and a large part of the e-textbook was devoted to the designing of a model rocket. The unfortunate consequence was the students' focus on the rocket as the only problem in the e-textbook. As one student in the Newton's Laws focus group commented "Well I definitely liked building the rockets, but I think filling out the workbook we might have got off the topic a bit, and it was sort of wasn't really done in a proper way where we all really worked together" (FGI NL1 S4). The 'filling out of the workbook' referred to the research the students were required to do before starting the rocket design, something which they did not properly complete. Increasing the focus on each of Newton's Laws before working on the rocket reduced the emphasis on building the rocket by having students work on separate problems related to Newton's Laws: This was commented on by students in the focus group interviews for Newton's Laws where they refer to the problems as experiments or pracs.

> Like through the experiment I actually understood like usually I read something and I just have to like remember what it says but I actually understood the process better by doing this. (FGI NL3 S2)

> I think I learnt more especially like with the pracs and everything like helping to like fill in everything and actually like put it into real life and stuff. (FGI NL3 S4)

Students needed to process the problem they were working on and needed the skills to be able to do so effectively. They needed to analyse the problem and plan their approach as well as research information and use appropriate equipment. They should possess, and be able to apply, prior knowledge, test ideas and be able to analyse their results, which is what Bogard et al. (2013, p. 467) termed "giv[ing] the problem form." The problem itself needed to be sufficiently structured so that students could analyse it effectively, but not so structured that a solution was immediately obvious. Presenting problems in small easily manageable sections that related in some way was essential. The problem should not become all-consuming since it was the process of solving the problem through the development of problem-solving skills that was the focus. One student commented on the development of these problem-solving skills in the focus group interview on Newton's Laws: "Yeah I feel that, I feel that I'm better at like problem-solving experiments which are the main like idea of the online booklet" (FGI NL3 S1).

Students need also to be able to transfer their problem-solving skills from one problem to another. If students cannot apply the problem-solving skills acquired in one problem to a future one, then those skills are too localised and problem dependent and, while near transfer may occur, far transfer may not (Jonassen, 2000). The issue of transfer remains problematic, and it was possible that improved scaffolding may have a role to play in improving transfer, but this remains uncertain. There was no evidence from classroom observations or focus group interviews of students being able to transfer problem-solving skills.

7.2.1.4 Unrealised student expectations of the teacher

The role of the facilitator in PBL is of critical importance (Ertmer & Simons, 2006; Hmelo-Silver, 2004); however, this role was a difficult one to implement given the students' expectations, familiarity with PBL and background knowledge. Ates and Eryilmaz (2015) found that students lacking sufficient background in topics preferred tutors who were specific in the support they provided rather than those who merely facilitated the group. They also noted that "Novice students attending PBL curriculum are unfamiliar with the PBL process … need guidance and rely heavily on their content expert tutor" (Ates & Eryilmaz, 2015, p. 827). Scaffolding is the obvious solution to this issue, but to simply imply that this will solve the problem is an oversimplification. Chin and Chia (2004) listed numerous issues, including how to proceed as a group and allocation of tasks to group members, that were encountered during a Year 9 Biology class. Similar issues appeared during this study and varied in nature, which required input and guidance from the facilitator. The fact that the students had no previous experience with PBL combined with their limited background knowledge made it difficult for the facilitator to provide all the necessary scaffolding. The hope was that the e-textbook would alleviate this problem by hard-scaffolding some of the processes involved in PBL. Initially, the amount and level of hard-scaffolding provided was inadequate. Subsequent revisions of the e-textbook improved the situation and reduced the amount of scaffolding expected of the facilitator. Therefore, the facilitator could assume the more customary role of providing guidance and the students were more accepting of this role.

Throughout the three cycles of this study, the role of the teacher as a facilitator changed continuously and this made transferring soft-scaffolds from the classroom into hard-scaffolds in the e-textbook problematic. As the study progressed, it was possible to identify some abilities that were transferable, including group-work, researching and engagement. However, some issues remained difficult to transfer because either the issues were transient (such issues included specific personality differences and prolonged absence of students) or they did not readily lend themselves to incorporation in the e-textbook. While an e-textbook can help alleviate the demands placed on a facilitator by continual updating of the hard-scaffolding, it cannot replace the facilitator completely.

7.2.1.5 The institution's educational philosophy's impact on students

PBL will be most effective when it is incorporated into the educational philosophy of the whole school rather than in isolation (Barrows, 1996; Kolmos, 2002) since the skills learned are reinforced and transferred (Gillies, 2008). Furthermore, there is less stress placed on students when they do not need "to move in and out of different learning approaches, passive versus active, dependent versus independent" (Barrows, 1996). The teaching philosophy of the school began to slowly change from cycle one with the appointment of a new principal who supported active learning over passive learning. As a result, students gradually became more accepting of the PBL approach as it became more widely adopted. As a result, it both reduced the students' concerns regarding the PBL approach not being an effective teaching method and acted to reinforce the skills they needed to take part in PBL successfully.

7.2.2 Pedagogical constraints to the use of e-textbooks to promote PBL

Some pedagogical constraints prevented students from fully benefiting from the PBL environment. These included inadequate scaffolding, lack of argumentation and a lack of understanding around PBL. Each of these constraints prevented some students from gaining the full benefit of PBL as a tool for their learning. As such, it is essential to discuss each separately to identify the characteristics of each.

7.2.2.1 Inadequate scaffolding

The importance of scaffolding in PBL has been well documented (Bulu & Pedersen, 2010; Greening, 1998; Hmelo-Silver et al., 2007; Kim & Hannafin, 2011; Saye & Brush, 2002; Simons & Klein, 2007). During this study, students received both domain-general prompts relating to problem-solving skills and domain-specific prompts that relate to specific topics they studied. Initially, the scaffolding was at a minimal level, which was ineffectual, both in the domain-general and specific categories. Figure A2.1 illustrates this minimalist approach to domain-general scaffolding, and Figure A2.8 illustrates the same approach in domain-specific scaffolding. Revision of the scaffolding to make it more extensive occurred in both domains (Figure A2.7 and A2.9). As shown in the evidence, the revision did not improve the situation since students were still not functioning well in groups and not interacting effectively with the problem. Therefore, there was a separation of domain-general information into two parts (Figure A2.5), one was an introduction, and the other dealt with specifics, including group-work. There was also an inclusion of an assessment of how the students understood PBL (Figure A2.6) and specific feedback about how they could improve in areas where they did not fully understand the concepts covered (Figure A2.7). This type of scaffolding improved the students' work in groups. Comments in the focus group interviews for Newton's Laws illustrated this point:

> I liked the video like it was like each slide not each slide but some slides had the video like explaining like how it works and so I thought that was really useful. (FGI NL3 S2)

Another student added specifics to this point by detailing what was provided to them in the video about group-work.

> First you have to discuss with your team and they do show that in the online thing. It shows you how to discuss and then assign tasks. That was good I learned a lot from that. (FGI NL3 S1).

The domain-specific scaffolding was also improved. These improvements involved developing better presentations for each of the problems and formulating questions for the students to reflect on after they had completed the experimental phase of the problem (Figure A2.10). Further domain-specific scaffolding was provided to support students in areas of weakness traditionally experienced by chemistry students, formula writing and equation balancing (Figure 7.2), by proving cognitive tools for both areas. These enhancements greatly improved the students content knowledge and group-work. A Wilcoxon Signed Rank two-tail test for paired samples performed on the tests of students showed improvement in knowledge. It showed a significant difference between the pre- and post-iteration scores ($\alpha = .05$ and $p = .023$) and scores ($\alpha = .05$, $p = .026$) for Newton's Laws and Chemical Reactions. Student comments from the focus group interviews show effective group dynamics:

> We weren't really friends, but now we're pretty good friends, and it was like, it was good getting their opinions because some of each other are smarter in different ways and like I think they really helped us doing the practicals and figure out what we were supposed to be doing. (FGI NL3 S5)
>
> Because you can all work together, and it made it easier to get results because instead of having everyone have to write down the results you could go in case you missed anything. (FGI CR3 S5)
>
> The group-work itself it made you want to do science because usually when we do the pracs I'm usually the one that does it by myself. (FGI CR3 S2)

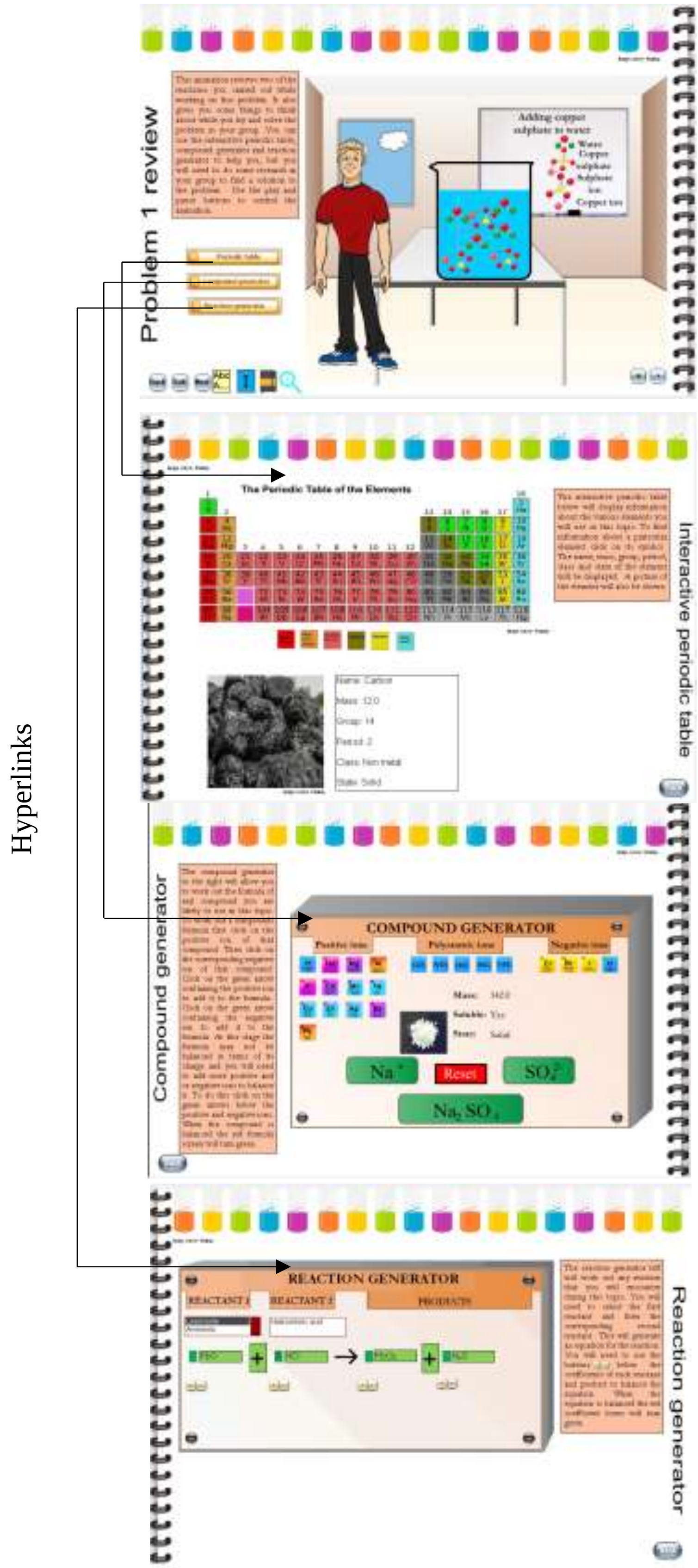


Figure 7.2. Screen shot from the Chemical Reactions e-textbook showing the interactive scaffolding provided to students in cycle three, iteration one.

Students were using the hard-scaffolding extensively for formula and equation writing as observed in the classroom observations. Support in the e-textbook was in the form of hard-scaffolding that was hardwired into the e-textbook before it was available to the students. Therefore, it was unchangeable during each iteration. In this study, providing minimal hard-scaffolding was found to be ineffective in supporting PBL and created a situation that required the use of large amounts of soft-scaffolding by the facilitator. This provision of soft-scaffolding placed too much pressure on the teachers because they worked with several groups, all of which required support at one time.

However, to attempt and provide all necessary scaffolding hardwired within the e-textbook was not a viable alternative since some scaffolding was group and problem dependent and could not be hardwired. Thus, there was a balance between the two types of scaffolding and this balance was not static (Figure 7.3). A basis for deciding about the types of scaffolding, including student familiarity with PBL and the dynamics of the groups engaged in PBL, was required. Consideration also needed to be given to the type of hard-scaffolding provided to the students. Students had received scaffolding in two main areas: PBL (such as working in groups and researching information) and specific science concepts. It was crucial that these types of scaffolding not only presented ideas and skills to the students but also assessed each student's understanding of these concepts and skills. Furthermore, where the assessment found that there were deficiencies in the student's understanding, feedback was provided to the student.

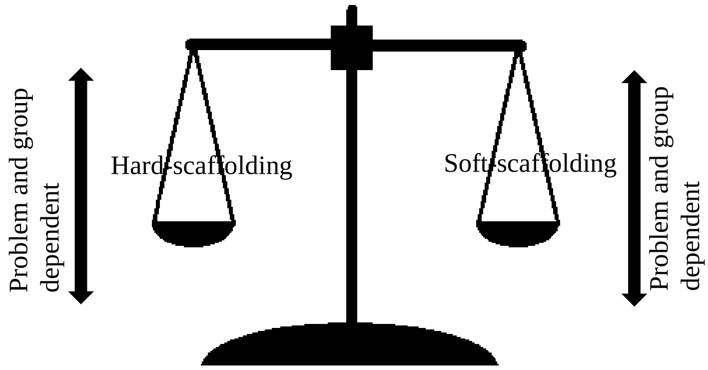


Figure 7.3. Scaffolding in e-textbooks is a balance between hard and soft and is variable between groups and problems.

7.2.2.2 Lack of argumentation

Argumentation is important in the PBL process (Belland, 2010; Belland et al., 2011; Cho & Jonassen, 2002). However, what is less clear is how to achieve argumentation. Gillies and Haynes (2011) believe it is the role of the teacher to provide soft-scaffolding to students that assist them in developing argumentation. However, there is a competing contention that hard-scaffolding should be used (Belland, 2010; Belland et al., 2011; Cho & Jonassen, 2002).

There is an issue with hard-scaffolding in that it is not easily able to respond to individual situations that are inherent in group-work. Ryu and Sandoval (2015, p. 350) noted that "more attention should be paid to the social influences on student argumentation and collaboration." The dynamics of each group will affect the level of cooperation and argumentation that occurs. For this reason, soft-scaffolding was used in this study to respond to a student's or group's needs on an as-required basis and hard-scaffolding for other supports, such as initial group working techniques and content-specific cognitive tools.

In the nascent stages of this study, argumentation was considered a 'bridge too far' for students who had no prior exposure to PBL and with e-textbooks that focused on collaboration without the addition of argumentation. As the study progressed, argumentation received due attention with different results in each case. Where there was very little argumentation, there was poor group dynamics and where there were effective group dynamics, high levels of argumentation were observed, which supported the earlier decision to rely on soft-scaffolding. Ryu and Sandoval (2015) noted that the type of exchanges occurring in groups between their participants determined the level of argumentation. This study supports the finding that argumentation can be encouraged using soft-scaffolding.

This study has shown that argumentation is a factor in the success of PBL. Through this style of discourse, students will be able to construct their understanding of the problem's solution, and more importantly, have that understanding challenged and tested, so that identification of misconceptions can take place and can be corrected. Argumentation is not a spontaneous occurrence but rather, one that develops and matures within a group. Therefore, argumentation is a group-dependent feature, which, despite having some generalisable characteristics, will be the product of interaction within the group. Effective group dynamics was a prerequisite for argumentation, but insufficient by itself, and was very difficult to quantify in the present study. Classroom observation of students in the last cycle that reflected on the interactions the teacher had with the groups was indicative of argumentation. Students had particular opinions or ideas that they brought to the group and which they had to defend with research against other students' informed questioning. Such interaction was not observed in earlier cycles when student achievement was much lower as indicated by pre- and post-iteration testing. Therefore, the logical argument is that given effective group dynamics, the development of argumentation must receive support in some way. This support can be in the form of hard or soft-scaffolding, and the relative amounts of each and its form is highly variable; as Belland et al. (2011, p. 669) noted, this should be "developed based on students' anticipated needs during a PBL unit."

7.2.2.3 Students lack understanding of the purpose of PBL

The change from a didactic teaching approach to PBL is challenging and disconcerting for students who have only experienced traditional teaching methodologies (Strobel & Van Barneveld, 2015). Alessio (2004, p. 32) noted that students in PBL courses had "partiality towards didactic or directed learning, perceptions of reduced learning efficiency, and feelings of uncertainty." These feelings of uncertainty and discomfort were also reported by Ates and Eryilmaz (2015). Throughout the study, there was confusion among the students as to the purpose of PBL. In the first cycle, this confusion manifested itself in the form of student's having expectations of the teacher that were contraindicated by the PBL process as seen in the focus group interview responses where students had certain, unmet, expectations of the teacher.

> Also like, how to put this in or how to make to this in. Even though the program that we had to work on to design our own bit and figure out how high it could even though it was help, but it wasn't like Mr Stewart's help. (FGI NL1 S2)

In the latter stages, the confusion became more pronounced with students questioning the actual process and preferring a return to a more didactic approach as opined by one student in the focus group interviews.

> If we have an open class that can ask questions of the teacher and talk to each other throughout the entire class and just be given the experiments and

> do normally as if it was part of the book. Not having and I think it would be a lot more efficient if we just continued doing it the normal way. (FGI NL3 S3)

Therefore, they did not feel comfortable with the challenges it presented to them despite knowing what the process of PBL was about in the iteration.

When presented with PBL environments, especially for the first time, students find the change to a *learning* emphasis from a *teaching* emphasis challenging and confronting (Henry, Tawfik, Jonassen, Winholtz, & Khanna, 2012). They are no longer in their comfort zone as a passive recipient of someone else's knowledge, but an active constructor of their own knowledge. It is demanding and challenging to develop in these students an understanding of how PBL can help them learn new concepts more effectively and develop new skills that can they can apply to problems encountered both at school and beyond the classroom. Crucial to this issue is the group and how it responds to the challenge. If the group is resilient and confident, then it will be able to work through the problem regardless. If the group is dysfunctional, then it will require their interaction to be supported before any progress on understanding PBL can be made (Albanese & Mitchell, 1993; Hung, 2011). Classroom observations in the first cycle indicated that students were out of their comfort zone. The Strobe Protocol in the first cycle showed only half the groups involved in on-task behaviour in the first three observations. When asked about how difficult the activity would be in the first cycle (Newton's Laws), 38.9% of students (pre-iteration), who said it would be difficult, stated that it was because it was unfamiliar, and this rose to 54.5%, post-iteration. In the third cycle, task difficulty decreased from 50% to 14.3%. A trend started to appear when comparing how the groups functioned in both cycles.

> Yeah, it was all communication. Everyone needed to communicate to understand everything, and if you didn't communicate well then everything didn't work. (FGI NL1 S6)

> 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)

In this cycle, the groups were generally dysfunctional and poor communication was one aspect of that problem, which leads to distraction and a failure of the groups to work collectively on the problem.

> First, you have to discuss with your team, and I think they do show that in the online thing. It shows you how to like discuss and then assign tasks and stuff like that yeah. That was good I learned a lot from that. (FGI NL3 S1)

> Our group kinda [*sic*] like worked really well together because we were all friends like or became friends and we were all together we really helped each other out, and we created new friends by doing this. (FGI NL3 S1)

By cycle three, the scaffolding had been improved, and the groups worked well together on the problem and achieved an appropriate outcome. If the group dynamics are appropriate, which can be scaffolded, then the group has a better chance of succeeding in PBL.

7.2.3 Technical constraints to the use of e-textbooks to promote PBL

Technical constraints were related to infrastructure, e-textbook design and functionality. Each of these constraints had the potential to prevent students from gaining the full benefit of using the e-textbook as a tool for their learning. As such, it is important to discuss each separately to identify the problems of each one.

7.2.3.1 Insufficient technology infrastructure to support e-textbooks

Problems with the technology infrastructure in the school used to implement the e-textbook continued through all three cycles, which is not an uncommon occurrence (Chen, Gong, & Huang, 2012; Gong, Chen, Cheng, Yang, & Huang, 2013; Hamedi & Ezaleila, 2015; Lee, Messom, & Kok-Lim, 2013). The main issue was that the infrastructure was unable to support multiple users so that not all of the students were able to access the e-textbook at once. This problem was evident in each of the cycles and using different delivery platforms did not alleviate its impact.

It was possible for some students to install the e-textbook onto their laptops, which meant that they did not have to access the e-textbook online. The installation of the e-textbook locally did take some of the pressure off the network. However, not all students were able to install the e-textbook owing to software incompatibility. The school's BYOD (Bring Your Own Device) laptop policy meant that a class of typical students had a wide variety of laptops, some of which were not compatible with the e-textbook. The compatibility problem was particularly the case with Apple MacBook™ and Windows 10™ machines.

BYOD has benefits for schools in that it reduces the cost of providing technology to students (Hill, 2011). However, it can be a double-edged sword since problems with compatibility and network support can emerge (Delgado, Wardlow, McKnight, & O'Malley, 2015). Both issues were apparent in this study, and no simple solution became available. Therefore, it is important to use software that is as cross-platform as possible and which reduces the stress placed on network bandwidth. The technology infrastructure in the school should support the use of e-textbooks. If this is not the case, then students become frustrated and the PBL process suffers as a result.

7.2.3.2 E-textbook design and functionality issues

While the previous technological constraint of inadequate infrastructure was an issue that could not be resolved by the researcher since it was a school-wide problem, the design of the e-textbook was integral to this study and received attention. The e-textbooks used in this study went further than the standard textbook's presentation of information to the student by facilitating PBL as they worked through the problems presented to them. Initially, the e-textbook was only a slight development beyond the traditional textbook with limited interaction and feedback. As such, it did not accomplish the task it was implemented to achieve. The platform used, Adobe InDesign™, was not sufficiently intuitive for the teacher to perform the task of providing an interactive teacher-designed e-textbook that students could use in PBL within a short timeframe.

A new platform, Matchware Mediator 9™, which was more versatile and allowed the production of more interactive e-textbooks, was used. The Matchware Mediator 9™ platform allowed for animation, audio, video and greater interaction and feedback, and the e-textbooks used incorporated these features. However, some design issues related to playing videos and saving work remained. In the focus group interviews for Newton's Laws in the second cycle, a student commented that "the videos were really small as well so if you could enlarge those videos and make them like full screen that would be really good" (FGI NL2 S5). In the Compression and Tension topic, a student commented that "if you have to exit it, make sure it is saved [because if you] go back and try to do more, then exit by the end it's just deleted all your work" (FGI CT2 S3). Improving the resolution in the e-textbook overcame the first issue and enforcing file saving when exiting the e-textbook solved the second. There were also issues relating to requiring students to engage with each page of the e-textbook before continuing observed in the early stages of the Newton's Laws second cycle. Implementing a process that forced students to engage with each page before continuing inadvertently prevented students from moving backwards in the e-textbook as well, which later e-textbooks remedied. An attempt was also made to improve the amount of hard-scaffolding related to chemical reactions, which was largely successful, but some minor technical glitches occurred, including some equations being incorrect in the reaction generator. In developing any form of innovative design, there is the potential for unavoidable issues that only arise after implementation, despite extensive testing, which only future iterations can remedy.

In cycle three, there was one aspect of the e-textbook worthy of special mention. Note-taking was included in the e-textbook to allow students to make notes as they worked through the e-textbook (rather than using a notebook), an important feature of e-textbooks (Chen et al., 2013). The hope was that this would encourage students to make notes relevant to each problem as they worked through each step for each one. However, there were several issues with this idea. Some students were observed preferring conventional note-taking and did not use the inbuilt note-taking facility. However, when the students had to write up the results of their experiment, they then saw the benefit of having relevant notes available to them in the e-textbook. As one student stated in the Chemical Reactions topic "Yeah, and-and it felt more worthwhile learning it than rather than just taking down some notes and going 'Oh, I've learned this for a test.' When you're actually doing it you go; I've actually learned something now, like you know apply it" (FGI CR3 S2). The writing up of practical notes in the e-textbook is a PBL skill that could be incorporated in future e-textbook hard-scaffolds when introducing PBL to students.

Facilitation of the student's interaction with the e-textbook occurred in several different ways. The e-textbook assessed student understanding of various concepts and provided feedback and targeted support when needed. The e-textbook had note-taking facilities, and students also had access to glossaries in later cycles. The students had specific support tools that they could use to, for example, write chemical formulae and balance chemical equations. Improvement to such tools occurred in each successive cycle during this study. In this way, the e-textbook is superior to a standard textbook in its ability to support students in the PBL environment with a greater range of presentation media and targeted scaffolding when required.

7.3 Research Question Two: What Design Features of the E-textbook Supported PBL Intervention Most Influenced Student Learning?

The second research question concerns the design features of the e-textbook facilitated PBL intervention that most influenced student learning in a secondary school science classroom. In answering this question, it is necessary to consider the factors that enabled students to work through the PBL intervention effectively using the e-textbook. These factors were distilled from the analysis of the data and included facilitation features, interaction features and enjoyment.

7.3.1 Facilitation features that influenced student learning when using e-textbooks to promote PBL

Facilitation features covered some different categories that included: practical focus, hands-on, self-paced, multimodal, argumentation and PBL. These factors can be coalesced into two main categories: problem design and e-textbook design. The number of facilitation features increased as the study progressed.

7.3.1.1 Problem design

All of the problems presented in the e-textbook had to relate to the Australian National Curriculum document (ACARA, 2016). These problems covered areas of the Chemical and Physical Sciences. The design of problems in PBL is axiomatic to the successful process of PBL in students (Sockalingam, 2015). However, the nature of the problems used in PBL is a broad church with many areas of contrast. Sockalingam and Schmidt (2011) categorised the features of problems into 11 categories (see Figure 7.4). The features described by Sockalingam and Schmidt (2011) are useful because they focus on the design of the problem and the intended results of working on the problem. As such, it is important to consider these features since they apply to the iterations conducted in this study. The format of the problem is the way it is presented to the students and includes "titles, clues or keywords, analogies, metaphors, stories, and pictures" (Sockalingam & Schmidt, 2012, p. 160) to facilitate PBL in students. The format evolved during this intervention to improve the way in which students interacted with the problem. Figure A2.8, A2.9 and A2.10 show the development of the problem format. Initially the format involved text with keywords defined and a few pictures and two videos. Later iterations included animation, video, audio and animations to present the problem to students.

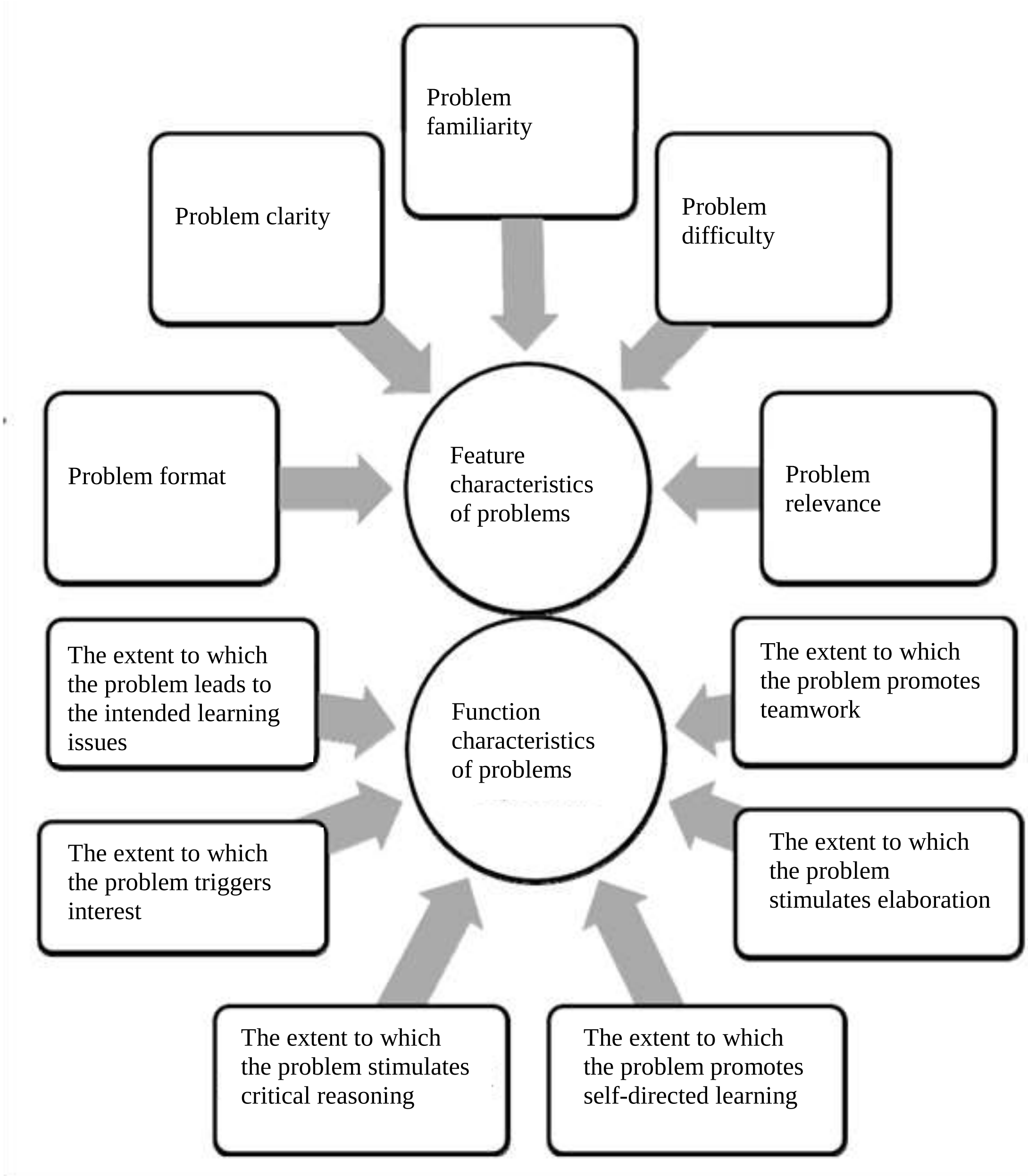


Figure 7.4. Feature and function characteristics of problem design (Sockalingam & Schmidt, 2011, p. 21).

Problem clarity is an important aspect of problem design and relates to the students' understanding of the problem presented to them (Sockalingam, Rotgans, & Schmidt, 2011). To provide clarity to students regarding the problems presented to them, the VARK model was used (Fleming, 1995). This model utilises different ways of communicating information: visual, aural, reading and kinaesthetic. Initially, the main styles utilised were reading and kinaesthetic. Reading related to the use of information in the form of text, and kinaesthetic related to the manipulation of equipment used to work through the problem with some visual information included, but this was an adjunct to the text information. As the study progressed, the e-textbook included all styles of the VARK model.

Problem familiarity is a “prior understanding and knowledge of the problem” (Scott, 2014, table 1). Familiarity with the problem poses a dilemma. If a problem is too familiar, it may not improve academic outcomes (Soppe, Schmidt, & Bruysten, 2005), but there is a negative relationship between problem familiarity and student learning (Scott, 2014) where “students are unable to relate to them” (para 14). However, Sockalingam and Schmidt (2012, p. 158) noted that an unfamiliar problem “stimulates significantly more questioning, thinking and reasoning than the familiar problem.” The problems provided to students were designed to have some aspects familiar to them. The Newton’s Laws iteration assumed that students would have some familiarity with rockets, and additional information was supplied to them to bridge the gap between what was familiar to them and what they needed to learn. Since the problem involved designing a model rocket, a video of a model rocket in flight was used (see Figure A2.12). Later, the presentation included a better video that was related more to the design of model rockets rather than the problems encountered with life-size rockets and more explanation of what was occurring in the video (see Figure A2.13). The improvements were made to relate the information more closely to the problem and provide the students with visual clues to which they could relate to their experiences.

Problem difficulty relates to a variety of factors, and some of these factors are beyond the control of problem developers to manipulate (Jonassen & Hung, 2008). Moreover, many of these factors interrelate to produce a complex ecosystem in which it is difficult to determine cause and effect. However, some speculation about the interaction of some aspects of problem difficulty is possible based on published findings, which is relevant to the consideration of problem design in this study. Figure 7.5 shows some interrelations as described, by (Sockalingam & Schmidt, 2012), and some possible interrelationships between the various characteristics problems used in PBL. It is reasonable to expect that the clarity and familiarity of the problem will affect a student's interest in the problem since students will be less likely to engage with a problem with which they have no commonality, or which is obscure to them. However, issues with clarity and familiarity only scratch the surface of the complexity of the interactions when considering problem difficulty in PBL. If problem difficulty is expanded to take into account the aspects described by Jonassen and Hung (2008), then the complexity of the ecosystem increases, but is also more illuminating as to how problem design affects PBL (Figure 7.6).

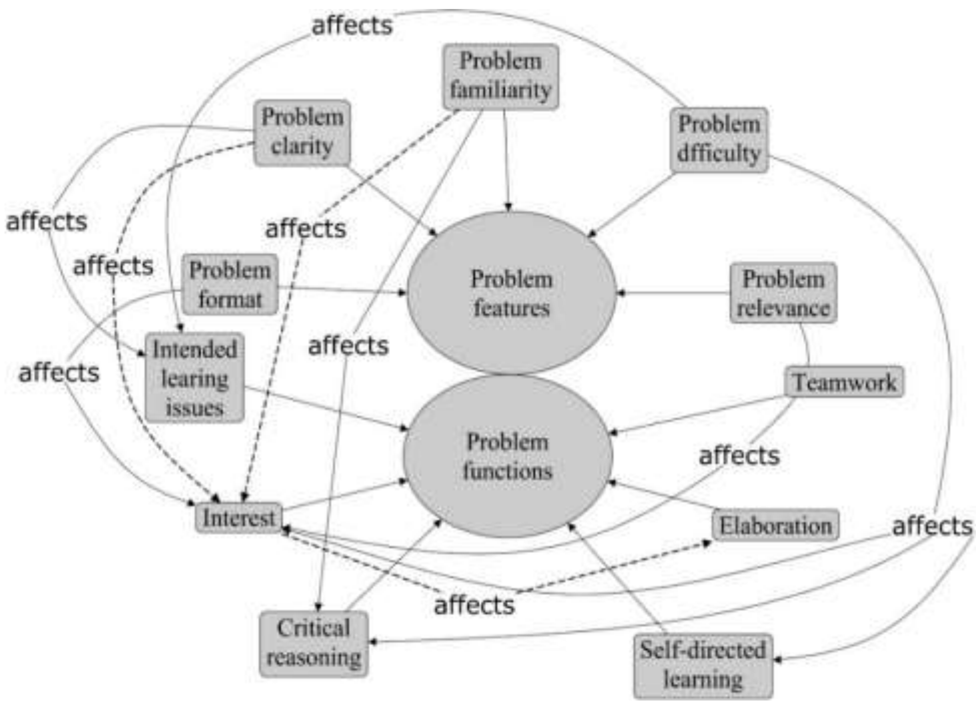


Figure 7.5. Interrelationships between various problem design features (Sockalingam & Schmidt, 2012). Described (__) and speculated (--).

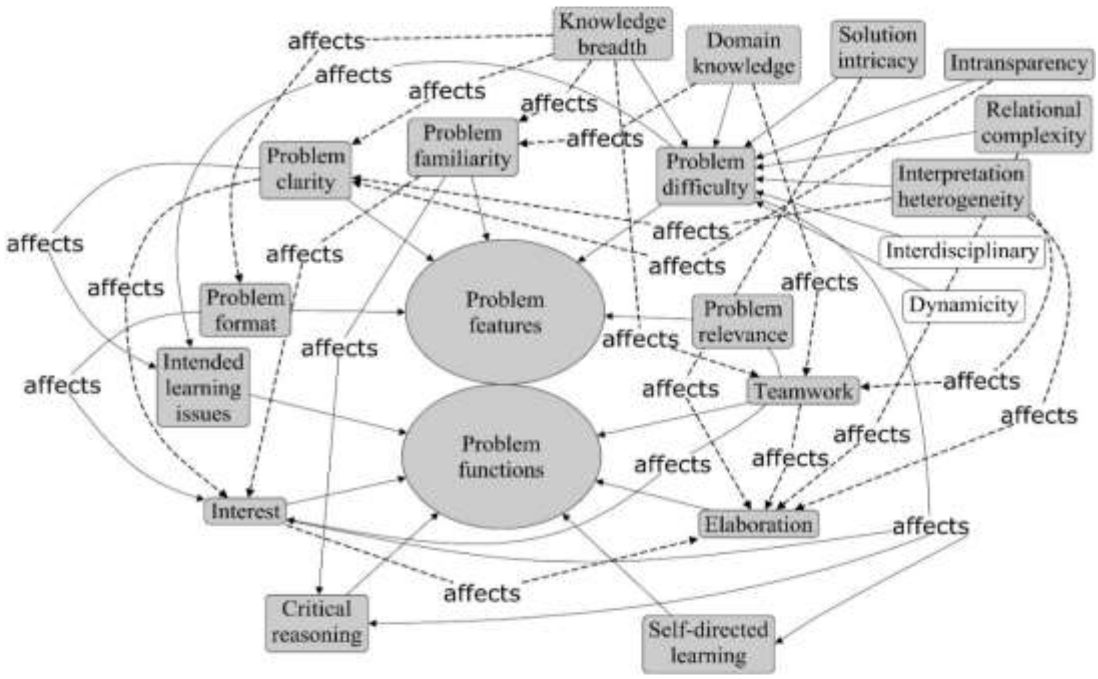


Figure 7.6. Interrelationship between various problem design features (Sockalingam & Schmidt, 2012) and aspects of problem difficulty (Jonassen & Hung, 2008). Described (__) and speculated (--).

The breadth of knowledge required of the students in all the problems was limited to a few concepts in each one. In Newton's Laws, for example, the concepts the students required knowledge about were inertia, forces (balanced and unbalanced), mass, acceleration and velocity with only some knowledge required in each problem. In the Chemical Reactions topic, the students required an understanding of chemical reactions, formula and equation writing and kinetic theory. In this case, each problem required most of the concepts. In the Compression and Tension topic, the concepts were limited to compression and tension. The breadth of knowledge required did not vary during this study. It is not unreasonable to link the required breadth of knowledge to the clarity as well as familiarity of the problem and to consider that the limited knowledge required compelled the designer to make the problems clear and familiar.

Domain knowledge related to how difficult the concepts covered in the problem were for students to understand (Jonassen & Hung, 2008). While the breadth of knowledge students required was limited, some of the concepts covered were challenging. Thus, concepts had to be presented to the students in a way that provided them with the means by which to comprehend the concepts effectively. In the Newton's Laws topic, for example, the number of concepts was low, but they were difficult to apply. Initially, Newton's Laws were considered all at once regarding presentation, investigation and review (see Figure A2.8). The domain knowledge of the students was not sufficient to work with the limited information presented to them. A quote from a student during the first Newton's Laws topic illustrates this point:

> This is hard because I have no idea how to build rockets. Just to know like what we're actually sort of doing, because I think it was more like we had to

go through the book sort of thing and then we were put on this program and I had no idea how to do that. (FGI NL1 S3)

Later, the students had more information provided to them that they would then have to apply to each of the problems (see Figure A2.14). For example, the mathematical applications that students would need to be able to apply to the problems (see Figure A2.15 and A2.16). As a result, students showed an improved understanding of how to apply these concepts to the problems encountered in the Newton's Laws topic and this improvement was attributable to greater problem clarity, familiarity and improved teamwork seen in cycle three. Two quotes from the Newton's Laws topic in cycle three illustrated this point. The first quote showed that students had shifted away from just memorising facts (definitions) and focused on using the equations from Newton's Laws that were applicable to the problem. The second quote confirms this application of ideas to real life, in this case, the rocket design.

> I learnt more about the equations more I didn't really focus on the information and usually we like have definitions we have to know for the test like we didn't really focus on that we focused more on the equations and finding those results and the practicals. (FGI NL3 S2)
>
> I think I learnt more especially like with the pracs and everything like helping to like fill in everything and actually like put it into real life. (FGI NL3 S4)

Both students also commented on how they worked in their respective groups, confirming the improved teamwork.

> Our team was really good because we're like friends and we worked really well together. (FGI NL3 S2)
>
> Yeah, our team was like had different like everyone had like different like opinions and ability and personality so it worked really well and I suppose the group working it is good coz [*sic*] it doesn't change. (FGI NL3 S4)

In the Compression and Tension topic, there were only two main concepts. However, they were difficult to apply to various situations. To assist students with applying these concepts to the problem, they were presented with animations to show them how the concepts of compression and tension applied to the problem they were considering, which was to build a bridge. Their application of these concepts was augmented further by showing students how to determine compression and tension forces before finally presenting them with the problem (see Figure A2.17). However, this did not help students in their application of these concepts to the problems encountered. When asked in a focus group interview for the Compression and Tension topic about what they learned about the topic, all of the students commented that they did not learn much about the content. The students had difficulty visualising how to solve the problem of building a bridge. One student commented that:

> 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)

Another student noted the difficulty they experienced in design the bridge before actually constructing it:

> 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 trial stuff. (FGI CT2 S1)

Therefore, it was difficult for the student to work in the abstract with these concepts, preferring to construct the bridge through trial and error.

The intricacy of the solution to the problem, which has been termed the solution path length, is dependent upon the amount and difficulty of the tasks required to be completed to solve the problem (Jonassen & Hung, 2008). The more intricate the solution (the more complex it is regarding its difficulty and number of tasks), the more the students will need to elaborate on the concepts covered. However, there is a point at which the intricacy of the task can be so great as to work against elaboration. Most of the problems encountered by the students in this study had a similar number of tasks, and the number increased only in the final problem of each iteration. The complexity of the tasks is a more nebulous concept. Does writing a balanced chemical equation for a decomposition reaction equate with determining the acceleration of different masses using a formula? While students exhibited varying levels of understanding in most topics, the most difficult was the Compression and Tension topic where there were a similar number of tasks to be completed but their overall complexity, for example in bridge building, was more challenging.

Relational complexity refers to the number of factors that interrelate (Halford, Wilson, & Phillips, 1998). The level of relational complexity was variable across each topic. For example, in the Newton's Laws topic there was considerable relational complexity. Students needed to relate displacement and time to determine velocity. Velocity was then used to calculate acceleration, which, in turn, was used to calculate force at various masses (see Figure 7.7). There was an increase in the support the students received regarding how each of the factors related to the others, and this aided their application of the concepts to each problem, which helped them to elaborate on the topic regarding how factors interacted. When students were asked to apply Newton's Second Law to a practical problem, 46% could do so correctly prior to the iteration compared with 58% at the conclusion of the iteration. In the third cycle, the results for correctly applying Newton's Second Law were 70% before the cycle compared with 80% at the conclusion. When asked to describe an example of Newton’s Second Law, 17% of students before the first cycle and 14% at the conclusion of that cycle could do so correctly. However, it is important to note that this was because of their not including all of the necessary information in their answers. The number of responses that contained misconceptions decreased from 52% to 23%. The inability of students to provide all the information necessary may have related to the relational complexity of the problem. The students were not able to consider all of the factors in Newton’s Second Law. In the third cycle, 12.5% of students could correctly describe an example of Newton’s Second Law prior to commencing the cycle compared with 44% at the conclusion. While not dramatically improving, there is an upward trend in student’s ability to describe and apply Newton’s Second Law with improved support in cycle three in terms of the presentation of the problem to the students.

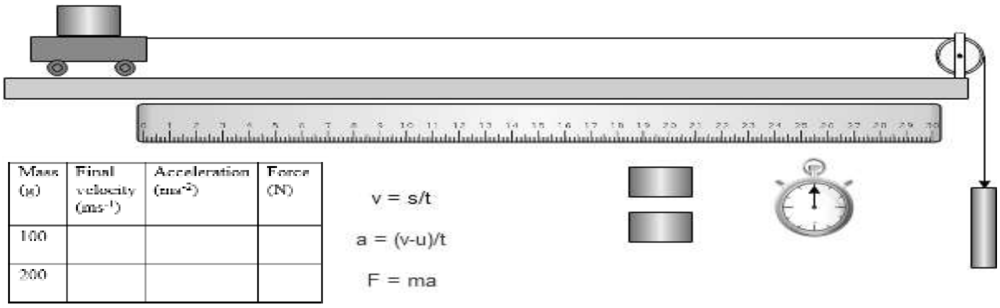


Figure 7.7. Representation of one group’s solution to the problem of establishing Newton’s Second Law showing the concepts that need to be related.

In the Chemical Reactions topic, the students needed to understand the concept of chemical reactions at the microscopic (molecular) level rather than the macroscopic level seen in the Newton’s Laws topic. Initially, the students received very little information at the molecular level about what was happening (see Figure A2.18). The amount of information was later increased to include a large amount of detail, at the molecular level, about how molecules interacted (related to each other) in decomposition reactions before and after the problem was completed (Figure 7.8).

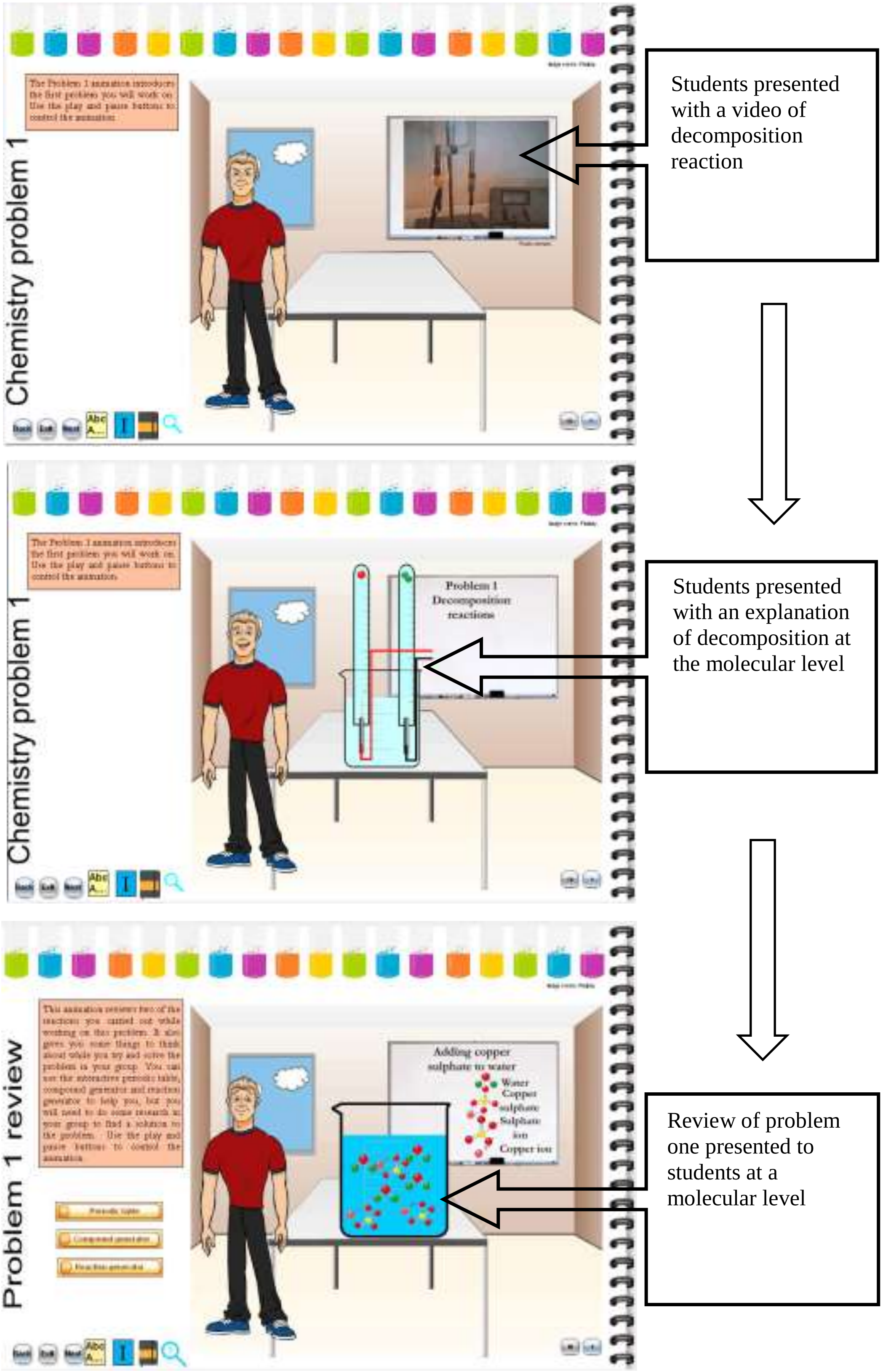


Figure 7.8. Screen shot from the Chemical Reactions topic showing the information provided to students in cycle three, iteration two.

The increased detail enabled the students to understand the relationship between molecules in each of the problems studied, which, in turn, made elaboration of the topic easier. When students were asked to explain the melting of an ice cube in cycle one of the Chemical Reactions topic, 6% of students prior to the iteration could do so correctly, and 0% could do so at the conclusion of the cycle. In the third cycle of the Chemical Reactions topic, the results were 30% and 50% respectively. In the third cycle of the Chemical Reactions topic, the explanation, at the molecular level, of the reactions was more detailed and students were able to describe changes at the molecular level more accurately. When asked to explain how a particular factor (e.g., temperature) affects reaction rate in cycle one of the Chemical Reactions topic, 0% of students prior to the cycle could do so correctly and 20% could do so at the conclusion of the cycle. In the third cycle of the Chemical Reactions topic, the results were 25% and 44% respectively. Again, students were able to explain the effect of the factor at the molecular level.

Intransparency refers to the amount of unknowns in a problem. Jonassen and Hung (2008) use the example of weather forecasting to illustrate a problem with high intransparency. There are many unknowns with unidentifiable effects. The level of intransparency was low in each of the problems the students encountered. While the relationships between various factors were unknown to the students, the factors themselves were known to them or made known. As a result, intransparency should not have interfered with the clarity of the problem.

Problem heterogeneity refers to the number of ways that the student can understand the problem (Jonassen & Hung, 2008). The level of heterogeneity was low in each problem with only a very limited number of ways for understanding the problem. The low heterogeneity would have aided problem clarity but hindered teamwork and elaboration since there was a reduced need for discussion of various solutions that would require less elaboration. The level of interdisciplinarity and dynamicity were not relevant to this study because there was no opportunity for students to use multiple disciplines to solve the problems and factors were not dynamic regarding the actions of the student or each other.

Problem design changed throughout this study in response to observations and student responses to the problems. For example, in the first cycle of Newton's Laws and Chemical Reactions, students had difficulty applying knowledge from the initial problems to the final one. In the Newton's Laws topic, there was not sufficient development of the concepts required to engage with the final problem successfully. In the Chemical Reactions topic, the initial problems lacked appropriate support for students to engage with them. Each problem needed to be able to be analysed by students, so they could plan a solution in their groups by conducting appropriate research and applying prior knowledge to produce testable hypotheses. The problems needed to be sufficiently structured so that students could work towards a solution, but not so structured to provide an obvious answer. In this study, it was preferable to use several small problems that interlinked particular concepts and skills rather than one large problem that did not allow for the development of skills or comprehension of concepts covered owing to too many concepts applied at one time. The result of the problem while important was not the main focus; it was the journey as well as the destination that was important. There was a change in the students' attitude in the Chemical Reactions topic between cycle one and three that illustrated their change in attitude to the practical (problem) work with the use of the problems that provide knowledge rather than notes:

> But I did find that when I do note-taking, like and it shows in my test results from both methods, that I do a lot better that I find that it is easier when it comes to a test I actually know what it's going to be on like I can study it. (FGI CR1 S1)

> I feel like with chemistry it's much better to have the more practical side because it's all about the reactions and what makes them, so it's better to actually see it than just write it down. (FGI CR3 S5)

> The practicals make it interesting and sort of confirm your understanding. (FGI CR3 S4)

7.3.1.2 E-textbook design

While the problems presented to the students in a PBL experience assume a place of prime importance, the mode of delivery to the students was an equally important aspect of this study. The e-textbook was designed to be a platform for which students were not only presented with a series of problems to work on, but also to help facilitate their development of problem-solving skills. Therefore, it is important to consider how the e-textbook's design evolution assisted students in their PBL journey.

Use was made of the VARK model (Fleming, 1995) in the design of the e-textbooks to varying degrees in each iteration to present problems and problem-solving skills to the students. In the first iteration, the main modes utilised were reading and kinesthetic with the remainder of the modes incorporated in cycles two and three. The simplistic nature of the e-textbook's presentation of the problem and problem-solving skills to the students in cycle one meant that it was of limited use to them. As such, the students did not find the e-textbook particularly helpful since, while there was a hands-on approach to the problem, there was not a true multimodal presentation of ideas. The multimodal aspect was developed in the second and third cycles and was an enabling factor for students using PBL and developing problem-solving skills, especially in cycle three. Students were continually observed using the animations, videos and cognitive tools during lessons while working on the problems.

Students could work through the e-textbook at their own pace. However, it became necessary in cycles two and three to constrain student progress. Students were apt to proceed too quickly through each page without stopping to engage in the concepts presented fully. Student progress was limited in two ways to ensure that they engaged fully with the concepts presented. In some cases, students could not move on to the next page for a certain time interval, and in other cases, they had to complete a particular evaluation of a particular skill before continuing. The control of student progress through the e-textbook helped to ensure that they engaged with and understood the concepts presented to them.

Traditional textbooks do not control a reader's progress through the information provided to the reader. The reader may refer to previous pages or skip ahead to points in the book. In designing the e-textbook, the former of these two habits is to be encouraged as it allows students to review past information to consolidate or confirm understanding of key concepts. The latter habit, however, should be avoided. In the first e-textbooks, students could move freely through it, which meant that they could skip through sections of the book that were important. Therefore, they missed key concepts that they needed to work on the problems presented to them later. It was, therefore, important to control the students' movement through the e-textbook by allowing them to move backwards for review but preventing them from skipping forward and missing important information.

7.3.2 Interaction features that influenced student learning when using e-textbooks to promote PBL

Interaction features covered two different categories: feedback and group-work. Each of these features influenced how students learned through the process of PBL and were facilitated by the e-textbook. Although these two features are interlinked, each feature will be considered separately.

7.3.2.1 Feedback

Students needed to be able to interact with the e-textbook in a purposeful way that supported their learning in a PBL environment. This interaction was always intended to be two-way, with the students receiving feedback from the e-textbook as they worked through it. Initially, this feedback was limited to correcting student responses to a multiple-choice questionnaire with feedback on why their answer was right or wrong (see Figure A2.19). Furthermore, this feedback did not cover PBL.

Subsequently, the level of feedback was improved to include targeted feedback to students in specific areas where they needed further support. Students received feedback about each of the problem's concepts that they completed before starting the next problem as well as PBL (see Figure A2.20). Students received targeted support about PBL as well, which linked to their responses to the questionnaire they completed (see Figure A2.21) This support assisted students by providing them with needs-based support for working in a group in a PBL environment. Students commented on this feedback in the focus group interviews:

> Better because we have like a normal you've done all these questions, but you don't even know if it's right or not, and there's like no answers at the end of the book or anything, so that was good because it like ticked off whether you got it right or not. (FGI NL1 S3)

> And in the e-text book 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 S3)

The provision of feedback in all areas of PBL is important. Incorporation of specific feedback that is responsive to student needs is an area that requires careful attention when designing e-textbooks for PBL. Such differential feedback means that individual differences within groups are, to some extent, catered for in the e-textbook.

7.3.2.2 Group-work

PBL classes operate in groups with learning occurring at the small group level rather than the whole class. However, productive group interaction does not just happen when students are brought together (MacQuarrie, Howe, & Boyle, 2012), but rather, it occurs as the result of a deliberate set of acts on the part of the facilitator (Frey et al., 2009). To move from a group of students sitting together to a group of students interacting with each other to learn together, it is necessary to upskill them in the specific requirements of working as a group in a PBL classroom.

An initial assumption was that students already knew, from previous exposure to group-work, that they would work effectively in groups. This assumption proved to be erroneous with group dysfunction contributing to a lack of learning in each of the groups. Furthermore, students were permitted to choose their groups, which impeded interaction within the group rather than supporting it. Thus, for example, there might be four students in a group, but not interconnecting with each other for PBL:

> 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)

For a group to successfully engage in PBL, it is necessary for individuals to be able to listen and respond to each other, allocate tasks on an equitable basis, research the problem and provide reasoned arguments for their solution. In this scenario, rather than just butting together, the group fits together like a jigsaw (see Figure 7.9). To achieve this, support for group-work was included in the e-textbook. However, students could move ahead in the e-textbook without fully engaging in the concepts presented. Subsequently, students were made to engage with the material presented, rather than skipping over it and this had the effect of at least ensuring that they were aware of material concerning effective group-work. While this design feature did not completely solve the problem of developing effective group dynamics, it did raise the baseline of student interaction as the quotes from the focus group interview indicate:

> Our team was like had different like everyone had like different like opinions and ability and personality so it worked really well and I suppose the group working it is good coz [*sic*] it doesn't change you but [you] build relationships. (FGI NL3 S4)
>
> It kinda [*sic*] pushes you but coz [*sic*] you're expected to do something it's like if you were by yourself it's like if you don't do it it's your fault but if you're in a group you kind of have to. (FGI NL3 S2)

The result was that the facilitator had more time to devote to providing each group with targeted support as and when needed instead of concentrating on group cohesion.

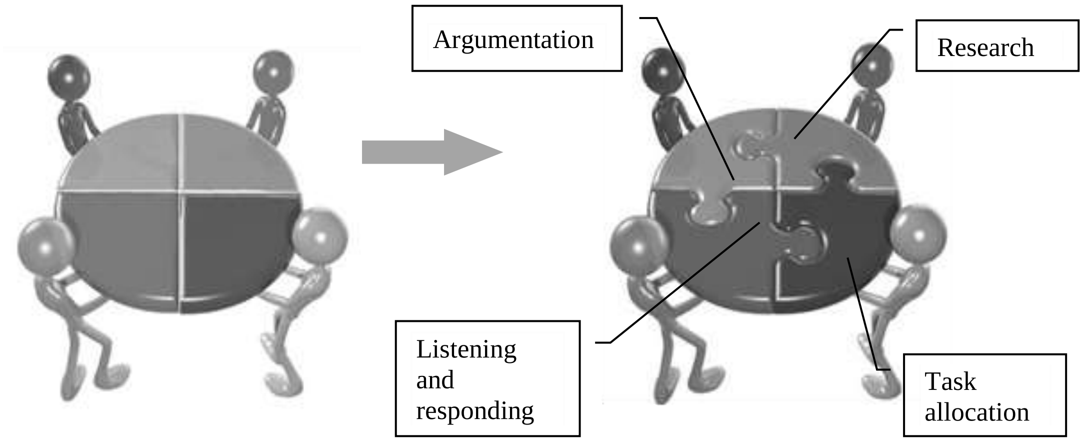


Figure 7.9. The shift from students in a group to students working as a group by listening and responding, allocating tasks, researching and engaging in argumentation. Image source: thegoldguys.blogspot.com/

The method of assigning students to groups also changed during the study. Initially, grouping occurred on a friendship basis, which was not productive. Randomly assigning groups did not improve the situation. However, when group assignment was random in a class of mixed ability, the most productive groups resulted since those who could grasp concepts quickly could explain these to group members who were experiencing difficulty with their understanding of these concepts. Furthermore, by explaining their ideas to other students and having those students then question their understanding, there was argumentation, which assisted the group's understanding of the problem solution as the following quotes from the focus group interview indicate:

> I found that with the last program that we did, I was in a group that was like majority my friends, I found I did the work a lot of the work myself like they would kind of talk and I would be doing a lot of the work ... But this one was we all played a part, and it was a lot better. (FGI CR1 S3)

> It was a lot like you could divvy up the work a lot easier so you could sort of he could sort of focus on something and I could focus on something then we could just collaborate it, and it would be a lot more efficient way of learning. (FGI CR1 S2)

> If you didn't know stuff you could just ask other people in the group. (FGI CR1 S5)

7.3.3 Enjoyment features that influenced student learning when using e-textbooks to promote PBL

Enjoyment influences how students learned through the process of PBL, and PBL positively influences their enjoyment of science (Ferreira & Trudel, 2012). In the Newton's Laws topic, the student's enjoyment related to the final part of the problem, which was the construction of a model rocket to illustrate Newton's three laws of motion. The intent had been to develop their understanding of Newton's Laws and then have the students apply them to the design of the rocket. However, this did not occur, and the rocket design became all-consuming and was a result of the e-textbook design overemphasising the rocket design and not developing Newton's three laws sufficiently. Giving greater emphasis to Newton's Laws and the design of the model rocket less emphasis resolved this issue. Each of Newton's Laws became a problem and the rocket design a separate problem. There was an appreciation of the importance of each problem as students no longer identified the rocket as the only part of the PBL experience they enjoyed. Quotes from the Newton's Laws focus group interviews in cycle one and three illustrate this change. In cycle one a student commented 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, and it was sort of wasn't really done in a proper way where we all really worked together. (FGI NL1 S4)

The comment indicates that the building of the rocket was the main attraction for the student. In cycle three, two students commented that:

> Like through the experiments [problems] I actually understood like usually, I read something, and I just have to like remember what it says, but I actually understood the process better by doing this. (FGI NL3 S2)
>
> I think I learnt more especially like with the practicals and everything like helping to like fill in everything and actually like put it into real life. (FGI NL3 S4)

The students appreciated all of the problems (experiments/practicals), and they considered the rocket design as part of the whole PBL experience. The change in attitude was due, in part, to the length of time available for each problem since the amount of time for the design and construction of the rocket was reduced in cycle three to limit its overall significance again. Furthermore, students could no longer skip over the first three problems and so gained a greater understanding of their importance to solve the last problem.

In each of the other topics, enjoyment either increased or remained the same. In the Compression and Tension topic, there was more of a practical focus, which the students enjoyed despite the concepts themselves being more esoteric in nature (Table A1.54). In the Chemical Reactions topic, the increase in enjoyment related to the practical nature of the problems in cycle one (Table A1.38). Making the Chemical Reactions topic problems more challenging, albeit with more support, regarding what the students had to understand resulted in a reported diluted enthusiasm of the students for the practical work, which accounts for their enjoyment not changing in cycle three. Turner, Ireson, and Twidle (2010) reported that the complex nature of chemistry experiments was one reason students did not enjoy the subject. As one student commented in the focus group interview for Chemical Reactions in cycle three:

> Personally I'm not a big chemistry fan so the whole the topic in general wasn't my favourite thing. (FGI CR3 S1)

However, this was not a universal impression. Two other students commented that:

> It was also easier to grasp the topics when you'd just done an experiment or a practical or a problem on and then you can also understand the practical once you've also worked out what the problem actually is an how to explain it. (FGI CR3 S4)

> It felt more worthwhile learning it than rather than just taking down some notes and going Oh, I've learned this for a test. When you're actually doing it you go, I've actually learned something now, like you know apply it. (FGI CR3 S2)

It is difficult to reconcile the two opposite ideas, but it may be that the students expectations of the Chemical Reactions topic were not affected by the PBL experience and students that like chemistry and those that disliked chemistry did not change their opinion.

7.4 Research Question Three: What was the Overall Impact of the E-textbook Supported PBL Intervention?

The third research question concerns the overall impact of the e-textbook intervention on student learning through using a PBL program in a secondary school science classroom. In answering this question, it was necessary to consider the areas in which the e-textbook had the greatest impact. This study focused on three main areas that were of interest in PBL: content knowledge; planning, monitoring and evaluation; and student engagement. Content knowledge involved learning specific concepts and applying what they have learned to new situations. Planning, monitoring and evaluation concerned how well students could transfer skills from one problem to another in terms of organising their approach to the problem, examining their progress and determining how well they performed while working on the problem. Student engagement examined how students participated in the PBL exercise and worked as a group.

7.4.1 The impact of the e-textbook intervention on student knowledge

In the context of this study, student knowledge is defined as content knowledge and application of that content knowledge. As students worked on problems, they moved from the initial state to a goal state along a solution pathway. The initial state is defined as "what is known" (Jonassen, 2000, p. 67), how the problem-solver understands it (Jonassen & Hung, 2008) and is a starting point (Pretz, Naples, & Sternberg, 2003). It is from this point that a student, as part of a group, will move down a solution pathway. The solution path is a "series of discrete transitions in a maze" (Ericsson, 2003, p. 39), "the problem-solution process" (Jonassen & Hung, 2008, p. 10) and "sequences of solution steps students" use to reach the goal state (Rivers & Koedinger, 2014, Related Work, para 1). The goal state is "what is trying to be achieved" (Jonassen & Hung, 2008, p. 13), an end point (Greiff, Holt, & Funke, 2013; Pretz et al., 2003) and a "well defined solution" (Jonassen, 2000, p. 67). These steps are together considered the problem space (Schwarz & Skurnik, 2003). In this study, students' content knowledge did not significantly improve in cycles one or two (Figure A1.1, A1.2 and A1.16). In cycle three, the students content knowledge did significantly improve in both iterations: Newton's Laws and Chemical Reactions topics (Figure A1.3 and A1.17).

It is in this problem space that students worked as a group to develop a solution to the problems presented to them in the e-textbook. Bogard et al. (2013) created a model that described 13 cognitive processes used by advanced learners working on complex problems. Their model has been adapted to define the problem space as it would exist for less advanced learners (secondary school students) working on less difficult problems (Figure 7.10). This model is used to describe the development of the students' knowledge as they worked through the e-textbook problems. When the students first encountered each of the problems, their initial response was to analyse the problem. In the first cycle, this was not well supported by the e-textbook. Students were asked to explore the topic regarding terms, concepts and issues with minimal prompting (Figure A2.22). The lack of scaffolding from the e-textbook made analysing the problem too difficult as students did not have a means by which to access any relevant prior knowledge that may have been useful in the analysis of the problem. The students were then provided with some background information and asked to write down what they knew about the problem (Figure A2.22). The student's responses commonly included statements such as "I do not know anything about this" or "what do I write?" Students were seemingly unable or unwilling to write down any information they considered relevant to the problem. Predictably, when students were asked to write down what they did not know they responded with "I do not know what I do not know" or "I do not know anything."

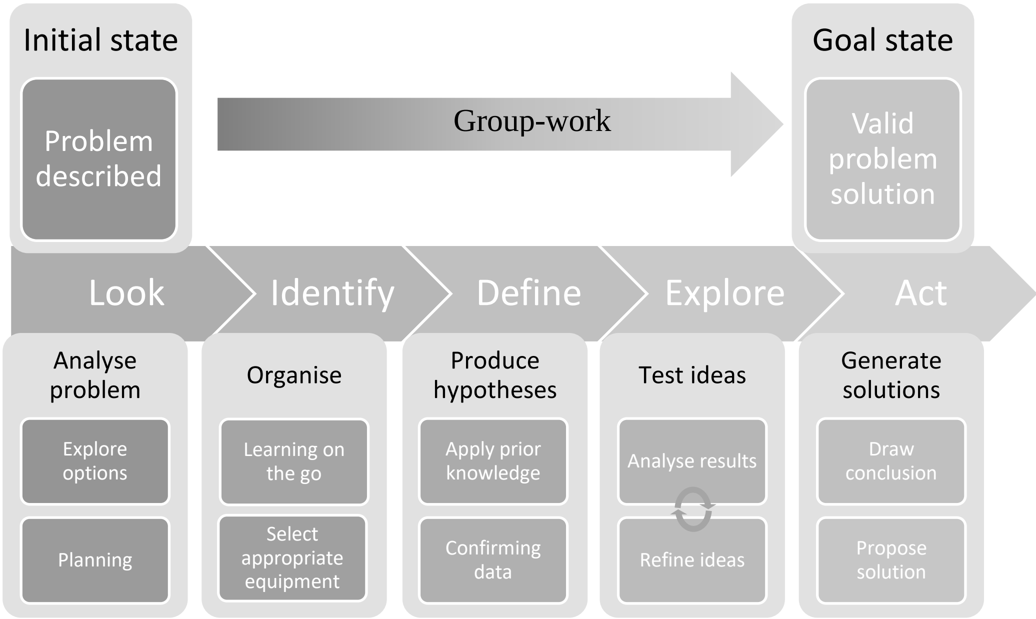


Figure 7.10. A description of the problem space from the initial state to the goal state based on Bogard et al. (2013).

Bogard et al. (2013) described the initial steps in problem-solving as orientation, which involves using cognitive tools and planning to develop ways of finding information. In the adaptation of this model, the first step is an analysis of the problem (Figure 7.10). In the first cycle, students were not able to orient themselves or plan any meaningful strategy to find information since the cognitive tools provided to them were insufficient.

These cognitive tools are “technology-based tools serv[ing] as scaffolds in learning environments” (Bogard et al., 2013, Introduction, para 4) and which are used by the students. Therefore, a large amount of soft-scaffolding was needed to compensate for the lack of these cognitive tools. Providing better cognitive tools to the students (Figure A2.9), alleviated the dependence on soft-scaffolding. There was an increase in the number of cognitive tools and their placement in the e-textbook. Students had more information about the concepts, and there was a review of these concepts at the end of each problem in the e-textbook. Students were then able to plan more effectively to obtain information. For example, in the first problem of Newton's Laws (cycle two, iteration one) the students could effectively plan a means of data collection (Figure 7.11).

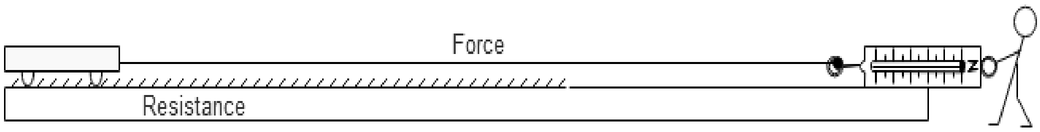
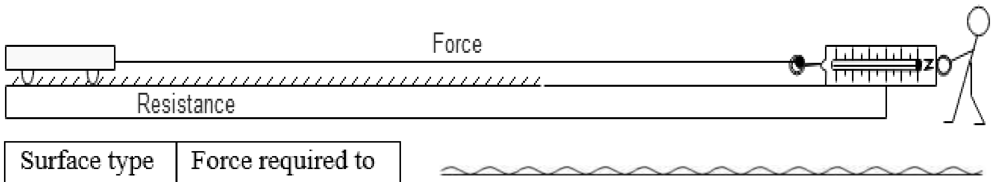


Figure 7.11. Representation of one group's solution to the problem of establishing Newton's First Law showing the factors that need to be identified.

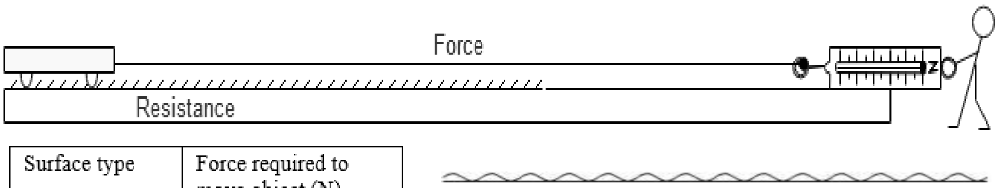
However, prior knowledge about conducting controlled experiments was not activated, which made comparing data meaningless in this situation (Figure 7.12). When the students attempted to test their ideas using different resistances, their analysis lacked a baseline for comparison. In refining their ideas, they then saw the need for a control that produced their baseline data, which allowed for hypothesis formation. However, they were unable to produce a satisfactory solution to the problem. This led to an improvement of the design of the cognitive tools ability to activate prior knowledge about controlled experiments (Figure A2.10). The students were then not only able to conduct a controlled experiment (Figure 7.13) but were able to propose a solution to the problem.

A similar problem arose in the Chemical Reactions iteration. Initially, there was minimal provisional of cognitive tools to the students (Figure A2.18). The result was that students were not able to analyse the problem effectively to plan a solution and so again a large amount of soft-scaffolding was necessary. The cognitive tools available to the students were significantly increased in later cycles (Figure 7.2 and 7.8) resulting in the students being able to analyse the problem, organise the equipment, apply prior knowledge and test their ideas. This led to a successful solution to the problem, which indicated that students had a deeper understanding of



Surface type	Force required to move object (N)
Carpet	
Sandpaper	

Figure 7.12. Representation of one group's solution to the problem of establishing Newton's First Law showing the factors that need to be measured.



Surface type	Force required to move object (N)
Control	
Carpet	
Sandpaper	

Figure 7.13. Representation of one group's solution to the problem of establishing Newton's First Law showing the factors that need to be measured and compared.

the concepts as also evidenced by classroom observation (Table A1.1 and A1.41).

7.4.2 The impact of the e-textbook intervention on problem-solving transfer

Problem-solving transfer is defined as occurring "when a person uses previous problem-solving experience to devise a solution for a new problem" (Mayer & Wittrock, 1996, p. 47). Mayer and Wittrock (1996, p. 49) described four different types of problem-solving transfer: general transfer of general skills, specific transfer of specific behaviours, specific transfer of general skills and metacognitive control of specific and general strategies. It is the fourth type of problem-solving transfer that is most relevant to this study because it involves selecting previously acquired skills, applying those skills to the new problem and considering their usefulness or otherwise in solving that problem as they progress (Mayer & Wittrock, 1996).

To determine how well students transferred their problem-solving skills to new problems, it was necessary to consider their planning, monitoring and evaluation regarding the model used to describe the impact of the e-textbook (Figure 7.10). These are domain-general skills that apply to any problem. Examination of how students planned their analysis of the problem (Table A1.7 and A1.31) showed a change in their approach to problem-solving in some areas as they moved from the first problem to the second problem. There was more emphasis placed on background reading and less emphasis on prioritising learning needs by the students between the first and second problems. Students needed more information to make sense of the problem presented to them. Allocation of resources remained important, and allocation of group members to tasks became less important. In all cases, there was a limited amount of resources available to students as the study progressed, and so these had to be allocated carefully and planned in advance. Allocating group members to tasks became less important as students largely used who was best suited or interested, an approach that had worked for them in the first problem.

In evaluating each step in the solution to the problem, students had a variety of different strategies, but in the third cycle, they used fewer strategies in both topics (Table A1.10 and A1.33). The improvements to the e-textbooks scaffolding to support the students working on the problems resulted in their using fewer strategies more effectively rather than a shotgun approach (Table A1.20 and Table A1.41).

Students had a variety of evaluation strategies (Table A1.12 and A1.34), including progress and the end result. It is difficult to provide a rationale for this change and may simply reflect individual student preferences.

In the Newton's Laws topic, students had to transfer ideas learned about Newton's three laws to the design of a rocket. The problem provided an example of far transfer since the problem was not familiar to the students and required the application of concepts to a nonroutine problem with more conscious effort (Jonassen, 2000). Initially, students found this very difficult with the designs of their rockets showing little improvement over the course of the iteration (Figure A2.23 top). The students had access to a cognitive tool in the form of the OpenRocket software program that allowed them to design and test their rocket designs. The use of this software was hard-scaffolded into the e-textbook, but students still found the program difficult to use. The students did not effectively apply what they had learned about Newton's Laws to the design of their rockets. An improvement in the presentation to the students of each of Newton's Laws and the soft-scaffolding of the use of the OpenRocket program did not lead to an improvement in the students' rocket design (Figure A2.23 middle). The e-textbook was modified to present students with specific concepts about the first three problems they worked on so that they could consider them in the design of their rocket. The e-textbook design change resulted in an improvement in the design of their rockets with students considering specific modifications (e.g., fin shape and nose cone shape) in their final designs (Figure A2.23 bottom).

In the Chemical Reactions topic, there was a similar far transfer required of the students. In the first problems, the students encountered regarding the different types of chemical reactions, the students needed to observe evidence of specific types of chemical change occurring. In the final problem, which involved factors affecting the rate of chemical change, there was a change from observation to measurement. Students did not understand this change and relied on observation in this problem as well. The students could conduct a controlled experiment with accurate measurement of the reactants and consider how to change the independent variable (e.g., temperature), but then relied on imprecise observation to determine the effect of temperature on reaction rates (Figure 7.14). By increasing hard-scaffolding in the e-textbook students received more support in the final problem regarding how to approach the problem and in writing formulae and equations. The result was that the students were able to arrive at a more sophisticated solution that involved measuring, under controlled conditions, the rates of a reaction in various conditions (Figure 7.15).

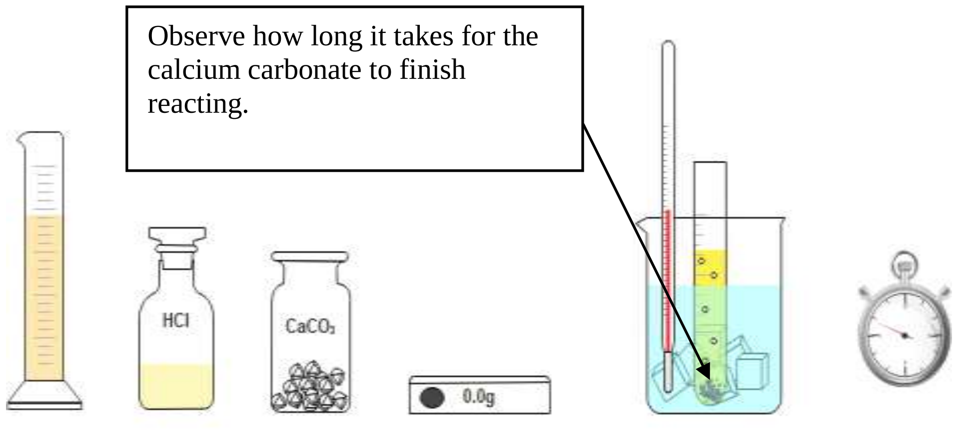


Figure 7.14. Representation of one group's solution to the problem of factors (temperature) that affect the rate of a reaction showing the use of observation in cycle one.

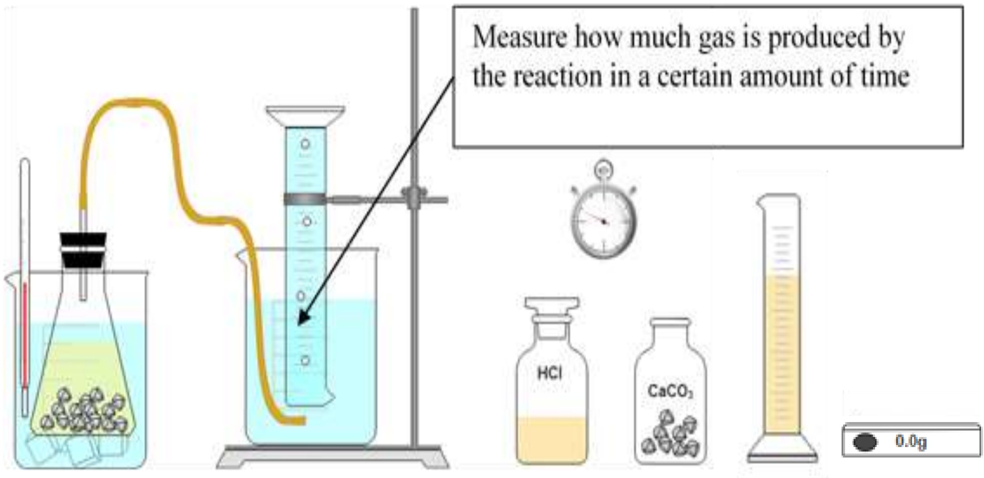


Figure 7.15. Representation of one group's solution to the problem of factors (temperature) that affect the rate of a reaction showing the use of measurement in cycle three.

Groups needed to plan what they will do in a PBL environment so that rather than reacting to the problem to find a solution they are proactive in finding a solution. The students, as a group, work collaboratively in a coordinated way to achieve the goal state. At the same time, students needed to have a strategy for monitoring their progress along the solution pathway. Strategies will vary according to the problem and the students comprising the group.

Students recognised the importance of planning and factors, including allocating resources, background reading, allocating tasks to group members and prioritising learning needs. However, the relative importance students assigned to each, although consistently important in most cases, varied. That students could plan was clear too from observations made during the cycles, although the level of success was dependent on how the group functioned.

Students used a variety of methods to assess their progress through each problem. These methods were variable and dependent on the problem and the groups working on those problems. However, all groups could put forward a functional strategy that they could use to monitor their progress. Being able to put forward a functional strategy illustrated that it is important not to emphasise a specific strategy to use, which is particular to PBL, but rather ensure that students know a set of possible solutions that they can use effectively.

7.4.3 The impact of the e-textbook intervention on engagement

Student engagement means that the students are productively participating in the problem-solving exercise and working, as part of a group, towards a solution. Factors such as usefulness and the difficulty of the content, the confidence of the students to approach the task, and the enjoyment they gained from the work determined their level of engagement and affected their motivation for working on the problems encountered. In all cycles and iterations, the students considered the problems to be somewhat difficult, and their level of enjoyment varied greatly with an acknowledged preference for different hands-on activities. Students did not see the relevance of the problems they were working on during the iterations. Students found working in a PBL environment challenging, even after completing one set of problems. While the hands-on nature of the topics was a positive factor, external influences such as a student’s choice of career path (affecting how they perceive science) did determine their level of enjoyment. E-textbooks can go part of the way to supporting students, especially regarding their confidence, by providing appropriate scaffolding. The support may also help students perceive tasks as challenging rather than unachievable if the e-textbook can, as was the intention of this study, be designed in situ to meet specific needs.

7.5 The Final Road Model for PBL Using E-textbooks: Lessons Learned

E-textbooks provide a useful way of introducing students to PBL and allowing them to develop as independent learners who can work in collaborative teams to achieve not only improvements in knowledge acquisition but also in transfer of problem-solving skills and engagement. In considering the achievement of the goal state at the end of the road, it is useful to review the initial state. In the initial state, many students were the passive receivers of knowledge, who would regurgitate isolated facts in tests and examinations. They were not able to transfer skills from one topic to another, even within the same discipline, and showed little engagement with the subject matter. Figure 7.16 details the students' transition to active learners who could transfer skills between problems and engage with the content they were learning. By changing many constraints into affordances, it was possible to achieve this transition.

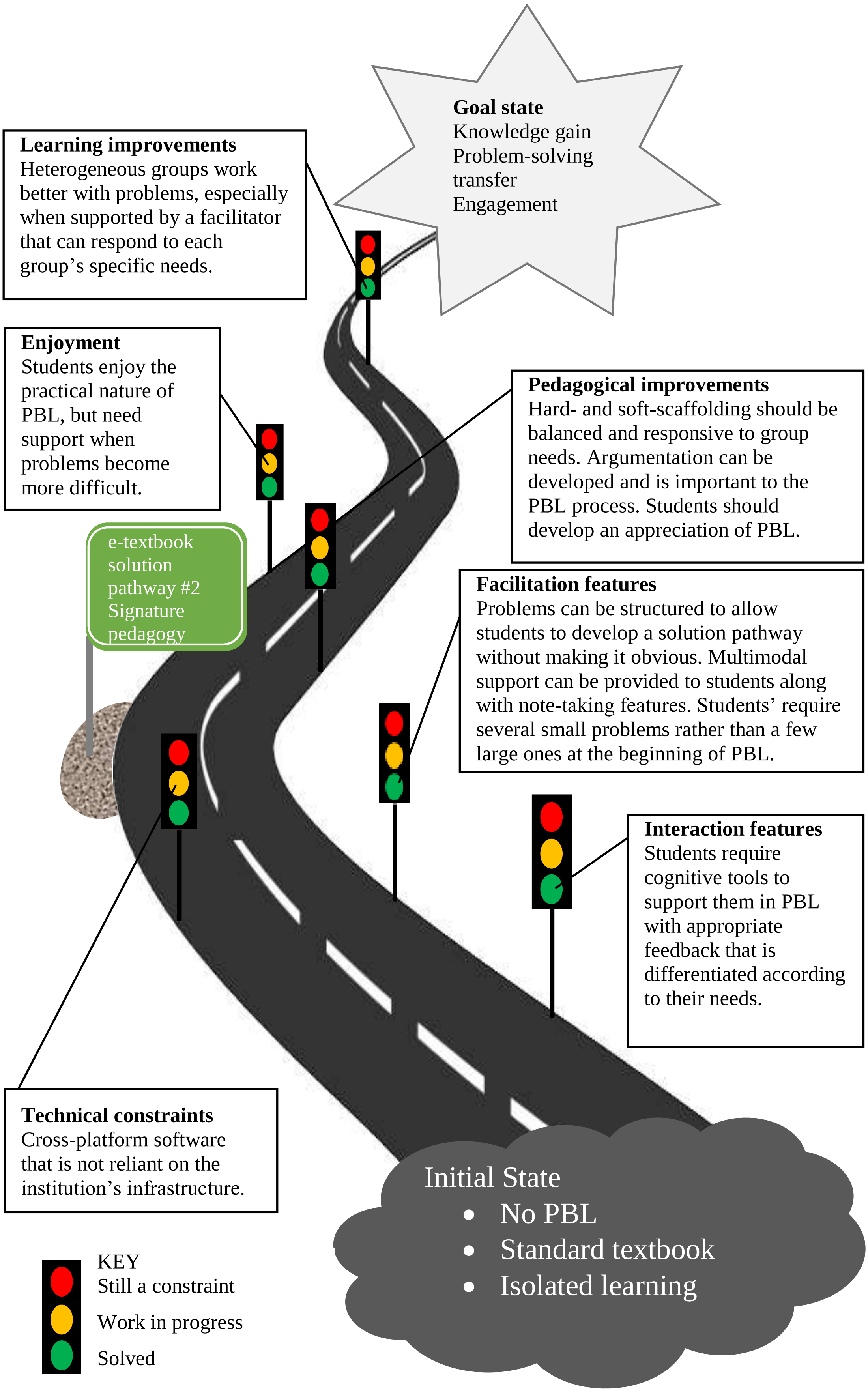


Figure 7.16. The final road model describing the development of the PBL e -textbook.

For PBL to work successfully, students need to be able to interact with several different aspects of the learning environment. Student interaction with each other was initially constraining student learning. By placing students in heterogeneous ability groups not based on friendship, this constraint was ameliorated (as seen in Figure 7.16). In working with such groups, the facilitator needs to be aware of indicators of group dysfunction and provide intervention (soft-scaffolding) as required. Hard-scaffolding can pre-empt some adverse contingencies by upskilling novice students in the fundamentals of working in a PBL group. Such hard-scaffolding can take many forms but should include animation, audio and text. Cheating (e.g., copying) is one aspect of student interaction that should be discouraged, and this can be achieved using problems that are perceived by students to have some form of authentic value to them, be it skill development, knowledge acquisition or another feature. While the problem is pre-eminent in fulfilling this requirement, explaining the purpose of the problem is also necessary as students may not appreciate the underlying objectives that the problem is attempting to achieve.

In using an e-textbook with students, their perceptions of what a textbook should provide constrained their learning. Therefore, it was necessary to develop an e-textbook that facilitated PBL by providing students with cognitive tools when required, accommodating different learning styles, providing targeted feedback and allowing for note-taking. In this way, the e-textbook not only maintains many of the features of the traditional textbooks, but also becomes superior to them while still maintaining the PBL environment for the students.

The problems presented to students require careful attention. The problems need to be structured enough to allow analysis by students to develop a solution pathway, but not so structured as to provide them with that pathway (as seen in Figure 7.16). Prior knowledge is important, although the level of such knowledge varies with the topic and forming heterogeneous groups ensures a variety of levels within the group. The problem should not be an end in itself, but a means to the end of promoting student learning, which includes the transfer of skills to other problems. In this regard, small, interrelated problems worked better than single large problems.

Throughout this study, the teacher's role as a facilitator changed continuously owing to students requiring different levels and types of support. However, some commonalities of the role existed that are transferable into hard-scaffolds in the e-textbook. These included group-work, researching and engagement. However, other issues were transient or did not readily lend themselves to incorporation in the e-textbook, such as specific personality differences and prolonged absence of students. Thus, while an e-textbook can help alleviate the demands placed on a facilitator by updating the hard-scaffolding, it cannot replace the facilitator completely, and their role remains crucial. Figure 2.3, presented in the Literature Review, described the relationship between the facilitator, the students and technology. The influence of the facilitator was shown to decline along with that of technology with a commensurate rise in student learning (self-regulation and knowledge). That model may have overstated the decline of the facilitator's influence and continued interaction of the facilitator with the groups was required, albeit at a reduced level in some instances.

Linked with learning constraints in PBL are pedagogical constraints that prevent students from achieving the benefits of engaging in PBL. These constraints need to be mitigated to allow students to engage in PBL purposefully. Scaffolding was shown to be crucial in enabling students to negotiate the PBL environment successfully. Both domain-general and domain-specific scaffolding were required, and it provided feedback to the students. Scaffolding was in two forms, hard and soft, and the balance between the two was determinable based upon student familiarity and group dynamics. However, factors such as student familiarity and group dynamics vary, which means that each situation will, to some extent, be unique and require specific in-situ modification.

Argumentation is another aspect of PBL that requires attention. Argumentation does not necessarily occur naturally but can develop and evolve within a group and will be aided by effective group dynamics. Therefore, even in situations of group dynamics, the development of argumentation must be supported. Support needs to be in the form of hard and/or soft-scaffolding with the relative amounts of each and its form being variable, depending on the group's experiences and interactions.

When confronted with PBL environments, students can find the change difficult and threatening. They are now responsible for the acquisition of their knowledge rather than simply trying to absorb it. The students need to know how PBL can help them learn new concepts more effectively and develop new skills that they can apply to problems encountered both at school and beyond the classroom. Crucial to this issue is the group's response to the challenges PBL presents to them. A resilient and confident group will be able to work through the problem effectively. A group that does not possess confidence and resilience will require support, before any substantial progress on understanding PBL can be achieved.

Students using laptops with different operating systems can cause issues regarding support for different platforms and accessing networks. Both issues were apparent in this study and no solution was found. Therefore, software must be as cross-platform as possible, and it should not place stress on networks by being machine, rather than server, based. The school technology infrastructure should be fit for purpose. If this is not the case, the PBL process suffers as students become frustrated (Figure 7.16).

Student interaction with the e-textbook occurred in several different ways. The e-textbook assessed the student's understanding of different concepts, providing feedback and specific support when required. In later cycles, the e-textbook had note-taking facilities and a glossary. Specific support tools provided scaffolding in areas where a lack of knowledge could adversely affect students' performance. For example, by including cognitive tools to assist students in writing chemical formulae and balancing chemical equations. Improvement of cognitive tools occurred in each successive cycle during this study informed by feedback and observation of students.

Features that needed to be incorporated into an e-textbook to affect student learning positively became apparent during the study. The design of the problems changed during this study in response to student observations, responses to the problems and feedback. The problems should allow analysis by students so that a solution can be planned in their groups through researching, using prior knowledge and producing testable hypotheses. There needs to be a balance in the structuredness of the problems between providing enough structure to allow students to develop a solution while not making the solution obvious. In designing such problems, many factors require consideration, including, but not exclusively, clarity, relevance and difficulty. Consideration also needs to be given to how the problem will develop teamwork, self-directed learning and critical reasoning.

In designing the e-textbook, it was important to include multimodal presentations for students that could match their preferred learning style. These presentations include not only the problems themselves, but hard-scaffolding related to basic concepts and PBL skills. Controlling student progress through the e-textbook was beneficial because it prevented them from skipping ahead and missing vital concepts, skills or feedback. Feedback in all areas of PBL was a significant aspect of the e-textbook design. The use of specific feedback that responds to students is an area that needs particular consideration when developing e-textbooks for PBL. Differential feedback in the e-textbook accommodates individual differences.

Enjoyment is an important consideration in designing a PBL environment and is perhaps the most difficult to control. Students enjoyed the practical nature of the problems, which is an important aspect of their design. In some cases, the practical aspect became all-consuming for the students resulting in less skill and knowledge acquisition than was desirable. Problems, where the difficulty level increased, saw student enjoyment decline, and increasing support did not ameliorate this decline. It is necessary to balance the amount of practical work in the problems with their difficulty and the amount of support provided. Ideally, small interconnected problems with hard- and soft-scaffolding were preferred.

Implementation of PBL by individual teachers in their classrooms is possible, but it is not an ideal situation. When an institution implements PBL, it is easier for the students to develop and maintain the skills required and places less stress on them as they do not experience completely different pedagogical approaches when moving between classes. However, changing the teaching pedagogy of an institution is generally beyond the purview of a classroom teacher, and as such, they can only act as an example of how classrooms could run. In such situations, it is important to remain faithful to the ideals of PBL while ensuring that they are workable in the school environment. To this end, the development of a signature pedagogy (Shulman, 2005) allows for the development of the PBL environment while accommodating the constraints placed on teachers. Shulman (2005) noted each profession has its own signature pedagogy or ways of teaching. Crippen and Archambault (2012, p. 162) defined inquiry-based instruction using technology as signature pedagogy of STEM education. However, this may be an oversimplification because working with technology involves balancing learning through PBL with the demands of timetables, student acceptance of PBL and assessment requirements. Therefore, a more flexible approach may be required, which could involve combining PBL with more traditional teaching methods to cover basic concepts. The balancing of different teaching approaches does not devalue PBL, but rather maximises the time available for its intended purpose of student-centred learning. The development of a signature pedagogy for PBL in secondary school science is essentially the road travelled during the course of this research, hence the Unknown Road in Figure 7.1 became the Signature Pedagogy Road in Figure 7.16.

Chapter Eight: Conclusion

8.1 Introduction

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

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

8.2 E-textbook Design Principles

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

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

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

8.2.1 An e-textbook supported PBL signature pedagogy

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

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

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

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

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

8.2.2 Heterogeneous groupings of students

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

8.2.3 Appropriate hard- and soft-scaffolding

The balance between hard- and soft-scaffolding was dynamic throughout this study and dependent upon several factors. Hard-scaffolding integrated into the e-textbook had the advantage of enabling the facilitator to focus on issues that were less predictable and often more transient. However, hard-scaffolds were also inflexible and unresponsive to specific student needs that arose within each iteration. As the study progressed, it was possible to predict some potential issues (e.g., working in groups, applying mathematical formulae and equation writing) and incorporate them into the hard-scaffolds of the e-textbook. Other issues that were specific to particular groups or particular problems were not predictable and could only be soft-scaffolded. By achieving a balance, albeit a dynamic one, between the two types of scaffolding, it was possible to maximise independent student learning while providing support on an as-needed basis. The balance between hard- and soft-scaffolding ultimately comes down to the skill and judgement of the teacher in supporting the PBL experience of the students.

8.2.4 Development of argumentation

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

8.2.5 Development of problems appropriate for the students

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

8.2.6 Use of multimodal design

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

8.2.7 Constant feedback for students

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

8.2.8 Technology infrastructure – fit for purpose

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

8.3 Implications for the Future of E-textbook Supported PBL

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

8.4 Suggestions for Future Research

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

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

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

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

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

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

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

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

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

8.5 Concluding Comments

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

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

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

Finally, with the use of technology in schools increasing, the harnessing of tools like e-textbooks affords future generations of students the chance to learn and develop skills important in the 21^{st} century. The development of e-textbooks allows teachers the opportunity to create bespoke educational material that is relevant to their students, develops the skills of the students and instils in them an inquiring mindset. Such developments will be to the benefit of future generations.

8.5.1 A Personal Reflection on the Study

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

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Appendix 1 Results

A1.1 Newton's Law

A1.1.1 Knowledge

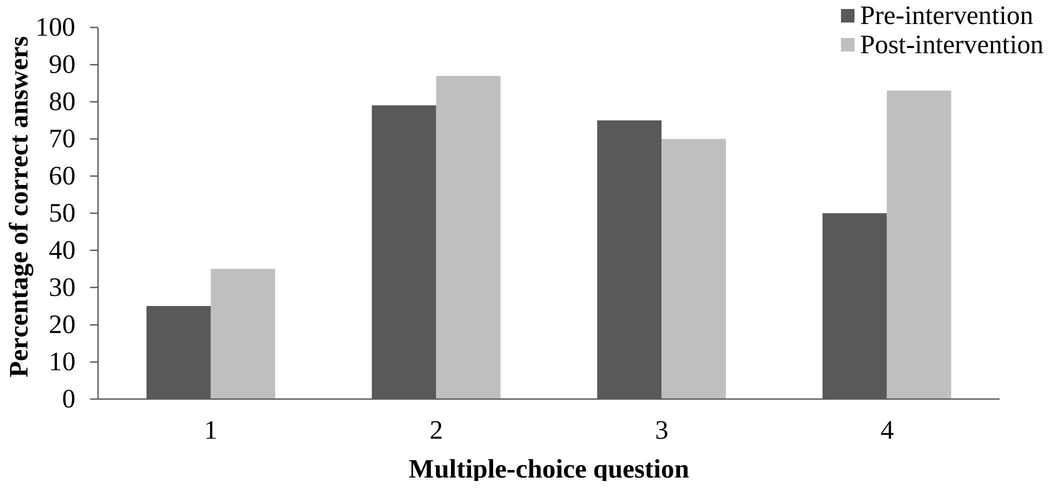


Figure A1.1. The percentage of correct responses to four multiple-choice questions regarding Newton's second law of motion for cycle one.

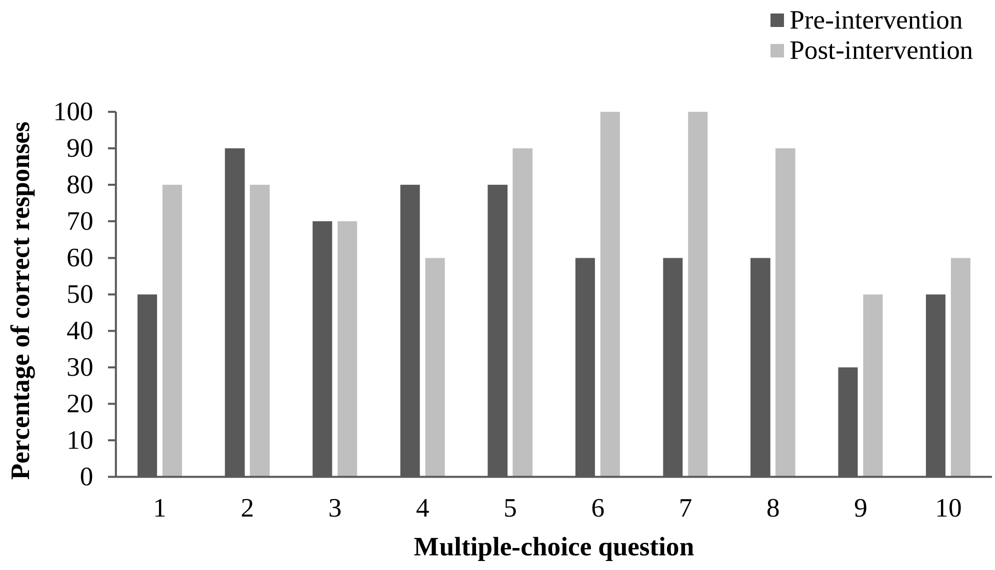


Figure A1.2. Percentage of correct responses to ten multiple-choice questions regarding Newton's second law of motion for cycle two.

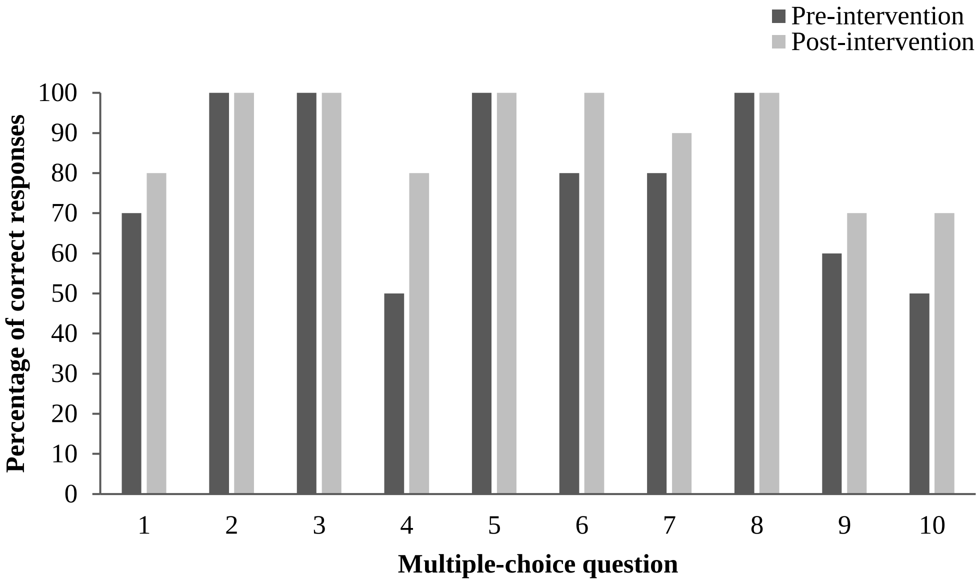


Figure A1.3. Percentage of correct responses to ten multiple-choice questions regarding Newton's second law of motion for cycle three.

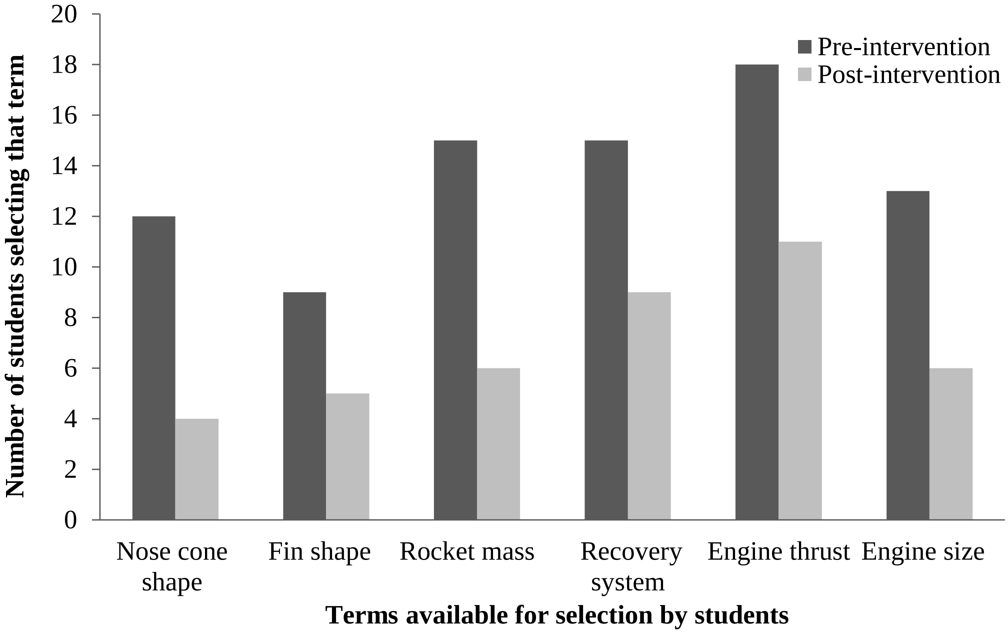


Figure A1.4. Student responses to the question "Circle the pieces of information below that you do not know about but may be relevant to the problem. Nose cone shape Fin shape Rocket mass Recovery system Engine size and Engine thrust" pre-and post-intervention for cycle one.

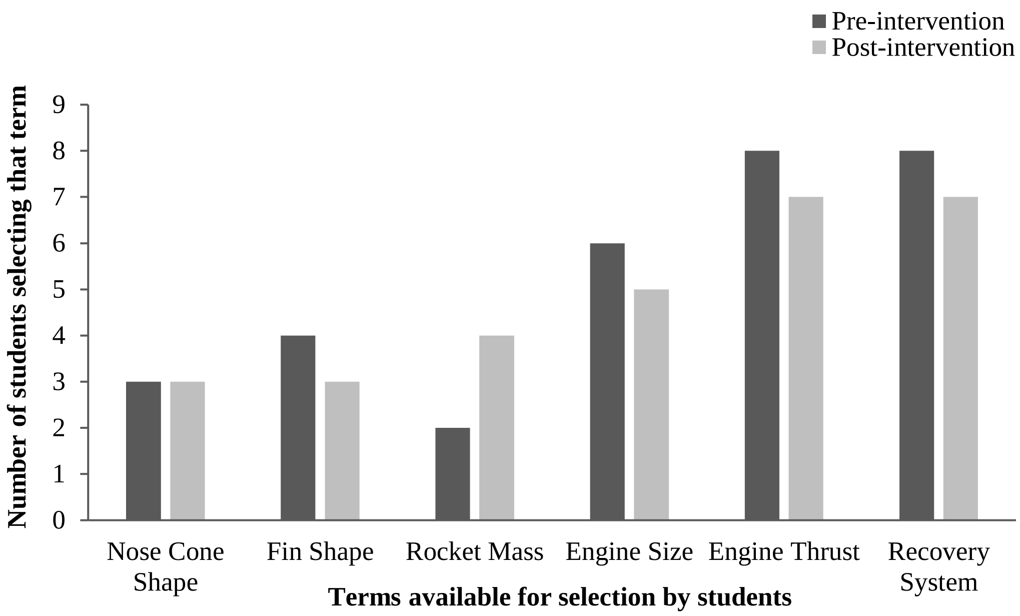


Figure A1.5. Student responses to the question "Circle the pieces of information below that you do not know about but may be relevant to the problem. Nose cone shape Fin shape Rocket mass Recovery system Engine size and Engine thrust" pre-and post-intervention for cycle two.

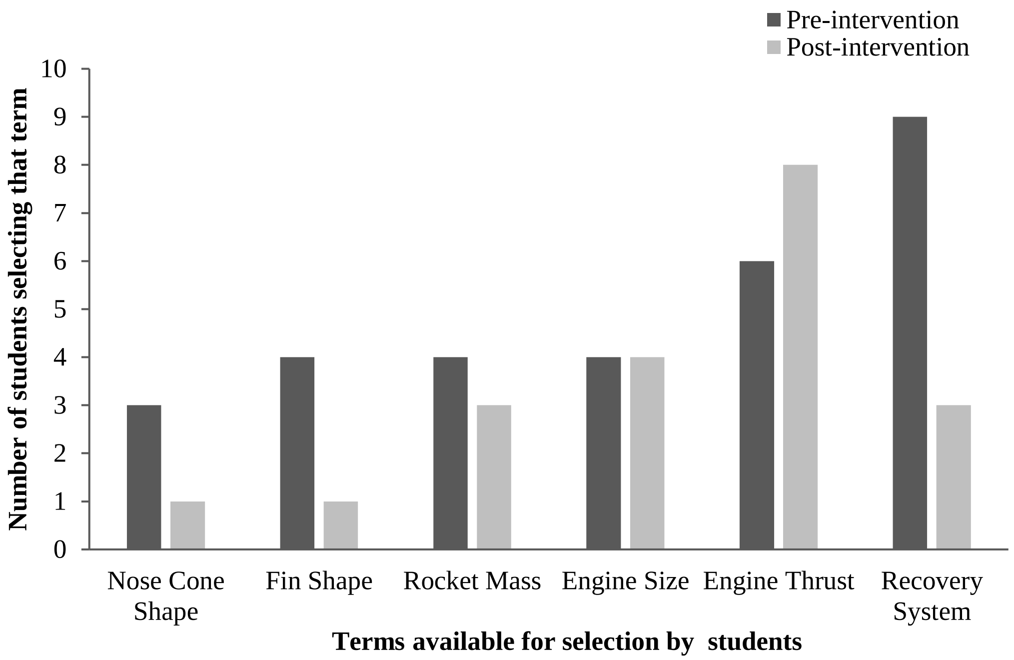


Figure A1.6. Student responses to the question "Circle the pieces of information below that you do not know about but may be relevant to the problem. Nose cone shape Fin shape Rocket mass Recovery system Engine size Engine thrust" pre-and post-intervention for cycle three.

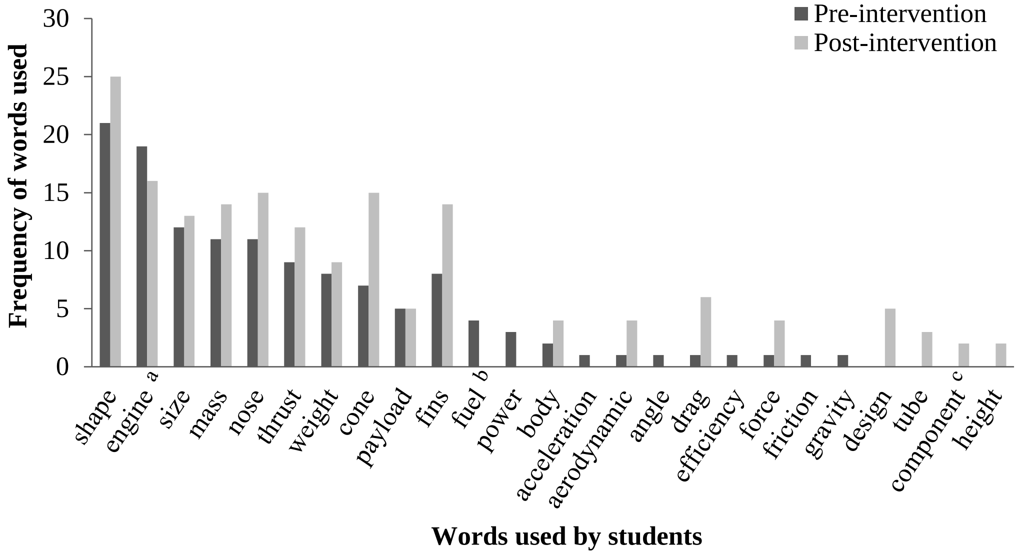


Figure A1.7. The frequency of the 25 most often used words by students when asked "In trying to improve a rockets efficiency in terms of altitude gained write down all the factors you know of that will affect it." in responses that were coded as referring to Newton's laws and streamlining pre-and post-intervention for cycle one.

a Terms engine and motor were combined
b Alternate spellings were combined
c Single and plural were combined

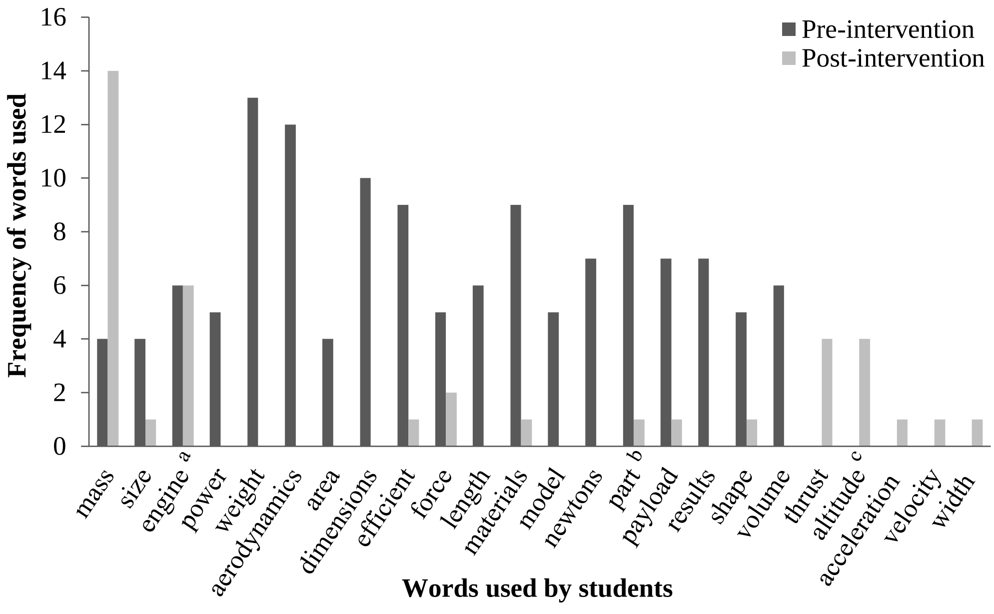


Figure A1.8. The frequency of the 24 most often used words by students when asked "In trying to improve a rockets efficiency in terms of altitude gained write down all the factors you know of that will affect it." in responses that were coded as referring to Newton's laws and streamlining pre-and post-intervention for cycle two.

a Terms engine and motor were combined
b Single and plural were combined
c Terms height and altitude were combined

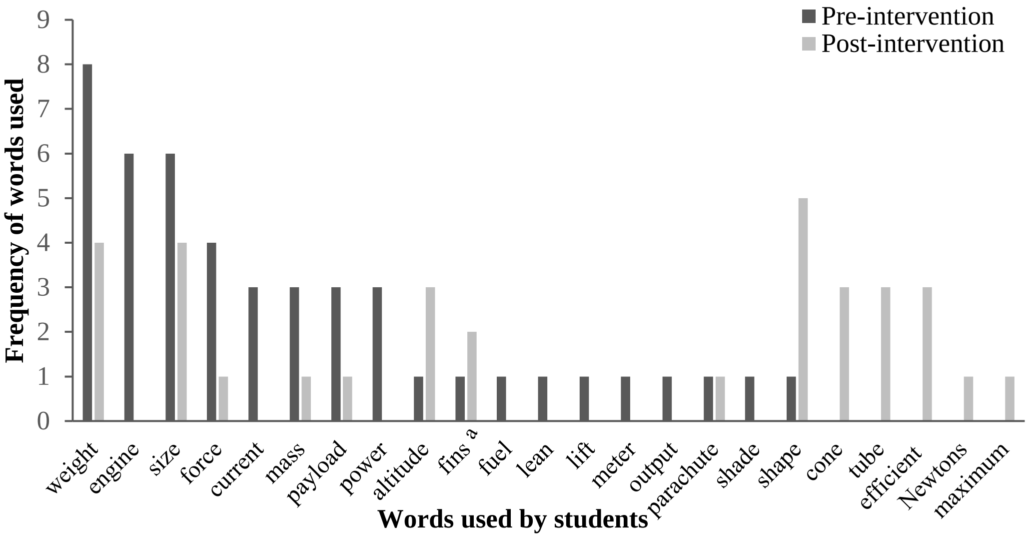


Figure A1.9. The frequency of the 23 most often used words by students when asked “In trying to improve a rockets efficiency in terms of altitude gained write down all the factors you know of that will affect it.” in responses that were coded as referring to Newton’s laws and streamlining pre-and post-intervention for cycle three.
[a] Single and plural were combined

Table A1.1
Responses by Students to a Question Regarding Recognising a Situation to which Newton’s Second Law was Applicable Pre- and Post-intervention

Question	Newton’s second law of motion states that the acceleration of an object is proportional to the force applied and inversely proportional to its mass. Describe a situation where the mass of an object affects its acceleration.					
Response coding	Description does not contain all necessary information		Description contains misconceptions or does not state a relationship		Example correctly describes the relationship	
Intervention stage	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	7	13	12	5	4	3
Frequency of response for cycle 2	6	4	2	2	3	4
Frequency of response for cycle 3	5	5	2	0	1	4

Table A1.2

Responses by Students to a Question Regarding Explaining a Situation to which Newton's Second Law is Applicable Pre- and Post-intervention

Question	Explain why only one person is needed to push the car, but several people are needed to push the truck.					
Response coding	Description does not contain all necessary information and or information irrelevant		Description contains misconceptions or does not state a relationship		Newton's second law applied correctly	
Intervention stage	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	12	7	1	1	11	11
Frequency of response for cycle 2	1	6	6	0	5	5
Frequency of response for cycle 3	3	2	0	0	7	8

Table A1.3

Responses by Students to a Question Regarding Explaining the Effect of Increasing Payload Weight on Rocket Altitude Pre- and Post-intervention

Question	Explain why increasing the payload weight of a rocket increases the force needed to lift it to a certain altitude.					
Response coding	No mention of mass		Mentions mass without mentioning force		Correctly applied Newton's second law	
Intervention stage	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	2	2	9	4	14	17
Frequency of response for cycle 2	0	2	4	2	6	6
Frequency of response for cycle 3	2	0	2	0	6	9

Table A1.4

Responses by Students to a Question Regarding Describing How to Apply Newton's Second Law to the Design of a Rocket in Order to Improve its Efficiency in Terms of Altitude Gained Using Newton's Second Law

Question	Describe how to improve the efficiency of a rocket in terms of altitude gained using Newton's second law.					
Response coding	Description does not contain all necessary information and or information irrelevant		Description contains misconceptions or does not state a relationship		Newton's second law described correctly	
Intervention stage	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	11	5	7	8	3	7
Frequency of response for cycle 2	3	8	3	0	1	0
Frequency of response for cycle 3	3	2	4	1	2	6

Table A1.5

Responses by Students to a Question Regarding How to Assign Group Members to a Specific Task Pre- and Post-intervention

Question	How would you decide which members of your group would be assigned to the different tasks required to complete this problem?									
Response coding	Allocated people to task		Determined who was best suited		Interest or preferred tasks		Trying different tasks		Combined group-work	
Intervention stage	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	3	5	14	9	9	9	1	2	0	0
Frequency of response for cycle 2	3	0	7	2	2	3	0	0	0	5
Frequency of response for cycle 3	2	2	6	2	0	3	0	0	0	3

Note. Coding of each method occurred where students selected more than one method for assigning people to groups

Table A1.6

Responses by Students to a Question Requiring an Explanation of How to Improve Rocket Efficiency Pre- and Post-intervention

Question	Explain how you increased the efficiency of your rocket									
Response coding	Answer is vague or contains misconceptions		Reduction of mass		Increase force		Improve streamlining		Combination of factors	
Intervention stage	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	3	4	3	2	2	1	5	10	10	5
Frequency of response for cycle 2	2	0	0	2	0	0	3	0	4	7
Frequency of response for cycle 3	2	1	1	2	1	0	0	3	6	4

A1.1.2 Planning, monitoring and evaluation

Table A1.7

Student Responses to a Question Regarding Rating Various Items in Terms of Importance When Planning a Project Such as Building a Rocket

Response scale			1 Not important		2		3		4 Important		5		6		7 Very important	
Intervention Pre/post		Cycle	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Scaled items	Reading some background information about the topic	1	0	1	0	1	0	2	6	6	1	1	4	3	12	9
		2	1	3	1	1	0	2	6	0	0	2	1	1	3	1
		3	0	0	0	0	1	3	2	2	0	2	4	2	3	1
	Prioritise the learning needs	1	2	0	1	2	3	3	8	8	2	1	3	2	5	7
		2	1	3	1	0	1	2	5	1	0	2	1	0	3	2
		3	0	0	1	1	2	1	4	2	2	2	0	2	1	2
	Set learning goals and objectives	1	2	1	2	0	2	4	7	6	7	2	1	3	3	7
		2	0	1	1	1	0	1	7	3	2	2	0	0	2	2
		3	0	0	0	0	3	1	1	3	3	3	1	0	2	3
	Allocate resources	1	0	0	2	2	4	2	1	7	5	3	3	1	9	8
		2	1	0	0	0	0	1	6	5	1	2	1	0	3	2
		3	0	0	0	0	1	1	3	3	2	3	1	2	3	1
	Identify which task each group member will do	1	1	1	1	1	1	2	10	8	3	2	3	3	5	6
		2	0	2	0	0	1	1	2	3	0	1	1	0	8	3
		3	0	0	0	2	1	2	1	4	4	1	2	2	2	2

Table A1.8

Student Responses to a Question Regarding Rating Various Items in Terms of Importance When Completing a Project Such as Building a Rocket

Response scale			1 Not important		2		3		4 Important		5		6		7 Very important	
Intervention Pre/post		Cycle	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Scaled items	Reading some background information about the topic	1	1	4	0	1	0	2	5	12	4	2	3	0	11	2
		2	2	4	1	1	1	1	6	2	0	1	0	0	2	1
		3	1	0	0	2	1	3	2	0	3	3	3	1	0	1
	Prioritise the learning needs	1	3	2	1	1	3	6	5	7	4	1	1	2	7	4
		2	1	2	2	0	1	2	5	4	1	1	0	0	2	1
		3	0	0	1	2	4	1	1	1	3	2	0	2	1	2
	Set learning goals and objectives	1	1	0	3	0	1	5	7	8	4	4	3	1	5	5
		2	0	1	1	0	1	0	3	4	2	4	1	0	4	1
		3	0	0	0	0	3	2	1	3	4	2	1	1	1	2
	Allocate resources	1	1	0	1	2	1	0	2	7	3	3	3	2	13	9
		2	0	0	1	0	0	2	3	3	1	1	2	1	5	3
		3	0	0	0	1	0	1	4	1	3	2	0	2	3	3
	Identify which task each group member will do	1	0	0	0	0	0	1	6	6	3	2	4	3	11	11
		2	0	3	0	0	0	1	3	3	1	1	2	1	6	1
		3	0	0	0	2	0	1	3	2	2	0	1	2	4	3

Table A1.9

Student Responses to a Question Regarding Allocating Times to Various Tasks When Working on a Project Such as Building a Rocket

Question	Describe how you would divide up your time in this activity between the planning and carrying it out. You have approximately five weeks.					
Response coding	Allocate time with general tasks		Allocate time with specific tasks		Tasking	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	11	13	3	2	4	8
Frequency of response for cycle 2	10	9	0	0	0	0
Frequency of response for cycle 3	4	7	4	1	1	2

Table A1.10

Student Responses to a Question Regarding Evaluating Each Step When Working on a Project Such as Building a Rocket

Question	Describe how you would evaluate each step in your progress towards a solution to the problem													
Response coding	Compare with another group member		Compare with other groups		Irrelevant response		Post consideration		Prior consideration		Testing at each step		Trial and error	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	2	5	1	0	3	4	1	2	6	10	5	3	4	1
Frequency of response for cycle 2	7	4	0	1	3	1	1	0	0	0	0	0	0	0
Frequency of response for cycle 3	2	1	0	0	0	3	4	0	0	0	1	1	0	3

Table A1.11

Student Responses to a Question Asking Them How They Would Search for Information

Question	Describe, in as much detail as possible, how you would search for information on this project									
Response coding	General book search		General Internet search		General person search		Specific book search		Specific Internet search	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1[a]	8	18	16	9	8	6	2	0	6	0
Frequency of response for cycle 2[a]	3	5	11	5	6	2	0	0	0	0
Frequency of response for cycle 3[a]	1	3	4	4	3	2	0	0	4	2

Note. [a] responses that fit more than one category were coded in each

Table A1.12

Student Responses to a Question Asking Them How They Were Performing a Task

Question	Explain how your group knew how well they were performing the task					
Response coding	Communicating		End result		Progress made	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	5	4	5	2	15	14
Frequency of response for cycle 2	4	2	3	3	5	5
Frequency of response for cycle 3	3	1	0	0	7	9

Table A1.13
Student Responses to a Question Asking Them How They Would Assess Information

Question	How would you assess the information you found for your group?					
Response coding	Comparing		Relevance		Testing	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	11	16	3	2	4	2
Frequency of response for cycle 2	6	6	2	2	1	2
Frequency of response for cycle 3	5	5	1	0	1	3

A1.1.3 Student engagement

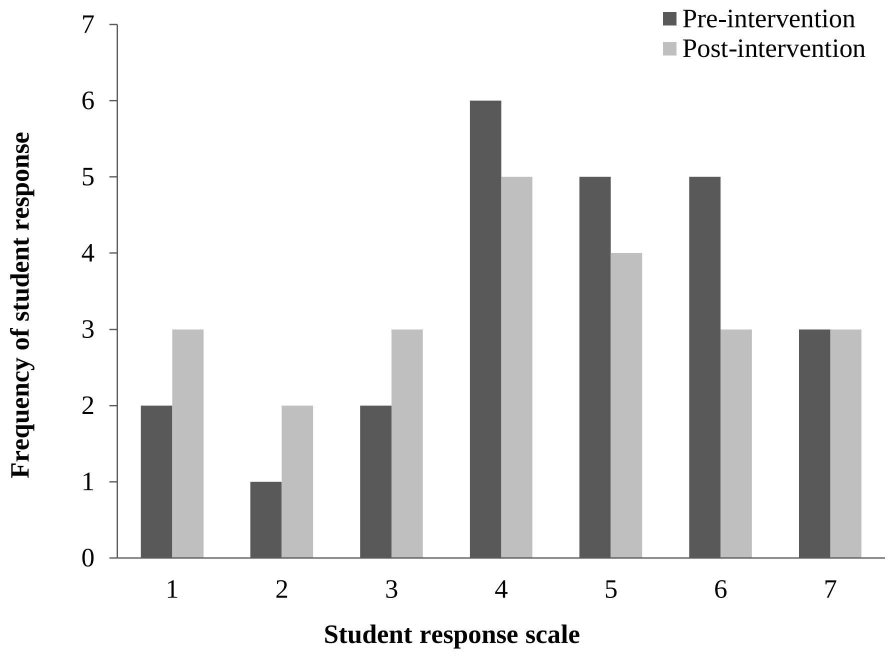


Figure A1.10. Frequency of student responses to a Likert scale with the question “How useful do you think this task would be to you on a scale of 1 to 7” Pre-intervention and “How useful do you think this task was to you on a scale of 1 to 7” Post-intervention for cycle one.

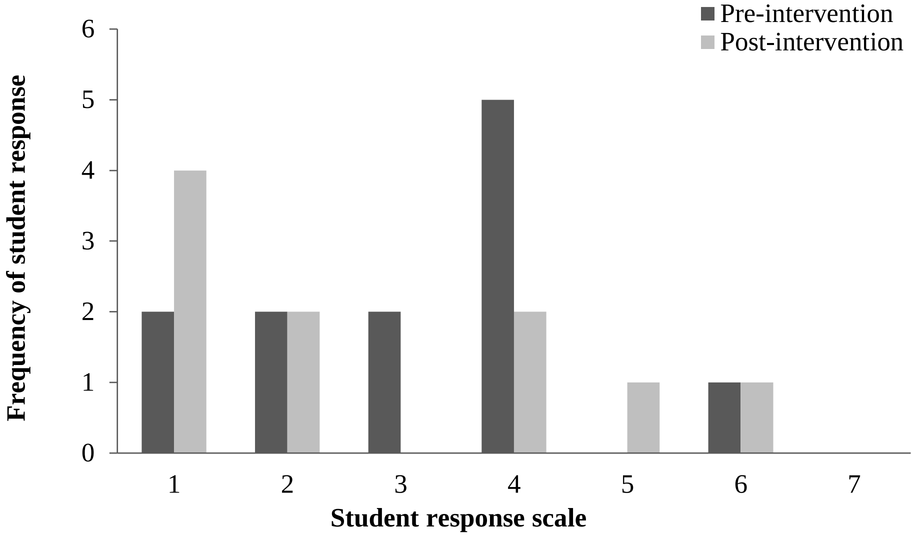


Figure A1.11. Frequency of student responses to a Likert scale with the question “How useful do you think this task would be to you on a scale of 1 to 7” Pre-intervention and “How useful do you think this task was to you on a scale of 1 to 7” Post-intervention for cycle two.

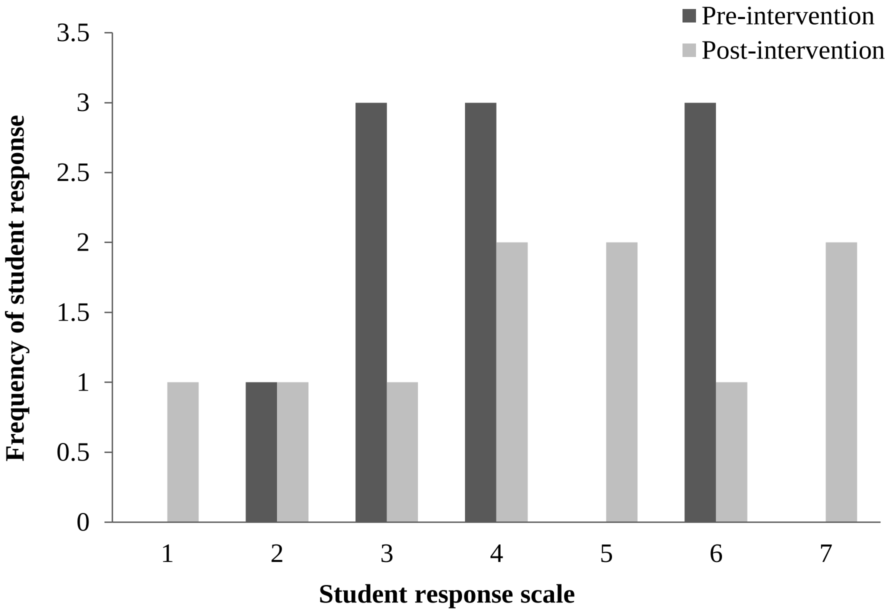


Figure A1.12. Frequency of student responses to a Likert scale with the question “How useful do you think this task would be to you on a scale of 1 to 7” Pre-intervention and “How useful do you think this task was to you on a scale of 1 to 7” Post-intervention for cycle three.

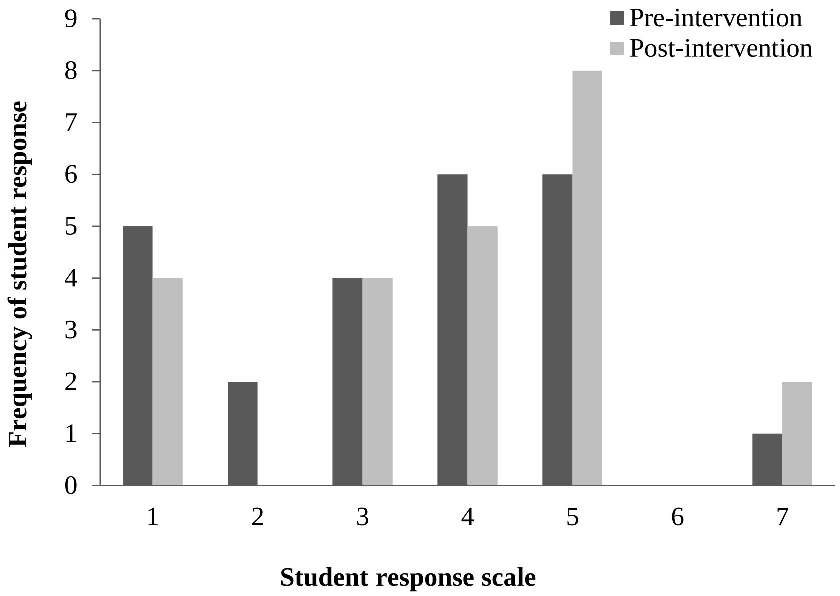


Figure A1.13. Frequency of student responses to a Likert scale with the question "How confident are you that you could complete this task without help on a scale of 1 to 7" Pre-intervention and "How confident are you that you could complete this task without help on a scale of 1 to 7" Post-intervention for cycle one.

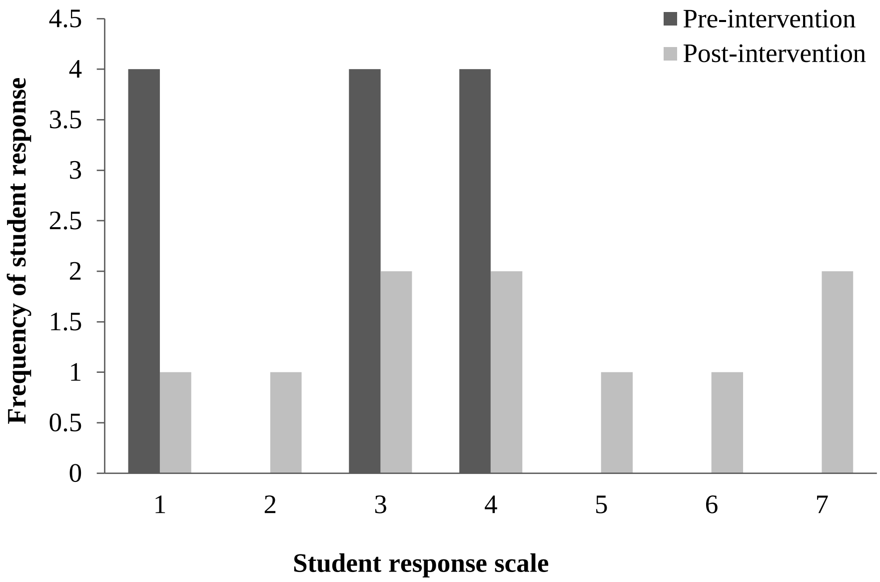


Figure A1.14. Frequency of student responses to a Likert scale with the question "How confident are you that you could complete this task without help on a scale of 1 to 7" Pre-intervention and "How confident are you that you could complete this task without help on a scale of 1 to 7" Post-intervention for cycle two.

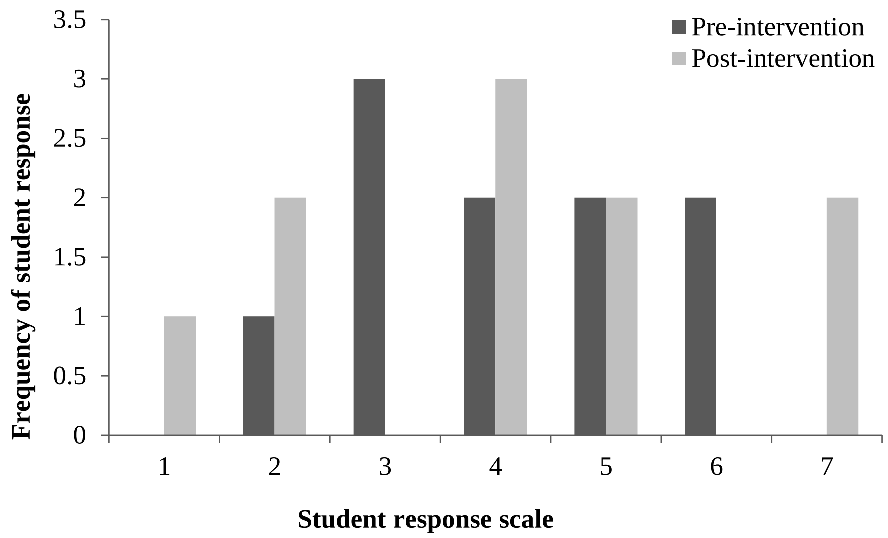


Figure A1.15. Frequency of student responses to a Likert scale with the question "How confident are you that you could complete this task without help on a scale of 1 to 7" Pre-intervention and "How confident are you that you could complete this task without help on a scale of 1 to 7" Post-intervention for cycle three.

Table A1.14

Student Responses to the Question Regarding How They Would Motivate Themselves

Question	Describe how you would motivate yourself to complete such a task											
Response coding	Good end result		Grades		Time limits		I have to		Support team		The topic	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	8	7	2	1	0	0	2	1	3	4	6	11
Frequency of response for cycle 2	3	3	1	2	0	0	4	3	2	0	1	2
Frequency of response for cycle 3	3	3	0	2	2	1	0	0	3	2	1	2

Table A1.15

Student Responses to a Question How They Would Respond to Easy and Difficult Tasks

Question	Describe how you think you would respond to tasks that are easy compared to those that are difficult in this activity											
Response coding	Easy first difficult later		Easy only		No difference		Prefer easy tasks		See difficult tasks as a challenge		Difficult first easy later	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	6	1	2	0	9	9	3	7	2	0	0	0
Frequency of response for cycle 2	3	3	0	0	3	3	2	3	1	1	2	0
Frequency of response for cycle 3	3	0	0	0	2	1	3	3	1	5	0	0

Table A1.16

Student Responses to a Question as to Whether They Thought the Activity Would be Enjoyable

Question	Explain why you think this activity would be enjoyable or not enjoyable.													
	Enjoyable								Not enjoyable					
Response coding	Hands on		New activity		Group-work		New skills		Boring		No interest relevance		Complex task	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1[a]	4	10	10	2	0	0	6	1	1	4	2	1	0	0
Frequency of response for cycle 2 [a]	3	1	3	4	0	2	0	0	2	4	1	3	0	0
Frequency of response for cycle 3 [a]	1	4	3	4	0	0	1	1	2	3	3	0	2	2

Note. [a] responses that fit more than one category were coded in each

Table A1.17

Student Responses to a Question as to Whether They Thought the Activity Would be Difficult

Question	How difficult did you find this problem? Explain with specific examples															
	Difficult										Not difficult					
Response coding	Boring not interested distracted		Complex problem		Poor group dynamics		Unfamiliar		Weak in subject area		Enjoy subject		Group support		Persevere	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	5	1	5	4	0	0	7	6	1	0	1	0	1	4	4	1
Frequency of response for cycle 2	2	0	0	4	3	0	0	1	1	2	1	0	0	3	2	0
Frequency of response for cycle 3	0	2	4	4	0	0	4	1	0	0	1	2	0	1	0	0

A1.1.4 Observations

Table A1.18

Cycle One - Informal Classroom Observations for Newton's Laws

Date	Observation
23/08/2013	Rocket PBL was started today with two Year 10 classes. Class one The first class period two and three had problems downloading the e-textbook due to its size 10 minutes + There were problems playing the video on the netbooks which will need to be sorted out Video was watched from the resources file Students responded well to the first video. All were interested in it and were commenting about the flight of the rocket not realizing that the video was taken from various angles. It generated some interest in students taking about the fight of the rocket The second video caused male students to laugh and female students to be shocked. but not much discussion came from it. Teacher went through how to use the e-textbook. Some issues with the use of tools like H command. Students passive Students worked through the first part of the e-textbook Exploring the problem Students were tentative and did not know what to write - students told to brain storm and discuss in their groups, but they were reluctant to do so. Some students tried to skip ahead and not do each part in sequence. Wrap up at end of lesson is important

(continued)

Date	Observation
	Class two The second class period six and seven had problems downloading the e-textbook due to its size as well There were problems playing the video on the netbooks which will need to be sorted out Video was watched from the resources file Students responded well to the first video. All were interested in it and were commenting about the flight of the rocket not realizing that the video was taken from various angles. It generated some interest in students talking about the fight of the rocket Some students questioned why build a rocket to blow up Teacher went through how to use the e-textbook. Some issues with the use of tools like H command. Students very passive Students worked through the first part of the e-textbook Exploring the Problem Students were tentative and did not know what to write - students told to brain storm and discuss in their groups, but they were reluctant to do so. Some students tried to skip ahead and not do each part in sequence. Students encouraged to expand on their answers the Step 1. Wrap up at end of lesson is important
25/08/2013	Class two Second lesson with this class Generally went well Some students off task Students needed to be told how to assign tasks within groups More communication within groups which was mostly on task
26/08/2013	Class two Students slow to start Organisation in groups is variable some are able organise themselves while others are off task Student engagement is a key issue here The requirement for students to be self-motivated is crucial. I feel that this is an area that will require more attention. Those groups that can organise themselves do much better in their group Students need to look at what they have achieved each day. Provide a space for this in the book. Most students now on task. Discussion is more focused on task 25 min into lesson. Generally happy with students, although there is some incidental chatter. Am I expecting too much too soon? IT issues are problem again! Unable to save in one case and access network in another. Class one Students slow to start, but quicker than previous class today. Again, it seems that student engagement plays an important part in this method Students still need a lot of direction in what to do. Discipline in this class is a problem, partially because students are still in the mode of teacher direction Statements by some students about the type of rocket they are going to build clearly show they have not assimilated the material - build biggest rocket with biggest engine.

(continued)

Date	Observation
	Can the e-book be made any more explicit? I think there will need to be a test to see how well students have mastered the concepts. Simple page turning in a book is not good enough. Interaction needs more direction Once a few discipline issues were dealt with students seemed to settle a bit - one was using internet to find extra information! Again, IT issues - access to student drives and features of e books not working. Jordan’s group is becoming quite needy. Talking to them they are capable of working through the problem.
28/08/2013	Class two Students seem to be getting used to the process and organising themselves a little better today. Not too much discussion however. I think the idea of a test mid-way has motivated them a little. Do these students know how to work as a team? The what have you learnt question is important Learning self-check - this needs to be developed more Students were playing some sort of a game outside and some students were more interested in this than what they were working on. A reflective journal needs to be an ongoing thing in this not just a thing done at one point in time during the PBL. The reflection question is a start, but more is needed. Is it ever possible to use this process effectively with all students. PURE PBL WILL NOT WORK WITH THE VAST MAJORITY OF STUDENTS. Is confidence an issue? Are the students able to work from the initial problems provided? The tools are not being used. Class one Students were re tasked at the beginning of the lesson regarding the purpose of the activity Students were quiet, but there is a sense of passive non-compliance Students seem to want to just copy each other’s responses rather than discuss their ideas and answers. Some groups (more able ones) seem more able (willing) to share ideas Do students really know how to use the tools they are provided with in e-books? Teacher input is still important, but as a guide. Student was able to understand Newton’s 3rd Law once she had some guidance. Same deal with another student and the first Law student did not apply the idea that an external force may affect motion There is not enough development of Newton’s Laws in the e-textbook I’m still not convinced that the level of engagement is high Ongoing technical issues saving work
29/08/2013	Class one Demonstration of rocket motors was good motivator except for one group Mass experiment was organised well by all teams Results are varied, but students do not self-check Questions are needed in this practical to guide students They do not remember how to calculate acceleration My role is changing definitely more facilitation Group dynamics are important worst group improved with one member gone.

(continued)

Date	Observation
	Class two Demonstration of motors was good but not as motivating as this morning time a factor? Organisation of the practical was much slower not as much basic idea of what to do time a factor but not as intuitive either. The students needed a lot more help this time with acceleration calculation. IT issues are still a problem. There is always the pressure of trying to cover the work and ensuring that the students understand what is going on.
30/08/2013	Class two Students busy, not giving the impression of being tired. Most groups are on task, but still hesitant about what they know. This is reasonable given the stage they are at. More scaffolding? Not totally focussed, but given the time this is reasonable Students do not know how to approach a problem to find a solution they do not know how to break a problem down. Is this because the initial problems don't provide enough support? Can this be scaffolded? how?
03/09/2013	Class two Test provided a circuit breaker for the class. Students only had a short time to work on books and they seemed to work steadily but were not as focused. Most students passed the test. Class one Test provided students with a pause. Most students and all but two groups managed to pass the test. The weakest group did he most poorly on the test. Other groups were able to move to the design phase of the rocket. Students were given rocket parts which seemed to motivate them more. The two teams that failed are very easily distracted and do not focus on the task. One of the weak groups has now started to actually work through the book and help each other. This did not last long however. The other group is still wasting a lot of time and not focusing on the work at all. Freedom v prescriptions Do we let students just work on the booklet or do we insist that they complete each stage. They cannot handle total freedom. There needs to be some direction to complete each stage. Groups working on rocket design do not use the tools provided to help them use the software and then have problems using the software.
04/09/2013	Class one Students continued to work on the design of rocket. Students were on task this morning and working well. There are still problems with students not engaging with the e-textbook and therefore not using the software to its full advantage. This is the first time these students have done this so maybe I am expecting too much.

(continued)

Date	Observation
	Class two Students generally working well on their rockets Generally, more interaction within groups regarding the problem All groups on task and involved in project Both male and female groups are engaged Students are using their plans
09/09/2013	Class two Students worked well today All students on task and many up to the design phase of their rockets None of the designs submitted meet the criteria which is a concern considering the amount of time spent talking to students about the importance of this aspect. Generally, students appreciated where they had gone wrong. Class one Students were in one of two large groups; Those that had worked through the e-textbook and new what they were doing and those that had not done so. The latter group wasted a lot of time, did not focus on what they had to do and generally did not get anything from the lesson. The other group did work through the e-textbook and made some progress on their design. As with the other class none of the submitted designs fulfilled the criteria. There are groups in this class that are clearly dysfunctional.
11/09/2013	Class one Data interpretation exercise Class two Period 2 data interpretation exercise. Period 3 students continue to work on the design of the rocket. Connect between information acquired and the problem is tenuous
12/09/2013	Class two Productive lesson with all but one group working well. Three groups completed the design of their rockets and are now at the build phase Most other groups are progressing well Small problems like containing the mass and positioning centering rings are creating the problem Class one Not a particularly productive morning Students still not able to complete rocket designs Some still wasting time rather than focusing on the task Definite need to provide a graduated lock step procedure to the PBL environment
13/09/2013	Class two Class seems quite focused although some students are off task. Student asking about using highlighting tool in e-book Technology understanding of students is generally poor! Tech issues with students unable to save are becoming a real issue. This needs to be addressed!!

(continued)

Date	Observation
	Class one Students are now either building their rockets or they are in the final stages of designing them. There is a noticeable disconnect between theory and practice. Also, students know how to organise themselves into groups and motivate themselves, but they do not seem to apply this to the classroom.
16/09/2013	Class one Students worked better today with a deadline of next week. Three rockets approved today. There is still disconnect between theory and practice They do not plan ahead well, they react rather than act.
17/09/2013	Class one Class generally worked well with all groups working on the rockets Skill problems with rockets are the main issue. Two groups are not able to organise themselves? There are some issues that are not solvable with e-textbooks, but possibly with more experience.
18/09/2013	Class one Students generally working well on their rockets Generally, more interaction within groups regarding the problem All groups on task and involved in project Both male and female groups are engaged Students are using their plans Class two Students are continuing to work on rockets One group still has to start All other groups are working well Perhaps not as task focused as I would like, but acceptable.
19/09/2013	Class one Students do not follow their plan closely enough. There is a disconnect here. Generally, students are working well, but do not link to theory of the course. The topic does provide engagement for most students but tends to become all-consuming for the students.
23/09/2013	Class two Students are near completion of project. Models generally conform to specifications Lot of chatter due to last week of term. Finishing touches are time consuming. Have they lost site of the problem - possibly? The students definitely get hung up on the minutiae of the design. Preference for big things rather than small detail.
24/09/2013	Class one Students are continuing to work on rockets Large difference between groups - female groups better than male groups. Female groups organised and working on parts of rocket, males off task.
27/09/2013	Students complete post PBL Evaluation Tool

Table A1.19

Cycle Two - Informal Classroom Observations for Newton's Laws

Date	Observation
28/07/15	Usual IT problems but roll out completed successfully.
29/07/15	Students fully engaged with e-textbook Animation seems to be holding student's attention
30/07/15	Students had completed both introductory pages; PBL and forces. Concerned that students are progressing through this too quickly. Are they actually engaging with material? Students completed both tests Students started using journal without prompting Students started first problem and had problems organising themselves in their groups and with how to approach problem Intervention was mainly about getting them to think about Newtons first Law and how to show it scientifically.
03/08/15	Students required a lot of help with the first problem. They knew Newtons Law but were unable to think about a practical way to demonstrate it. Very limited conversation between members of each group. Students unfamiliar with how to use equipment. A lot of trial and error.
4/08/15	Started by reviewing problem one with students Looked at the problem and what we were trying to achieve by working through the problem Gave student's two reports to compare regarding the problem; one very good and one poor. Discussed why one report was better. Placement of journal questions is dependent on the topic. Journal questions need to be more specific to the topic under consideration. Generally better class today, but they still need a lot of help.
05/08/15	Students seem to have successfully completed problem 1 and are now working on problem 2. The students again are reluctant to talk in their groups and do not know how to demonstrate Newton's 2nd despite knowing what the Law states. Keeping all variables except one constant was an issue as was not being able to apply formulas correctly to the problem. Difficult to get around to all the groups.
06/08/15	Students are working well on problem 2. Many groups are now talking amongst their members about the problem. Some groups stubbornly refuse to do so – this cannot be taught. This is a cultural thing that is pervasive in science. The technology should be a tool to be used by the students to help them learn. Difficulties with the technology create a new set of problems that the students need to overcome which are not related to the problems eg printing. Some members in some groups are still content to copy each other's work completely without thinking about it themselves. The journaling is helping some students consolidate their thoughts. A debrief may be a good idea. Students evaluate each other's responses anonymously. There is no review of what they have done in some groups.

(continued)

Date	Observation
11/08/15	Not a good day many students off task and not taking the investigation seriously. Students expect investigation to work first time Not willing or able to work around problems to solve issues.
12/08/15	Much better today. Students talking in groups and working on their investigations. Taking a more mature approach.
13/08/15	Students have finished the second problem; however, some are still not collecting data from their experiments and their reports are trivial in many respects Some students are treating this more like a game than a serious investigation. Some groups are still not functioning well.
17/08/15	Students are tackling the third problem The students are finding this problem easier in terms of designing the experiment but are not sure what data to collect.
18/08/15	Most students have finished problem three, but again their reports are lacking depth. Motivation to do a good report seems totally lacking.
19/08/15	Students have started to design their rockets. This does not seem to be motivating the students as much as I expected.
20/08/15	Students are continuing to work on the rockets, but not a lot of thought is going into the design.
24/08/15	There were some issues with the rockets. Some were damaged. Students are getting hung up on minor issues rather than focusing on the main features of the design.
25/08/15	Students are adding finishing touches to the design. Many students still not able to justify their design in terms of Newtons Laws.
26/08/15	Rockets have been completed and are ready for testing. Students seem largely disinterested.
31/08/15	Students have completed and tested their rockets Students do not seem motivated or excited about their accomplishments
01/09/15	Post PBL Evaluation

Table A1.20

Cycle Three - Informal Classroom Observations for Newton's Laws

Date	Observation
17/5/16	Started the rocket e-book with students. Huge issues with down loading e-book to students' laptops. Only two students could download their e-books. E-book functionality severely degraded.

(continued)

Date	Observation
18/5/16	E-book successfully downloaded. Students working through the first problem. Students well organised in their groups. Providing students with help regarding setting up equipment.
19/5/16	All students working on 1st problem. Students progressing well. Having students writing up pracs with explanations seems to be working. Able to help individual groups.
25/5/16	All students working well. Some students up to the 2nd problem. This problem requires more thought from students and more soft-scaffolding is required. Students seem relatively independent, but one group requires a lot of support.
26/05/16	All groups up to the second problem. Students confused about how to measure force applied to a trolley. Once students had this problem solved they found the rest of the task easy. Students completed trials of the experiment. Students found the relationship between mass and acceleration when force was held constant through discussion. Data recording was good, but some students prefer writing notes rather than entering them into the e-textbook
30/05/16	Students using language with more confidence, but some still not sure about their understanding. Some groups a little off task. These PBLs need to be short or students get bored/frustrated. Generally, students working well and discussing ideas in their groups.
31/05/16	Students are continuing to work on problem 3. Good ideas being generated and students working well together. Students are engaged in the problem-solving experience.
1/06/16	Students again working well. Collecting good data from their problem, but again students reluctant to use e-textbook to record data. Much discussion in class on topic.
2/06/16	Generally, students working OK. Third problem was completed. Some anxiety of the exams next week.
13/06/16	Students experienced some difficulty with the Openrocket program. Students became frustrated when their design did not work. Some students became disengaged.
14/06/16	Eased the requirements for the rockets payload and altitude. Students were more focused and on task today. Good levels of discussion about design. Most completed plans for their rocket.
15/06/16	Students now building their rockets. Building is going well. Able to help groups with individual design issues.
16/06/16	Students have mostly completed their rockets. Launching of the rockets was enjoyed by all students!
20/06/16	PBL Evaluation Tool

Table A1.21

Cycle One - Results of Seven Observations of Year 10 Classes Undergoing PBL Intervention for Newton's Laws

Time interval	Group activity							On task behaviour							Type of on task behaviour							Teacher behaviour							Teacher interaction						
Obs. No.	1	2	3	4	5	6a	7a	1	2	3	4	5	6a	7a	1	2	3	4	5	6a	7a	1	2	3	4	5	6a	7a	1	2	3	4	5	6a	7a
0	W	W	W	W	W	S	W	AA	AA	H	A	A	A	AA	N	N	I	RW	N	NVP	L	T	O	T	T	T	TO	T	T	T	T	T	T	TO	T
5	W	S	W	W	W	S	S	AA	AA	A	A	A	AA	H	N	N	I	RW	N	NVP	T	M	O	T	T	M	TO	O	M	T	T	O	M	TO	T
10	S	S	S	W	S	S	S	AA	AA	A	A	A	A	A	N	N	NVP	RW	N	NWM	L	M	O	T	T	M	TO	T	M	T	O	O	M	TO	T
15	S	S	S	W	S	S	S	H	AA	H	A	AA	AA	AA	N	N	N	WM	N	NVP	VP	M	I	M	T	M	T	O	O	T	T	O	O	T	M
20	S	S	S	W	S	S	S	AA	H	A	A	A	AA	A	N	N	N	WM	N	NWM	CW	O	O	M	O	M	T	M	TO	L	M	O	TO	T	T
25	S	S	S	W	S	S	S	AA	H	A	A	A	AA	H	N	N	N	WM	N	NVP	WM	O	O	M	O	O	T	TO	TO	T	M	O	TO	T	T
30	S	S	S	W	S	S	S	H	AA	A	A	AA	AA	A	N	NVP	N	N	N	NWM	WM	O	M	M	T	O	TO	M	TO	T	M	T	TO	TO	T
35	S	S	S	S	S	S	S	H	AA	H	A	AA	A	H	N	NVP	NVP	WM	N	NVP	WM	O	M	M	M	O	T	O	TO	M	O	M	TO	T	T
40	S	S	S	S	S	W	S	H	AA	H	A	AA	A	H	N	NVP	NVP	WM	N	NWM	WM	M	O	M	M	M	T	T	TO	T	M	T	TO	T	T
45	S	S	S	S	S			H	AA	A	A	AA			N	NVP	NVP	WM	N			O	O	M	M	O			TO	T	M	T	TO		
50	S	S	S	S	S			H	AA	A	A	AA			N	NVP	NVP	WM	N			M	M	M	M	M			TO	M	M	T	TO		
55	S	S	S	S	S			H	H	A	A	AA			N	NVP	NVP	WMN	N			O	M	M	M	O			TO	M	T	T	TO		
60	S	S	S	S	S			H	AA	A	AA	AA			N	NVP	NVP	VP	N			M	M	T	T	M			M	M	T	T	M		
65	S	S	S	S	S			H	AA	H	AA	AA			N	NYP	NVP	VPN	N			M	O	M	O	M			M	T	M	T	M		
70	S	S	S	S	S			H	AA	A	AA	AA			N	N	NVP	VPN	N			O	M	M	M	O			O	M	M	T	O		
75	S	S	S	W	S			H	AA	H	A	AA			N	N	NVP	N	N			O	O	M	T	O			M	M	M	T	M		
80	S	S	W	W	W			A	A	A	AA	A			N	N	NVP	N	N			O	O	T	M	O			O	T	T	T	O		

Note. W = whole class S = Sub groups A = all AA = almost all H = half N = Notebook I = Individuals
VP = verbally passing WM = working with materials T = talking O = organise
M = monitoring L = listening CW = checking work
[a] Observations made in a single 40-minute period

Table A1.22

Cycle Two - Results of Four Observations of Year 10 Class Undergoing Physics PBL Intervention for Newton's Laws

Time interval	Group activity				On task behaviour				Type of on task behaviour				Teacher behaviour				Teacher interaction			
Obs. No.	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
0	SG	W	SG	W	A	A	A	A	N	L	N	L	TO	T	MTH	T	SG	W	SG	W
5	SG	W	SG	SG	A	A	A	A	N	L	N	L	TO	TL	MTH	TL	SG	W	SG	SG
10	SG	SG	SG	SG	A	A	A	A	N	VP	WM	WM	TO	TL	MTH	TL	SG	SG	SG	SG
15	SG	SG	SG	SG	A	A	A	A	N	VP	WM	WM	TO	H	LTH	H	SG	SG	SG	SG
20	SG	SG	SG	SG	A	A	A	A	N	WM	N	WM	TO	M	LTH	M	SG	SG	SG	SG
25	W	SG	SG	SG	A	H	A	A	N	WM	N	WM	T	O	MTH	O	W	SG	SG	SG
30	W	SG	SG	SG	AA	H	A	A	N	WM	WM	WM	M	TL	LTH	TL	W	SG	SG	SG
35	W	SG	SG	SG	AA	H	A	A	N	WM	N	WM	M	TLO	LTH	TLO	W	SG	SG	SG
40	W	W	W	W	A	AA	AA	AA	N	VP	D	VP	T	T	LTH	T	W	W	W	W

Note. W = whole class S = Sub groups A = all AA = almost all H = half N = Notebook I = Individuals
VP = verbally passing WM = working with materials T = talking O = organise
M = monitoring L = listening CW = checking work AS = Asking HP = helping
[a] Observations made in a single 40-minute period

Table A1.23

Cycle Three - Results of Four Observations of Year 10 Class Undergoing Physics PBL Intervention for Newton's Laws

Time interval	Group activity				On task behaviour				Type of on task behaviour				Teacher behaviour				Teacher interaction			
Obs. No.	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
0	W	W	SG	SG	A	A	A	A	N	L	N	L	TO	T	MTH	T	W	W	SG	SG
5	W	SG	SG	SG	A	A	A	A	N	L	N	L	TO	TL	MTH	TL	W	W	SG	SG
10	SG	SG	SG	SG	A	A	A	A	N	VP	WM	WM	TO	TL	MTH	TL	SG	SG	SG	SG
15	SG	SG	SG	SG	A	A	A	A	N	VP	N	WM	TO	H	LTH	H	SG	SG	SG	SG
20	SG	SG	SG	SG	A	A	A	A	N	WM	N	WM	TO	M	LTH	M	SG	SG	SG	SG
25	W	SG	SG	SG	A	A	A	A	N	VP	N	WM	T	M	MTH	O	W	SG	SG	SG
30	W	SG	SG	SG	AA	A	A	A	N	WM	WM	WM	M	TL	LTH	TL	W	SG	SG	SG
35	W	SG	SG	SG	AA	A	A	A	N	WM	N	WM	M	TLO	LTH	TLO	W	SG	SG	SG
40	W	W	W	W	A	AA	AA	AA	L	L	L	L	T	T	LTH	T	W	W	W	W

Note. W = whole class S = Sub groups A = all AA = almost all H = half N = Notebook I = Individuals
VP = verbally passing WM = working with materials T = talking O = organise
M = monitoring L = listening CW = checking work AS = Asking HP = helping D = Describing
[a] Observations made in a single 40-minute period

A1.2 Chemical Reactions

A1.2.1 Knowledge

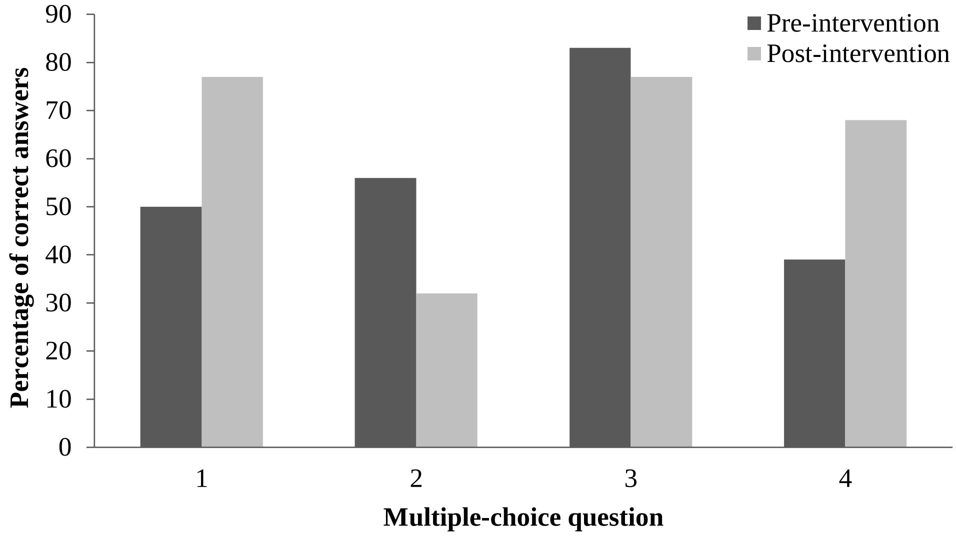


Figure A1.16. The percentage of correct responses to four multiple-choice questions regarding chemical reactions for cycle one.

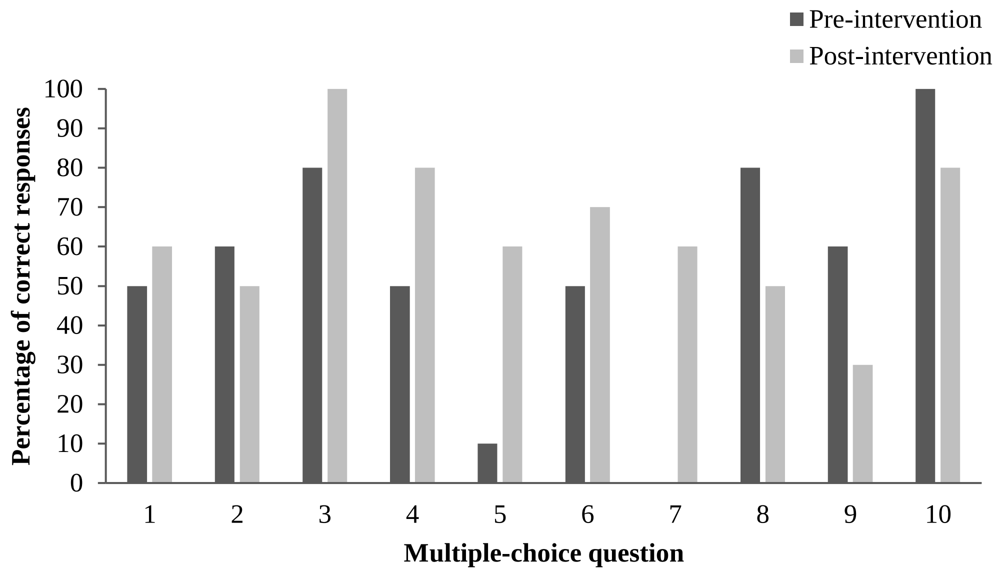


Figure A1.17. Percentage of correct responses to ten multiple-choice questions regarding chemical reactions for cycle three.

Table A1.24

Responses by Students to a Question Regarding Kinetic Theory Pre- and Post-intervention

Question	Explain why the ice cube on the right has melted more than the one on the left.					
Response coding	Changes in kinetic energy explained		Contains misconceptions		Describes the situation as shown	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	1	0	1	3	15	19
Frequency of response for cycle 3	3	5	2	1	5	4

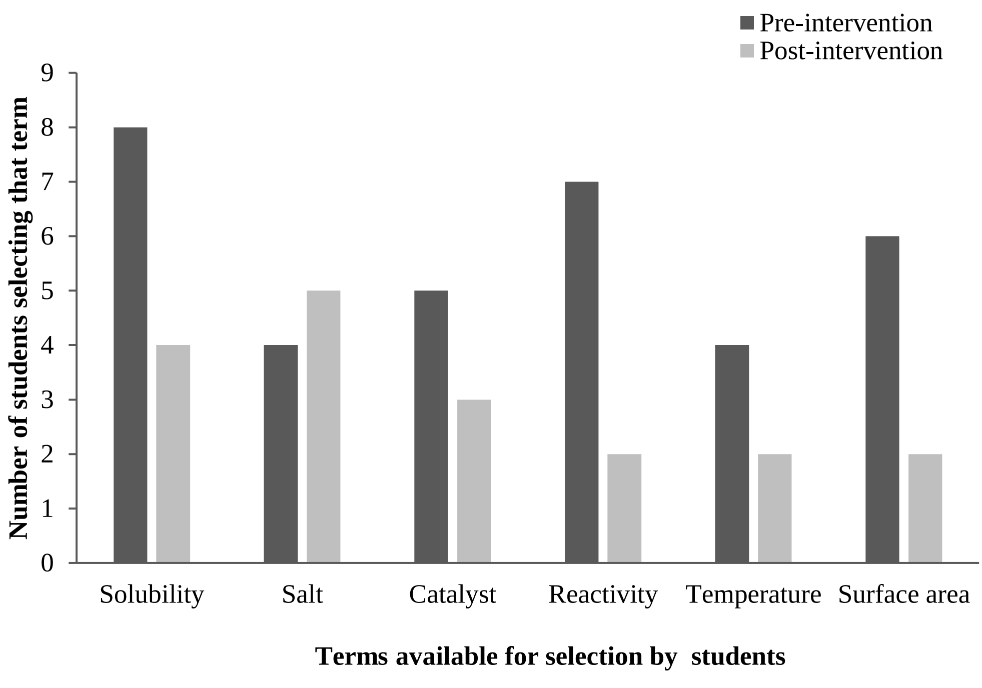


Figure A1.18. Student responses to the question “Circle the pieces of information below that you do not know about but may be relevant to the problem. Solubility Salt Catalyst Reactivity Temperature Surface area” pre-and post-intervention for cycle one.

Table A1.25

Responses by Students to a Question Regarding Increasing Reaction Rates Pre- and Post-intervention

Question	Describe how to increase the rate of a chemical reaction							
Response coding	Confuses chemical and physical changes		Contains misconceptions		Describes method correctly with elaboration		Describes method correctly without elaboration	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	4	1	5	5	0	1	8	14
Frequency of response for cycle 3	0	0	2	1	2	1	6	8

Table A1.26

Responses by Students to a Question Asking Them to List All Factors Affecting Reaction Rates Pre- and Post-intervention

Question	In trying to increase the rate of a reaction write down all the factors, you know of that will affect it.							
Response coding	Many factors listed with half or more correct		Many factors listed with more than half incorrect		One correct factor		One incorrect factor	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	7	17	10	2	0	2	1	2
Frequency of response for cycle 3	9	10	0	0	1	0	0	0

Table A1.27

Responses by Students to a Question Regarding How to Assign Group Members to a Specific Task Pre- and Post-intervention

Question	How would you decide which members of your group would be assigned to the different tasks required to complete this problem?									
Response coding	Allocated people to task		Determined who was best suited		Interest or preferred tasks		Combined group		Trying different tasks	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	4	9	10	5	8	1	0	0	0	6
Frequency of response for cycle 3	2	2	5	3	3	1	0	3	0	0

Table A1.28

Responses by Students to a Question Regarding Explaining How a Factor Affects Reaction Rates Pre- and Post-intervention

Question	Explain why increasing one factor that affects the rate of a reaction makes the reaction go faster.							
Response coding	Contains loose terminology		Contains misconceptions		Correctly explains factors affects		Restates the question	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	2	6	2	6	0	3	8	0
Frequency of response for cycle 3	6	2	0	1	2	4	0	2

Table A1.29

Responses by Students to a Question Regarding Explaining How to Use Equipment to Measure Reaction Rates Pre- and Post-intervention

Question	Describe how you would use the equipment below to measure the effect of temperature on the rate of a reaction. You may use items more than once.							
Response coding	Confuses measuring effect of different temperature on reaction rate with temperature of the reaction		Explanation does not relate to measuring reaction rate		Partial explanation of procedure		Proper use of equipment	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	2	0	11	10	2	7	0	2
Frequency of response for cycle 3	0	0	9	6	0	0	0	3

Table A1.30

Responses by Students to a Question Regarding Explaining How to Increase Reaction Rates Pre- and Post-intervention

Question	Explain how you would increase the rate of a reaction.							
Response coding	Factor correctly identified and explained		Factor identified but no explanation		Specifies a factor, but does not indicate which way increases the reaction rate		Irrelevant answer	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	0	2	7	8	0	3	6	7
Frequency of response for cycle 3	0	0	6	1	0	9	2	0

A1.2.2 Planning, monitoring and evaluation

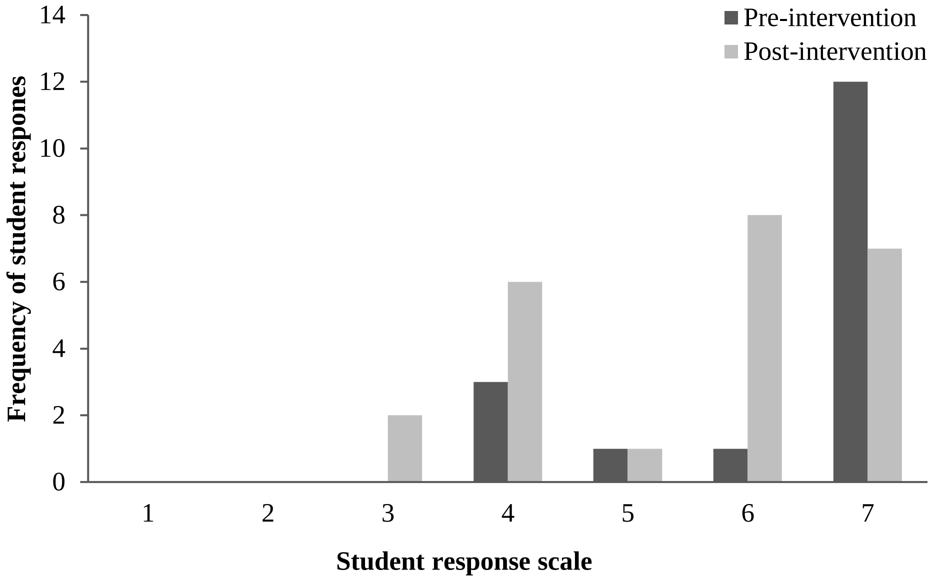


Figure A1.19. Frequency of student responses to a Likert scale with the question "How important is it that all group members contribute equally to the problem on a scale of 1 to 7" Pre-intervention and "Rate how well all group members contributed equally to the problem on a scale of 1 to 7" Post-intervention for cycle one.

Table A1.31

Student Responses to a Question Regarding Rating Various Items in Terms of Importance When Planning a Project Involving Rates of Reactions

Response scale			1 Not important		2		3		4 Important		5		6		7 Very important	
Intervention Pre/post		Cycle	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Scaled items	Reading some background information about the topic	1	1	3	0	0	1	3	5	2	1	2	3	4	7	8
		3	0	0	0	0	1	1	1	2	1	3	4	1	2	3
	Prioritise the learning needs	1	1	1	2	1	1	0	7	11	3	5	1	1	3	3
		3	1	0	1	3	3	1	2	4	2	1	0	1	1	0
	Set learning goals and objectives	1	2	2	1	2	1	3	5	6	3	5	2	3	4	1
		3	0	0	1	0	2	3	2	4	2	1	2	1	1	1
	Allocate resources	1	1	3	2	1	1	1	4	8	2	0	5	1	3	8
		3	0	0	0	1	1	1	2	2	3	0	3	2	1	4
	Identify which task each group member will do	1	0	1	2	4	2	1	6	7	2	5	3	2	3	2
		3	0	0	1	0	0	1	3	1	1	1	4	5	1	2

Table A1.32

Student Responses to a Question Regarding Rating Various Items in Terms of Importance When Completing a Project Involving Rates of Reaction

Response scale			1 Not important		2		3		4 Important		5		6		7 Very important	
Intervention Pre/post		Cycle	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Scaled items	Reading some background information about the topic	1	0	0	1	0	3	3	4	7	3	3	0	2	6	7
		3	0	0	1	0	3	3	2	2	2	3	1	1	1	1
	Prioritise the learning needs	1	2	2	1	2	1	3	6	7	2	5	1	0	4	3
		3	0	0	1	2	3	1	4	4	0	0	2	3	0	0
	Set learning goals and objectives	1	1	2	0	4	1	4	2	4	5	4	3	2	5	2
		3	0	0	1	0	1	3	3	3	1	2	2	0	2	2
	Allocate resources	1	1	2	0	1	1	0	2	6	5	5	3	3	5	5
		3	0	0	0	1	0	1	2	2	1	0	4	2	3	4
	Identify which task each group member will do	1	1	1	1	2	0	0	4	4	2	5	4	4	5	6
		3	0	0	0	0	1	0	1	3	3	1	3	2	2	3

Table A1.33

Student Responses to a Question Regarding Evaluating Each Step When Working on a Project Such as Investigating Reactions

Question	Describe how you would evaluate each step in your progress towards a solution to the problem													
Response coding	Compare with another group member		Compare with other groups		Irrelevant response		Post consideration		Prior consideration		Testing at each step		Trial and error	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	4	2	2	3	6	4	1	0	2	4	1	8	2	1
Frequency of response for cycle 3	5	1	0	0	0	0	2	4	0	0	1	4	0	0

Table A1.34

Student Responses to a Question Asking Them How They Were Performing a Task

Question	Explain how your group knew how well they were performing the task					
Response coding	Communicating		End result		Progress made	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	4	9	1	11	14	2
Frequency of response for cycle 3	0	0	2	0	7	10

Table A1.35

Student Responses to a Question Asking Them How They Would Search for Information

Question	Describe, in as much detail as possible, how you would search for information on this project											
Response coding	General book search		General Internet search		General person search		Specific Internet search		Specific book search		No search	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1 [a]	4	9	12	14	9	6	1	3	0	1	1	1
Frequency of response for cycle 3 [a]	2	4	8	9	3	3	1	0	0	0	0	0

Note: [a] Responses that fit more than one category were coded in each.

Table A1.36

Student Responses to a Question Asking Them How They Would Assess Information

Question How would you assess the information you found for your group?								
Response coding	Comparing		Relevance		Testing		Irrelevant	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	14	16	2	2	0	1	1	0
Frequency of response for cycle 3	4	5	1	2	2	3	0	0

A1.2.3 Student engagement

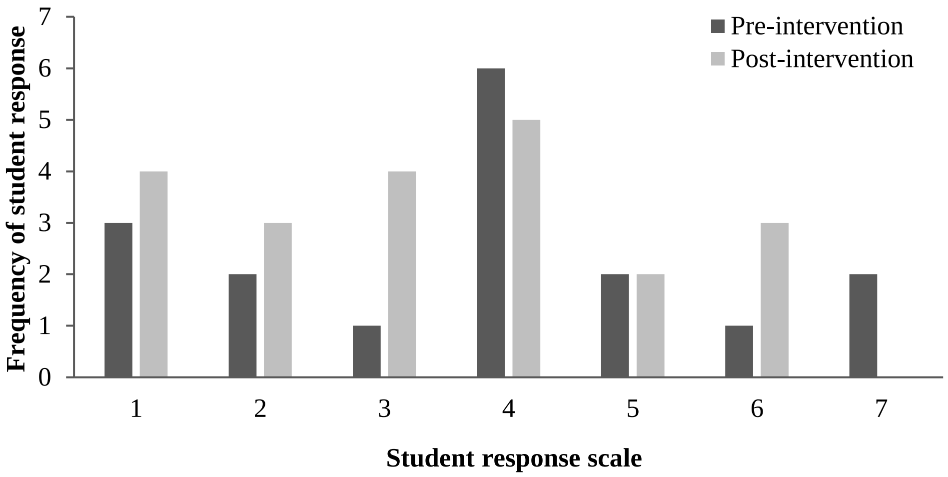


Figure A1.20. Frequency of student responses to a Likert scale with the question "How useful do you think this task would be to you on a scale of 1 to 7" Pre-intervention and "How useful do you think this task was to you on a scale of 1 to 7" Post-intervention for cycle one.

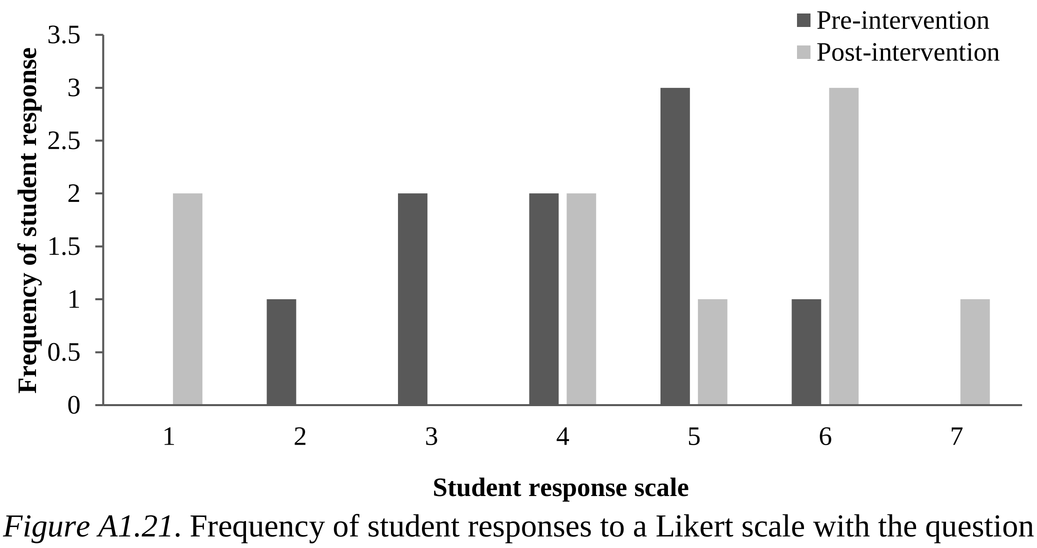


Figure A1.21. Frequency of student responses to a Likert scale with the question "How useful do you think this task would be to you on a scale of 1 to 7" Pre-intervention and "How useful do you think this task was to you on a scale of 1 to 7" Post-intervention for cycle three.

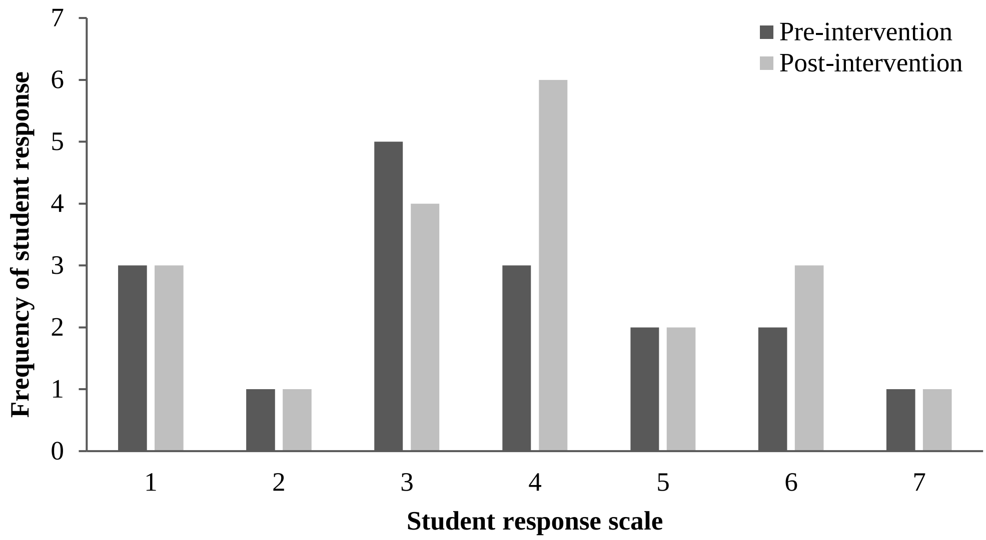


Figure A1.22. Frequency of student responses to a Likert scale with the question "How confident are you that you could complete this task without help on a scale of 1 to 7" Pre-intervention and "How confident are you that you could complete this task without help on a scale of 1 to 7" Post-intervention for cycle one.

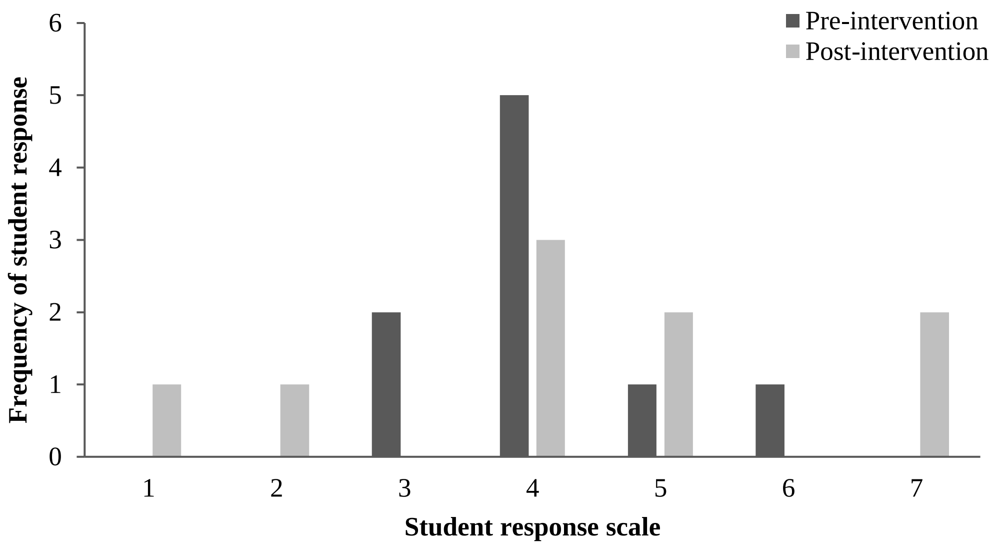


Figure A1.23. Frequency of student responses to a Likert scale with the question "How confident are you that you could complete this task without help on a scale of 1 to 7" Pre-intervention and "How confident are you that you could complete this task without help on a scale of 1 to 7" Post-intervention for cycle three.

Table A1.37

Student Responses to a Question How They Would Motivate Themselves

Question	Describe how you would motivate yourself to complete such a task															
Response coding	Good end result		Grades		I have to		Learn something new		Not motivated		Support team		Timing		The topic	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	4	1	3	8	2	4	0	1	0	1	6	5	0	0	1	1
Frequency of response for cycle 3	1	1	0	2	2	0	0	0	0	0	0	2	6	2	0	3

Table A1.38

Student Responses to a Question as to Whether They Thought the Activity Would be Enjoyable

Question	Explain why you think this activity would be enjoyable or not enjoyable.											
			Enjoyable						Not enjoyable			
Response coding	Both		Hands on		New skills		Group work		Boring		No interest relevance	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	3	0	2	11	2	0	0	2	2	7	4	2
Frequency of response for cycle 3	0	0	2	4	1	1	2	0	0	0	4	4

Table A1.39
Student Responses to a Question as to Whether They Thought the Activity Would be Difficult

Question	How difficult did you find this problem? Explain with specific examples											
	Difficult								Not difficult			
Response coding	Boring not interested distracted		Complex problem		Unfamiliar		Weak in subject area		Group support		Persevere	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 1	1	1	2	2	0	7	9	0	4	1	2	8
Frequency of response for cycle 3	1	0	4	1	1	0	3	1	0	2	1	0

A1.2.4 Observations

Table A1.40
Cycle One - Informal Classroom Observations

Date	Observations
18/10/2013	Class two Introduced students to new topic. Introduced students to the e-book - some problems with the e-book Explained that they would be working in smaller group on smaller scale problems. Wrong time to introduce new topic, but no real choice. Some students started work on problem one, but others had switched off.
21/10/2013	Class two Students started the first problem today carrying out 10 simple experiments to identify decomposition reactions. Groups were assigned randomly with no group larger than 4. All but one group was fully engaged on the task. One group had two members that were not engaging. Most students seemed to have a good idea of what they were doing, but the same two members of one group were recording nothing. This lesson was much more successful, but it will be interesting to see how the analysis goes on Wednesday!

(continued)

Date	Observations
22/10/2013	Class one Students were organized and worked through the first problem well. All groups were on task although participation of various members in each group varied. Recording of information by all member of the group is still an issue.
23/10/2013	Class one This was a good lesson. Students were once again working on the ten reactions for the first problem. All groups completed the 10 reactions and started to work on identifying the decomposition reactions. Most students were recording their results. Class two Students worked well. Helped individual groups with problems. Students needed guidance with working through problems. Most could work through and identify different reactions. Some chemistry prior knowledge was accessed by students with help which was encouraging as was the level of engagement and motivation with a difficult topic.
24/10/2013	Class one Students write of first problem. Not as successful as other group however students were still motivated and on task. However, they had to be given a lot more help with identifying the reactions. Maybe more background information. A number of issues concerned with the printing of the reports. However almost all produced a report. Class two Students finished reports and printed at start of lesson. issues with printing and students finishing reports. Students start second problem. Students completed reactions within one period except for 2 groups. Students worked well and were on task. Not a lot of difference in observations between problem 1 and 2 despite this being highlighted to them.
28/10/2013	Class one Students carried out the second problem reactions. Students worked quickly through the reactions. Students were taking notes of the reactions results. Students had some time to start analysis, but a number of them did not use this time well. This may be due to OED camp tomorrow. Class two Students completed the reactions for Problem 2 Students worked through the reactions well. Good analysis of the reactions with less questioning of me. Students were able to work through the problem independently. Students completed the problem today (Monday)

(continued)

Date	Observations
04/11/2013	Class one Students are completing write up of 2nd problem. Most groups are on task, but with no sense of urgency. Third problem started. Students seem unable to make connections between the problems they are working on. Class two Students started problem 3. Students were slow to start today and off task. Once one group had started most of the other groups followed. This was a more challenging problem for the students as they were given less help from the ebook. Students for the most part were less confident.
05/11/2013	Class two Reviewed what was required for the first three steps for problem 3. Class was responsive, but not enthusiastic. Report on second problem was not as good as the first. Students just copied information and did not provide evidence for their reactions. Students, mostly seem to be engaging with materials. Basic skills like reading a table are missing from these students. They do not have the tools to work on the problems - this needs to be addressed,
06/11/2013	Class one Students working on problem 3. Most students on task and working well. Not many questions from students though. However, some students are finishing ahead of time. Class two Students working on problem 3. Students working well and interacting with background info. Identified problem in solubility table! Students generally seemed to engage with the problem in this session.
07/11/2013	Class one Students completed problem 3 and started problem 4. Students set up experiment. I am not convinced that the students understood the purpose of the experimental set up. Went through steps 1 and 2 with students and this did help them identify what they needed from the set up, but students do not self-start. Students then had to identify what they did not know on their own. Again, students find it hard to motivate themselves. Class two Students started problem 4. The situation was identical to the other class. Students are not aware of why they are doing the experiment in terms of what it is supposed to show them. Doing steps 1 and 2 with the class was helpful, but again do not self-start. Students left to do step 3 but were not highly motivated. A lot of time wasted.

(continued)

Date	Observations
08/11/2013	Class two Students had results from oxidation experiment today. Spoke to them regarding linking evidence with results which they did not do in their last report. Students collected results from the experiment. Most were working on interpreting their results. General discussion of their results occurred with students mostly working in groups. The current format of the PBL is not working well. This needs a radical overall to be in tune with what students are capable of proving. Need to identify key ideas that students can work with in their ebook.
11/11/2013	Class one Students are much less motivated. Results of problem 3 were varied with many good results. Students reluctant to even look at results. Most students reluctant to ask questions Most students on task, but some clearly off task. Students are mostly capable of working through the problem if they are willing to think. Class two Results of last problem were varied with some very good results and some poor ones. Students did not provide evidence of the reactions. Working on the next problem students are getting better at knowing what questions to ask and working through the problem to a solution.
13/11/2013	Class one A very clear distinction is developing between students that are totally disengaged and those that are willing to work through the problem. The cause is most likely that many students will not be doing science next year. Students who work through the problem are capable of getting answer to the problem. The current format is unworkable and needs modification. Class two Students worked well on the problem Most groups engaged, and they were able to complete the answer in 2 periods.
14/11/2013	Class one Students worked on problem 6. Generally worked well on the problem, but at a simplistic level. Students needed help ensuring that they changed only one variable and measured all reactants.
18/11/2013	Class two Not a good lesson due mainly to a lack of equipment.

Table A1.41

Cycle Three - Informal Classroom Observations

Date	Observations
	Students completed pre-evaluation. Students loaded e-textbook – surprisingly few issues.
8/08/16	Students working quietly through the first part of the e-textbook. Very little interaction between students. Slowly groups are starting to discuss the first problem. Groups need encouragement. Groups are not confident about talking about chemistry even amongst themselves. Some still prefer to talk to the teacher?????? Will review what they know about decomposition reactions tomorrow briefly.
9/08/16	Students working well. Accessing extra information regarding decomposition reactions. Students discussing decomposition reactions in their groups. Discussion of what they are looking for with the decomposition reactions was helpful.
10/08/16	Students generally were working well. Students have progressed on to the experiments for problem 1. Students conducted experiments well with only a few safety issues. Students still have problems interpreting their results which shows a lack of applying prior knowledge. Students still have issues with writing equations. Students still not clear about what a decomposition reaction is or if one has occurred.
11/08/16	Students working on problem 1 Most students on task with good discussion about the problem Trying to facilitate learning in 5 groups is a challenge. Students struggle to apply what they already know to what they are working on. Specifically writing ionic formula and balancing equations. The formula and equation writer are helping students A couple of students were off task.
15/08/16	Not a good day. Network was down and students could not access e-textbook. Students used normal textbook instead.
16/08/16	Generally, students working well. Good interaction between students discussing problem 2. Accessing information on Progress is a little slower than I would have liked due to students not assimilating prior knowledge.
17/08/16	Students working well. One group is on to problem 3 Some issues with the e-textbook. Despite testing and checking errors have crept into the e-textbook which is frustrating.
18/08/16	Students continue to work well. Students seem more confident with the chemistry topic including formula writing and equations due to the formula and equation writer despite some problems.

(continued)

Date	Observations
22/08/16	Students are working well together on problem 4. Students are helping each other and are working as a group.
24/08/16	Students continue working well. Much discussion occurring between members of each group.
25/08/16	Students working on final problem. Some confusion as to how to measure rates of reaction. Continuing to access information Generally, students working well.
29/08/16	Students working through final problem. Some students are getting conflicting results which prompted much discussion.
30/08/16	Students continue to work well.
31/09/16	Some groups have finished. Students are getting tired of the process now.
1/09/16	PBL Evaluation Tool.

Table A1.42

Cycle Three - Results of Four Observations of Year 10 Class Undergoing Chemical Reactions PBL Intervention

Time interval	Group activity				On task behaviour				Type of on task behaviour				Teacher behaviour				Teacher interaction			
Obs. No.	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
0	SG	W	SG	W	A	A	A	A	N	L	N	L	TO	T	MTH	T	SG	W	SG	W
5	SG	W	SG	SG	A	A	A	A	N	L	N	L	TO	TL	MTH	TL	SG	W	SG	SG
10	SG	SG	SG	SG	A	A	A	A	N	VP	WM	WM	TO	TL	MT	TL	SG	SG	SG	SG
15	SG	SG	SG	SG	A	A	A	A	N	VP	WM	WM	TO	H	LT	H	SG	SG	SG	SG
20	SG	SG	SG	SG	A	A	A	A	N	WM	N	WM	TO	M	LTH	M	SG	SG	SG	SG
25	SG	SG	SG	SG	A	A	A	A	N	WM	N	WM	T	O	MT	O	SG	SG	SG	SG
30	SG	SG	SG	SG	AA	A	A	A	N	WM	WM	WM	M	TL	LTH	TL	SG	SG	SG	SG
35	SG	SG	SG	SG	AA	A	A	A	N	WM	N	WM	M	TLO	LTH	TLO	SG	SG	SG	SG
40	W	W	W	W	A	AA	AA	AA	N	VP	D	VP	T	T	LTH	T	W	W	W	W

Note. W = whole class SG = Sub groups A = all AA = almost all H = half N = Notebook
I = Individuals VP = verbally passing WM = working with materials T = talking O = organise
M = monitoring L = listening CW = checking work AS = Asking HP = helping
a Observations made in a single 40-minute period

A1.3 Compression and Tension

A1.3.1 Knowledge

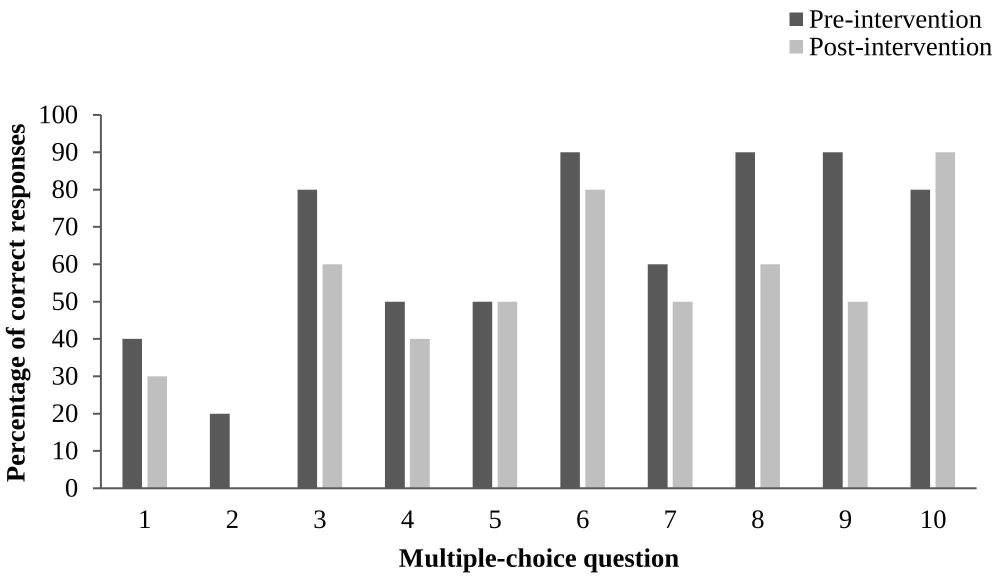


Figure A1.24. Percentage of correct responses to ten multiple-choice questions regarding Compression and Tension for cycle two.

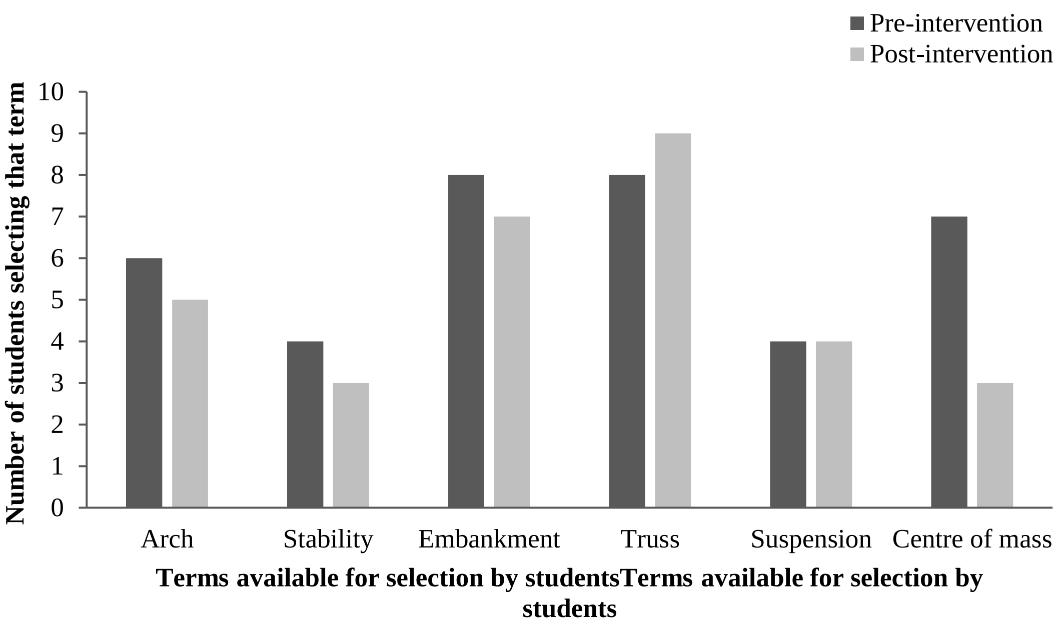


Figure A1.25. Student responses to the question “Circle the pieces of information below that you do not know about but may be relevant to the problem. Arch, Stability, Embankment, Truss, Suspension and Centre of mass” pre-and post-intervention for cycle two.

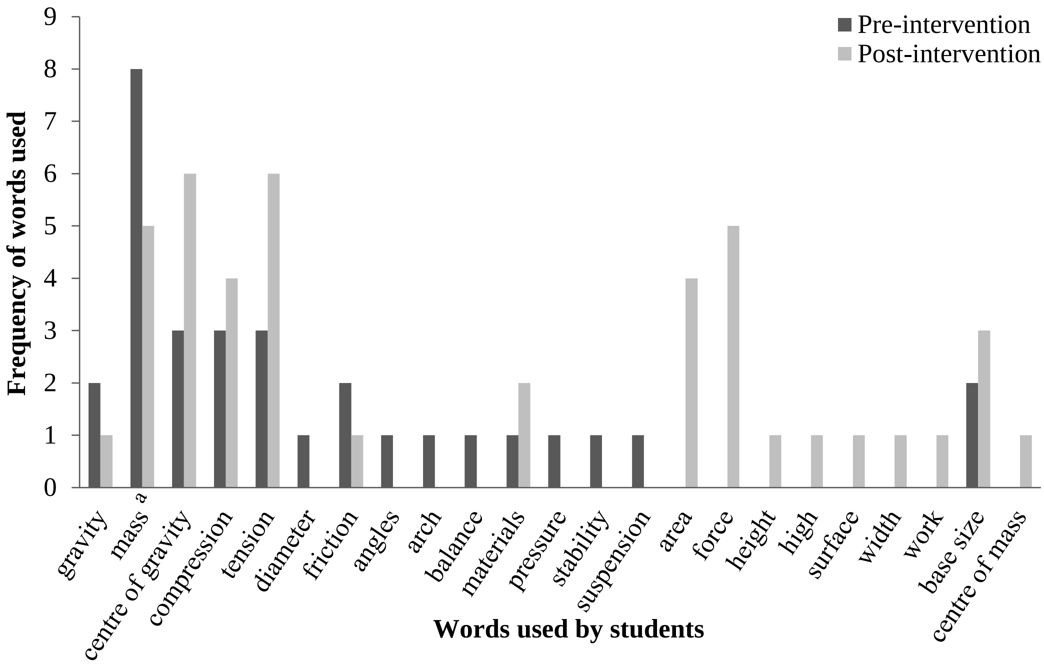


Figure A1.26. The frequency of the 23 most often used words by students when asked "In trying to reduce stress on an object write down all the factors you know of that will affect it." pre- and post-intervention for cycle two.

[a] Terms mass and weight were combined

Table A1.43

Responses by Students to a Question Regarding Describing an Example of Stress Reduction Pre- and Post-intervention

Question	Stress is related to the amount of force that is applied over an area. Describe a situation where stress has been reduced in a structure.							
Response coding	Mass reduction		Base size increase		Contains misconceptions		Irrelevant	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 2	3	0	1	3	0	2	1	1

Table A1.44

Student Responses to a Question Regarding Stability of Two Towers

Question	Explain why the first tower is stable and the second is not.									
Response coding	Centre of gravity		Leaning		Materials		Base size		Centre of mass	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 2	1	1	3	0	1	2	1	6	4	0

Table A1.45

Responses by Students to a Question Regarding Describing an Example of Compression Reduction Pre- and Post-intervention

Question	Describe how to reduce compression on a bridge column.							
Response coding	Mass reduction		Base size increase		Add tension		Irrelevant	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 2	6	2	2	0	0	3	0	1

Table A1.46

Responses by Students to a Question Regarding How to Assign Group Members to a Specific Task Pre- and Post-intervention

Question	How would you decide which members of your group would be assigned to the different tasks required to complete this problem?							
Response coding	Allocated people to task		Determined who was best suited		Interest or preferred tasks		Combined group-work	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 2	2	0	2	0	4	2	1	7

A1.3.2 Planning, monitoring and evaluation

Table A1.47

Student Responses to a Question Regarding Rating Various Items in Terms of Importance When Planning a Project Such as Building a Bridge for Cycle Two

	Response scale	1 Not important		2		3		4 Important		5		6		7 Very important	
	Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Scaled items	Reading some background information about the topic	1	1	2	1	1	2	5	2	0	0	1	1	0	2
	Prioritise the learning needs	3	0	2	2	0	1	5	2	0	0	0	3	0	1
	Set learning goals and objectives	0	3	1	0	4	3	4	1	0	0	0	1	1	1
	Allocate resources	0	0	1	1	1	0	1	2	2	1	1	2	4	3
	Identify which task each group member will do	2	0	0	0	0	0	2	5	1	2	2	1	3	1

Table A1.48

Student Responses to a Question Regarding Rating Various Items in Terms of Importance When Completing a Project Such as Building a Bridge for Cycle Two

Response scale		1 Not important		2		3		4 Important		5		6		7 Very important	
Intervention Pre/post		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Scaled items	Reading background information about the topic	0	1	0	2	3	0	4	1	1	0	1	2	1	3
	Prioritise the learning needs	2	2	1	0	0	2	5	2	0	0	0	2	2	1
	Set learning goals and objectives	0	1	2	0	2	2	4	4	1	0	0	1	1	1
	Allocate resources	0	1	1	0	0	1	1	1	2	1	3	1	3	4
	Identify which task each group member will do	2	1	0	0	0	0	1	2	0	2	1	1	6	3

Table A1.49

Student Responses to a Question Regarding Evaluating Each Step When Working on a Project Such as Building a Bridge

Question	Describe how you would evaluate each step in your progress towards a solution to the problem									
Response coding	Compare with another group member		Irrelevant response		Post consideration		Prior consideration		Testing at each step	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 2	3	1	1	2	2	0	0	2	0	2

Table A1.50

Student Responses to a Question Asking Them How They Would Search for Information

Question	Describe, in as much detail as possible, how you would search for information on this project							
Response coding	General book search		General Internet search		General person search		Specific Internet search	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 2 [a]	2	2	8	6	5	1	0	2

Note: [a] Responses that fit more than one category were coded in each.

Table A1.51

Student Responses to a Question Asking Them How They Were Performing a Task

Question	Explain how your group knew how well they were performing the task					
Response coding	Communicating		End result		Progress made	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 2	1	0	3	6	4	3

Table A1.52

Student Responses to a Question Asking Them How They Would Assess Information

Question	How would you assess the information you found for your group?					
Response coding	Comparing		Relevance		Testing	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 2	7	3	0	2	2	3

A1.3.3 Student engagement

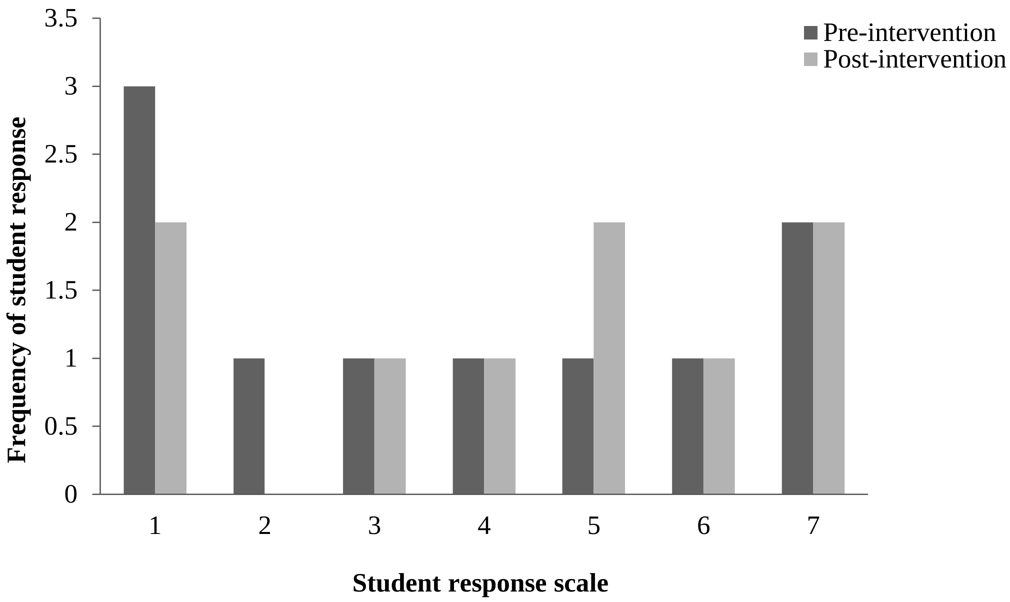


Figure A1.27. Frequency of student responses to a Likert scale with the question "How useful do you think this task would be to you on a scale of 1 to 7" Pre-intervention and "How useful do you think this task was to you on a scale of 1 to 7" Post-intervention for cycle two.

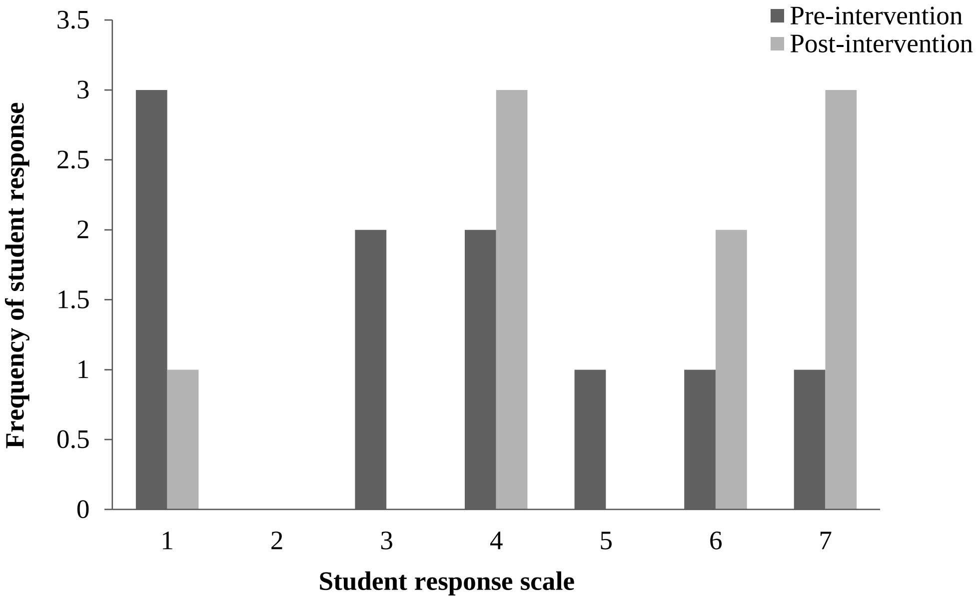


Figure A1.28. Frequency of student responses to a Likert scale with the question "How confident are you that you could complete this task without help on a scale of 1 to 7" Pre-intervention and "How confident are you that you could complete this task without help on a scale of 1 to 7" Post-intervention for cycle two.

Table A1.53

Student Responses to a Question How They Would Motivate Themselves

Question	Describe how you would motivate yourself to complete such a task									
Response coding	Good end result		Grades		I have to		Support team		The topic	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 2	3	4	1	0	1	2	2	0	1	2

Table A1.54

Student Responses to a Question as to Whether They Thought the Activity Would be Enjoyable

Question	Explain why you think this activity would be enjoyable or not enjoyable.					
Response coding	Enjoyable				Not enjoyable	
	Hands on		Group-work		No interest relevance	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post
Frequency of response for cycle 2 [a]	4	4	1	1	5	3

Note: [a] Responses that fit more than one category were coded in each.

Table A1.55

Student Responses to a Question as to Whether They Thought the Activity Would be Difficult

Question	How difficult did you find this problem? Explain with specific examples											
	Difficult						Not difficult					
Response coding	Boring not interested distracted		Complex problem		Weak in subject area		Group support		Enjoy subject		Persevere	
Intervention Pre/post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Frequency of response	1	1	1	3	2	0	1	1	4	3	0	1

A1.3.4 Observations

Table A1.56
Cycle Two - Informal Classroom Observations

Date	Observations
10/11/15	Briefly talked about PBL and assessment for topic. Started e-textbook today with students. Book loaded ok and students worked quietly on PBL section. Students engaged in e-textbook. No tech problems.
11/11/15	Students continued with e-textbook. Students had to re do PBL if not completed which caused some frustration. Some students found a way around this using the index. Generally, students were working well and engaged. Little talk about problem 1 in some groups, however others were discussing ideas. Have to explain to some groups about communicating. Students resort to looking for information in textbook. Others using internet.
12/11/15	Students are well engaged in the topic. Some frustrated over the limitations, but they have to accept these limitations E-book is now not being used as students move into the problem. This is good! Much on task discussion. Today I would class this as successful. As the lesson progressed students became more disengaged but were still on task most of the time.
16/11/15	Some groups working well – those who have designed their bridges. Internet problems have stalled some groups. Some members in some groups are reluctant to contribute – lazy. Personality of group members plays an important role.
17/11/15	All groups have now started building their bridges. Involvement between groups is variable. A number of students are in the don't care mode. Some groups working well although bridge designs are not particularly good. I don't think a lot of research has been done. They are relying on intuition.
18/11/15	Two groups have completed their bridges and tested them. Both groups did not meet the full design specifications for their bridge. All other groups were working well on their bridges with good group discussion.
23/11/15	Groups working on reports or bridges. Groups working, but without any degree of urgency. It is like it is something they have to do rather than something they want to do or interested in. Again, some members of the group are not working/involved. Three groups have completed their bridge and tested it with each design an improvement on the previous groups. One group is on to the tower problem.
24/11/15	Two groups presenting their reports. Huge technical issues with students on their laptops accessing network Groups working on bridges. One group's bridge had been smashed and they had to rebuild it.

(continued)

Date	Observations
30/11/15	Resumed after two-day break. Some students had their bridges destroyed. Most group have now finished their bridges and are working on their reports.
1/12/15	Students continued working today. Most groups functioning well. Students seem to have settled into a routine.
3/12/15	This was not a good lesson. Students who were working on their projects were OK. Students working on reports were less motivated. One group working on their design for the tower were not really trying. This was the last lesson for the class.
4/12/15	PBL Evaluation Tool.

Table A1.57

Cycle Two - Results of Four Observations of Year 10 Class Undergoing Physics PBL Intervention for Newton's Laws

Time interval	Group activity				On task behaviour				Type of on task behaviour				Teacher behaviour				Teacher interaction			
Obs. No.	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
0	W	W	SG	W	A	A	A	A	N	L	N	L	TO	T	MTHP	T	W	W	SG	W
5	SG	W	SG	SG	A	A	A	A	N	L	N	L	TO	TL	MTHP	TL	SG	W	SG	SG
10	SG	SG	SG	SG	AA	H	H	A	N	VP	WM	WM	TO	TL	MTHP	O	SG	SG	SG	SG
15	SG	SG	SG	SG	AA	H	AH	A	N	VP	WM	WM	TO	HP	LTHP	H	SG	SG	SG	SG
20	SG	SG	SG	SG	AA	H	AH	H	N	WM	WM	WM	TO	M	LTHP	M	SG	SG	SG	SG
25	W	SG	SG	SG	AA	H	AH	H	N	WM	N	WM	T	O	MTHP	O	W	SG	SG	SG
30	W	SG	SG	SG	AA	H	AH	H	N	WM	WM	WM	M	TL	LTHP	TL	W	SG	SG	SG
35	W	W	SG	SG	AA	H	H	H	N	WM	WM	WM	M	TLO	LTHP	TLO	W	W	SG	SG
40	W	W	W	W	A	AA	AA	AA	N	VP	N	VP	T	T	LTHP	T	W	W	W	W

Note. W = whole class S = Sub groups A = all AA = almost all H = half N = Notebook I = Individuals VP = verbally passing WM = working with materials T = talking O = organise M = monitoring L = listening CW = checking work AS = Asking HP = helping
[a] Observations made in a single 40-minute period

Appendix 2 Discussion

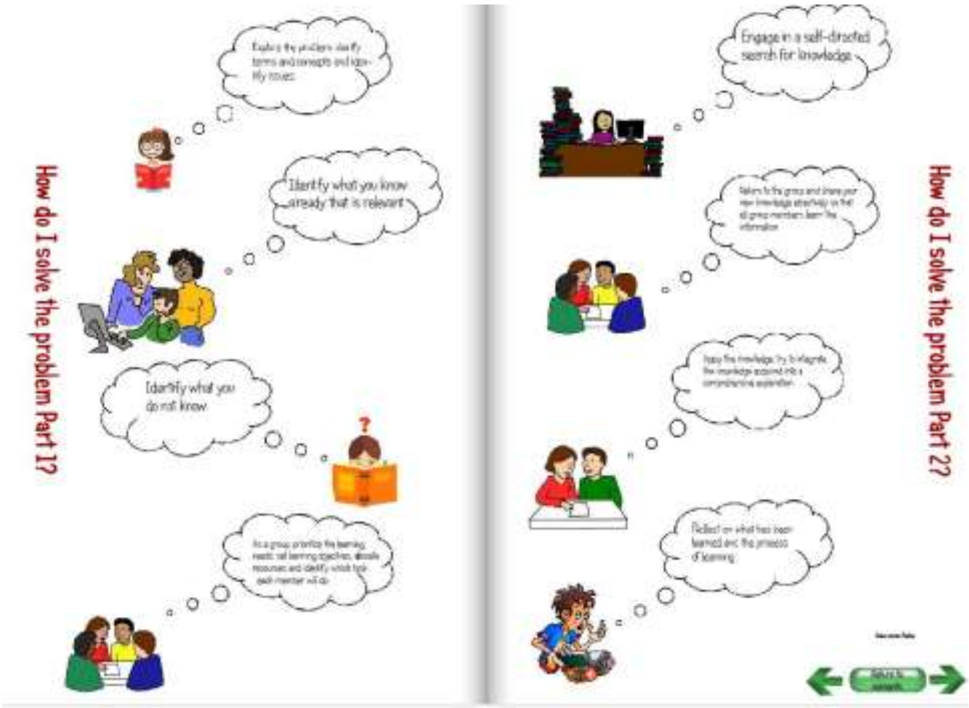


Figure A2.1. Screen shot from the Newton’s Laws e-textbook showing PBL techniques in cycle one, intervention one and two.

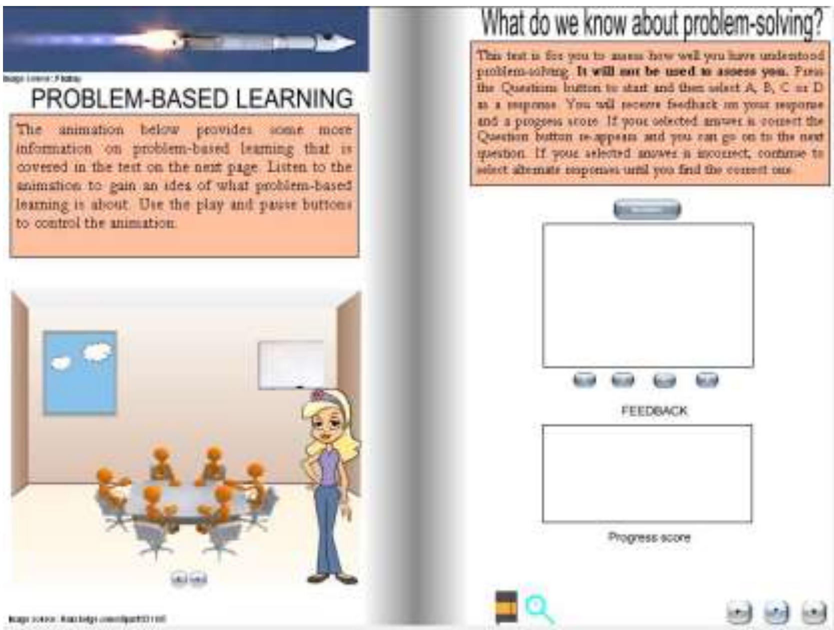


Figure A2.2. Screen shot from the Newton’s Laws e-textbook showing PBL techniques in cycle two, intervention one.

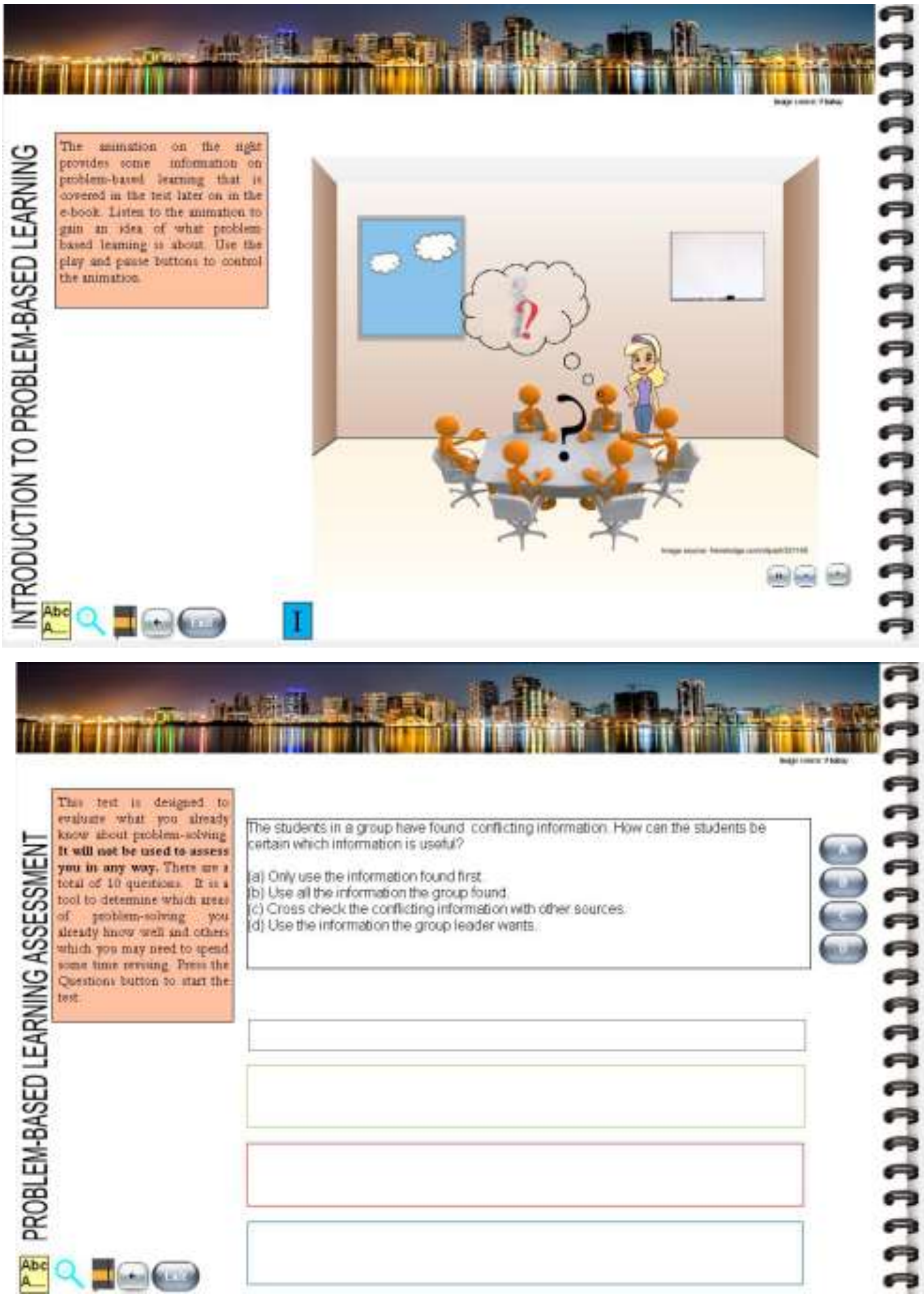


Figure A2.3. Screen shot from the Compression and Tension e-textbook showing PBL techniques and assessment in cycle two, intervention two.

Figure A2.4. Screen shot from the Compression and Tension e-textbook showing the review of PBL topics covered; Research, Group-work and Motivation in cycle two, intervention two.

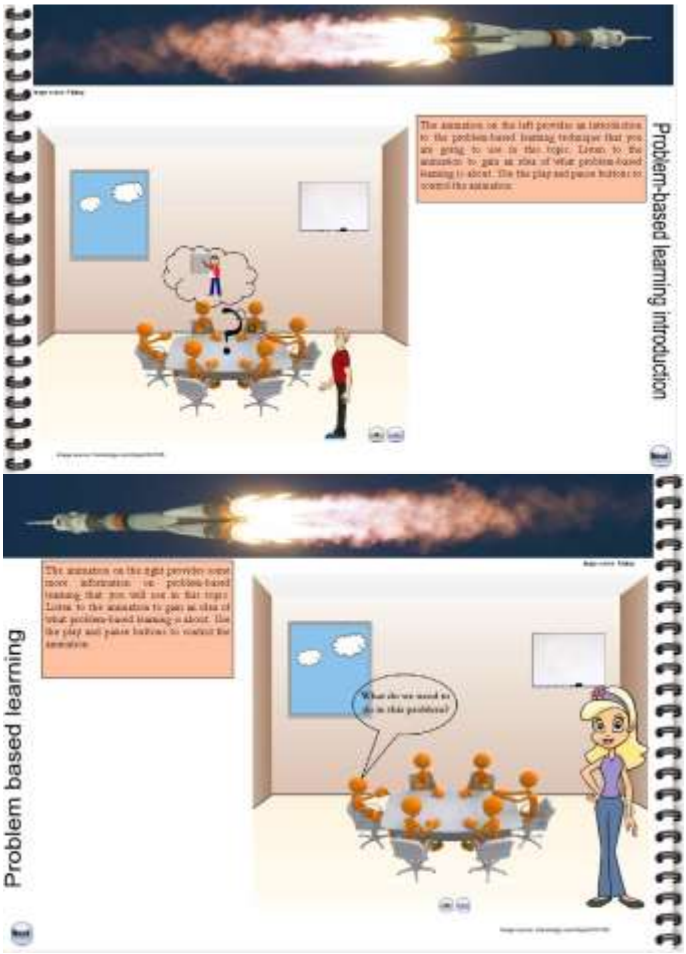


Figure A2.5. Screen shot from the Newton’s Laws e textbook showing the introduction to PBL presented to students in cycle three, intervention one and two.

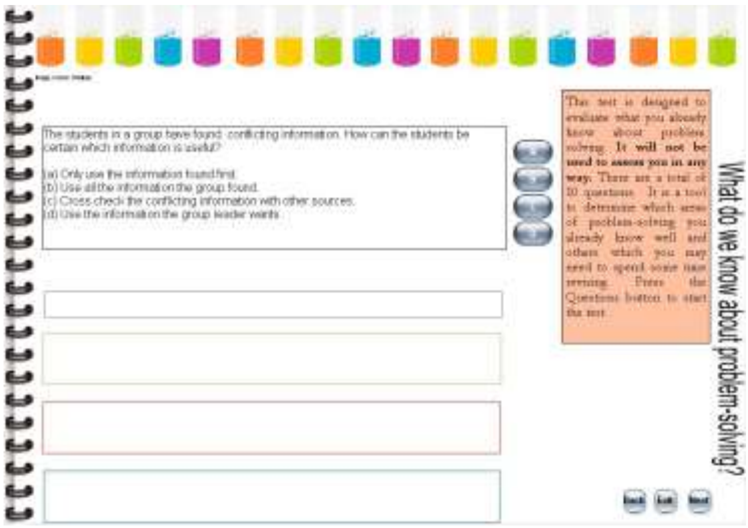


Figure A2.6. Screen shot from the Chemical Reactions e-textbook showing the PBL assessment presented to students cycle three, intervention two.

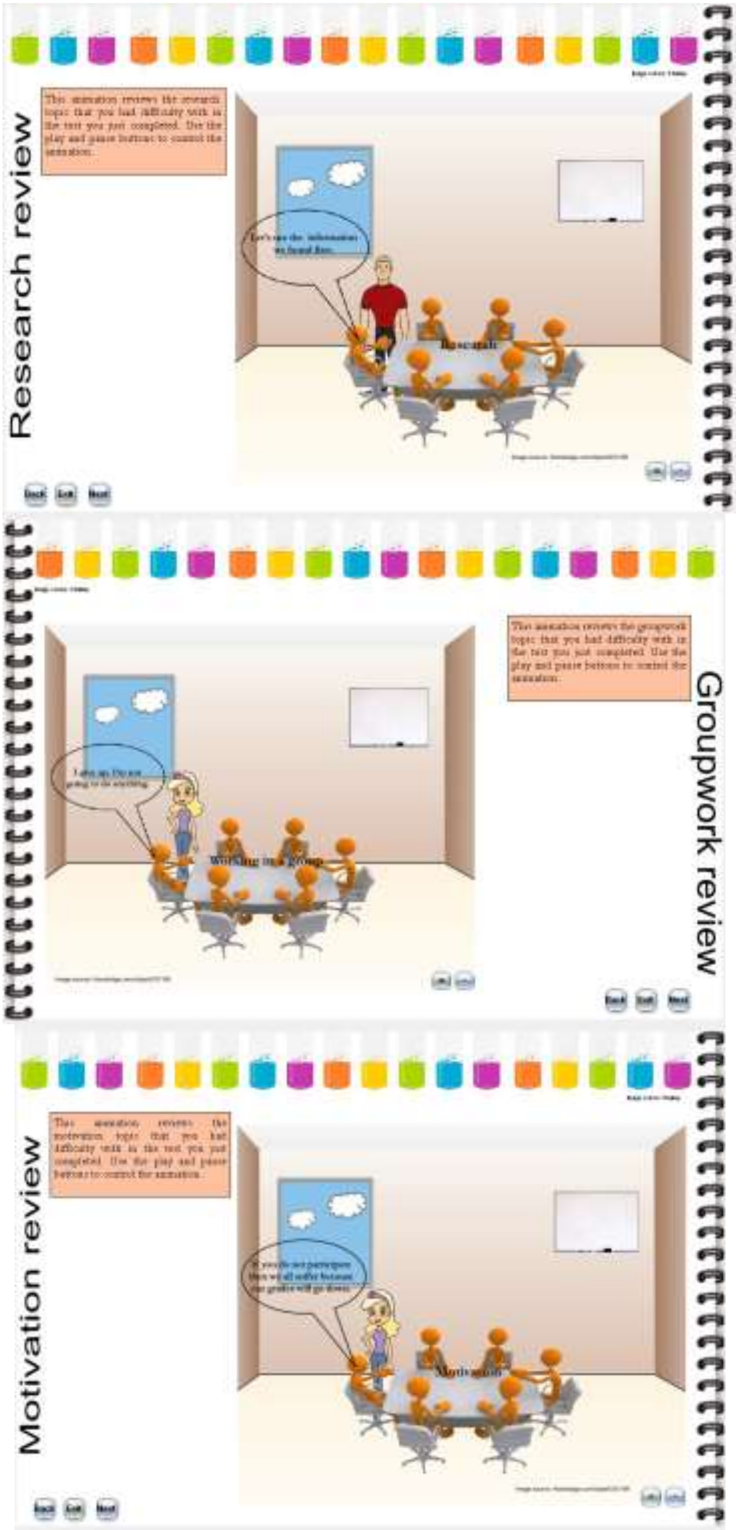


Figure A2.7. Screen shot from the Chemical Reactions e-textbook showing the review of PBL topics covered; Research, Group-work and Motivation in cycle three, intervention two.

Figure A2.8. Screen shot from the Newton's Laws e-textbook showing the coverage on Newton's Laws from cycle one, intervention one.

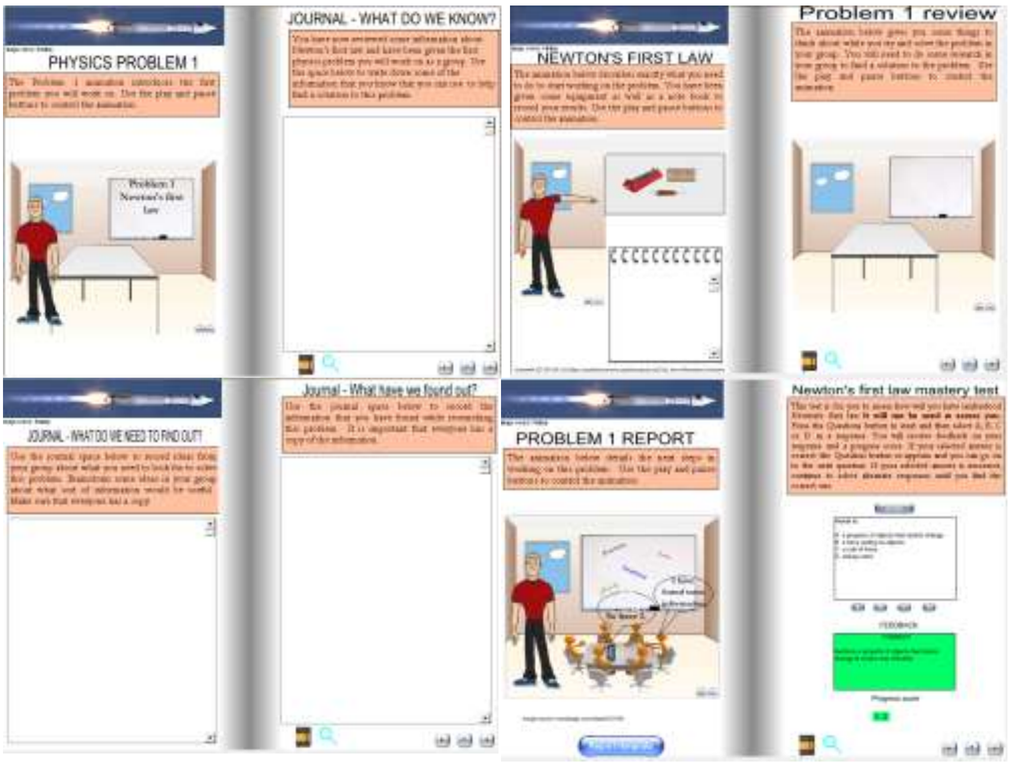


Figure A2.9. Screen shot from the Newton's Laws e-textbook showing the coverage of Newton's First Law from cycle two, intervention one.

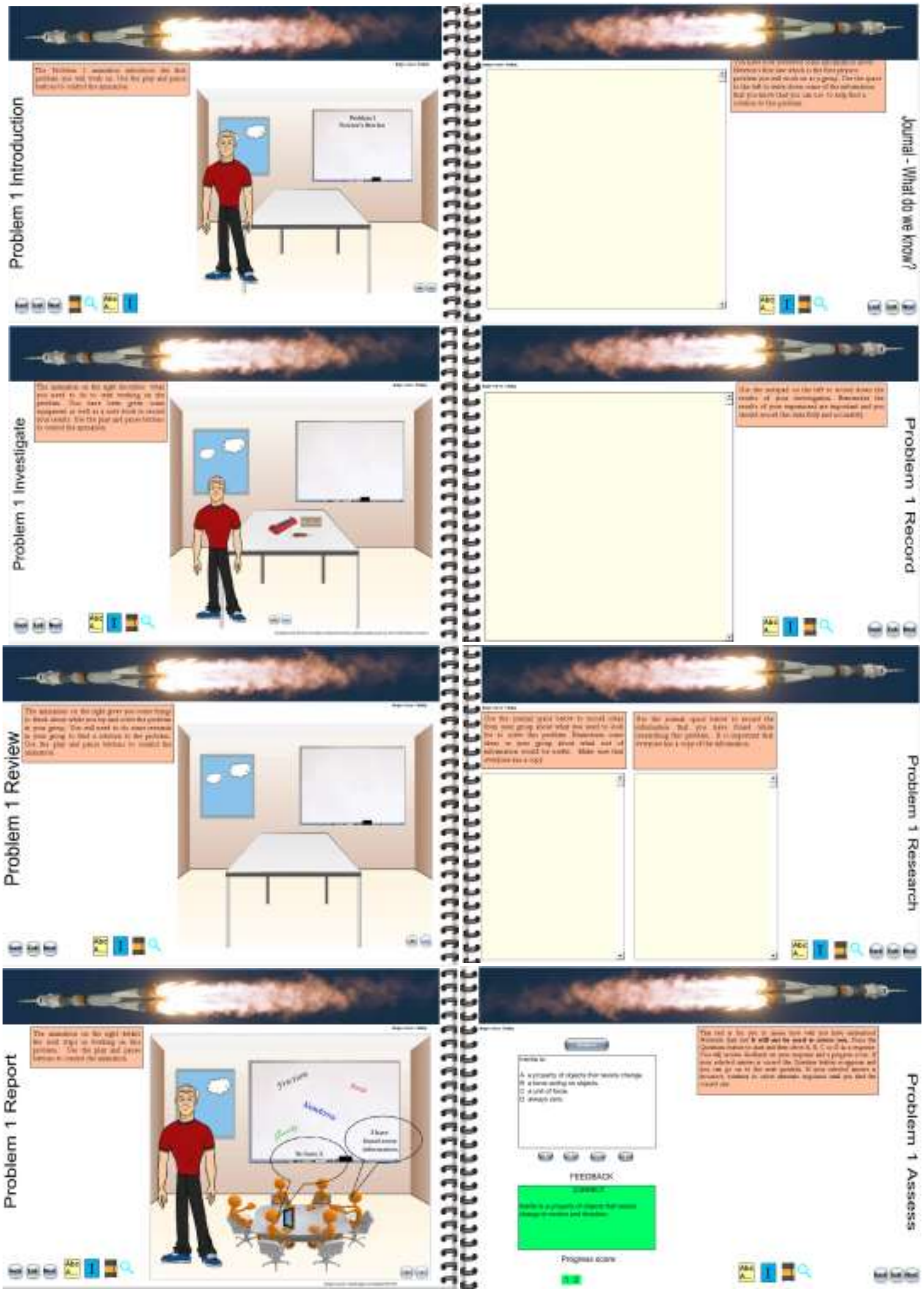


Figure A2.10. Screen shot from the Newton’s Laws e-textbook showing the coverage of Newton’s First Law from cycle three, intervention one.

Figure A2.11. Screen shot from Newton's Laws e-textbook showing the introduction of the rocket problem to students in cycle one, intervention one.

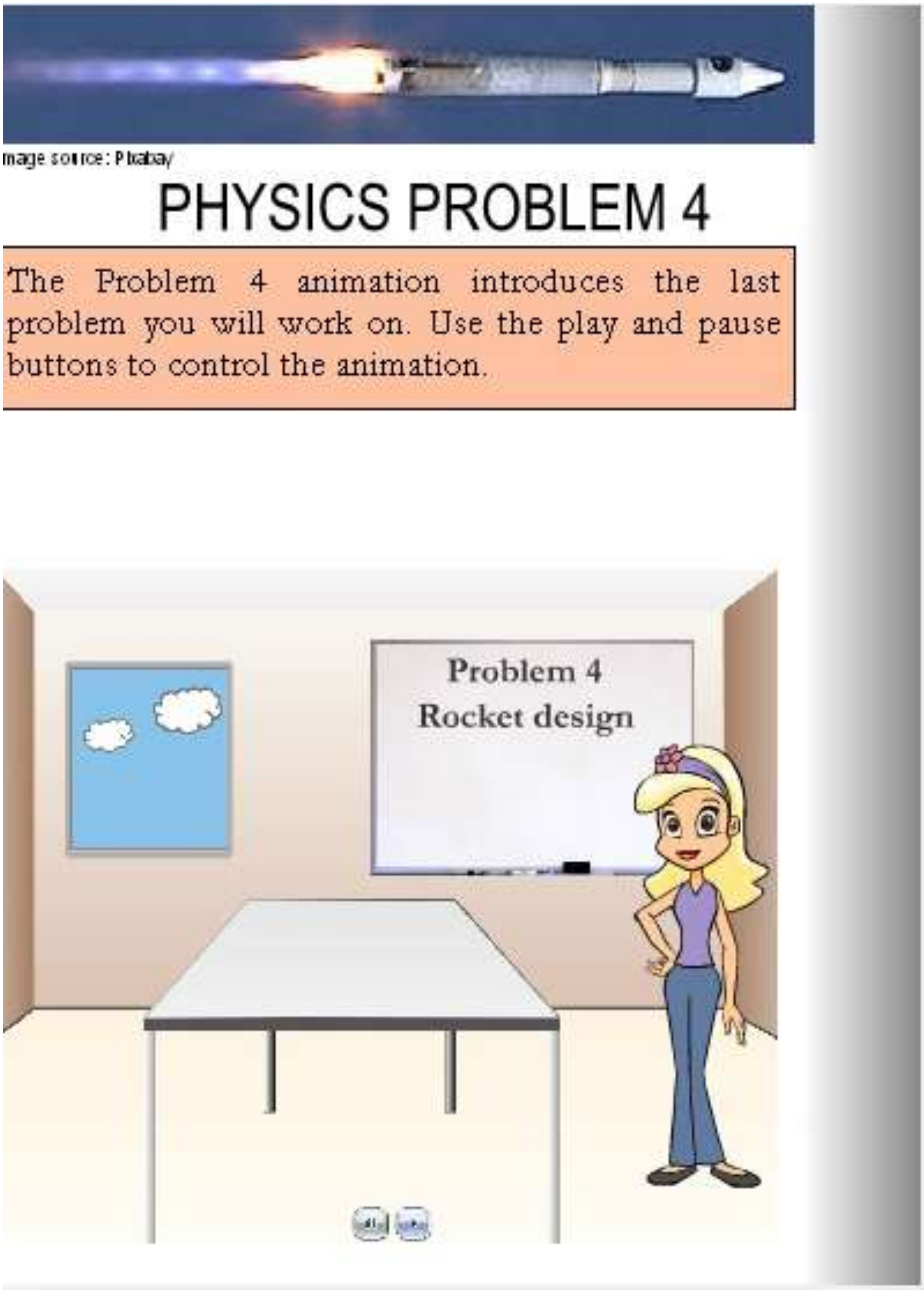


Figure A2.12. Screen shot from Newton’s Laws e-textbook showing the introduction to problem four to students in cycle two, intervention one.

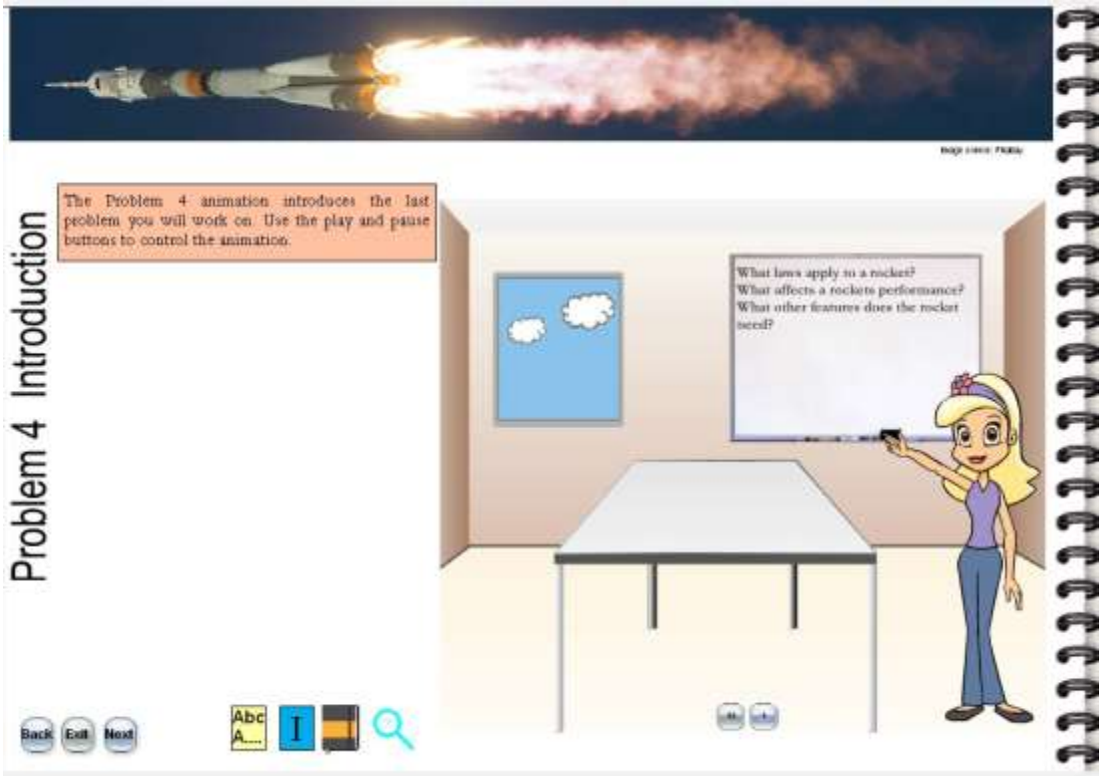


Figure A2.13. Screen shot from Newton's Laws e-textbook showing the introduction of problem four to students in cycle three, intervention one.

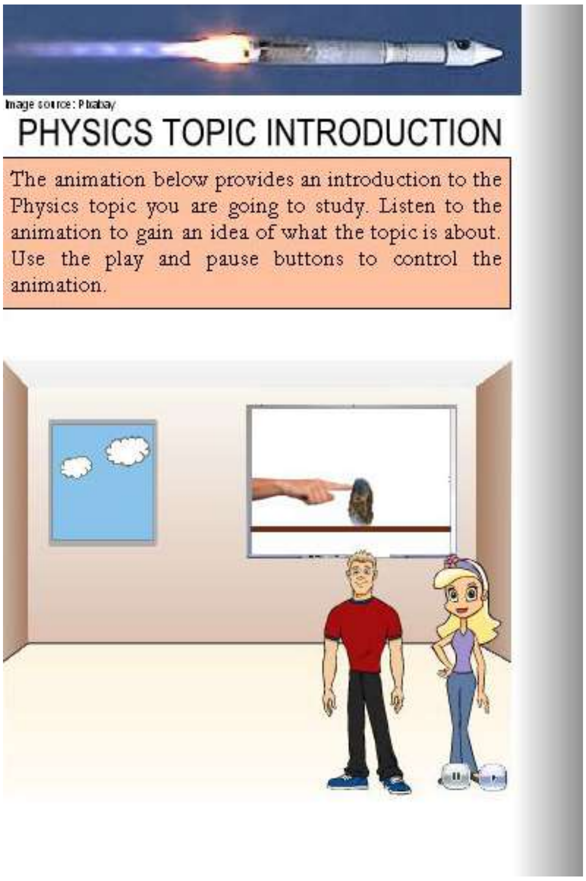


Figure A2.14. Screen shot from Newton's Laws topic showing the introduction of physics concepts to students in cycle two, intervention one.

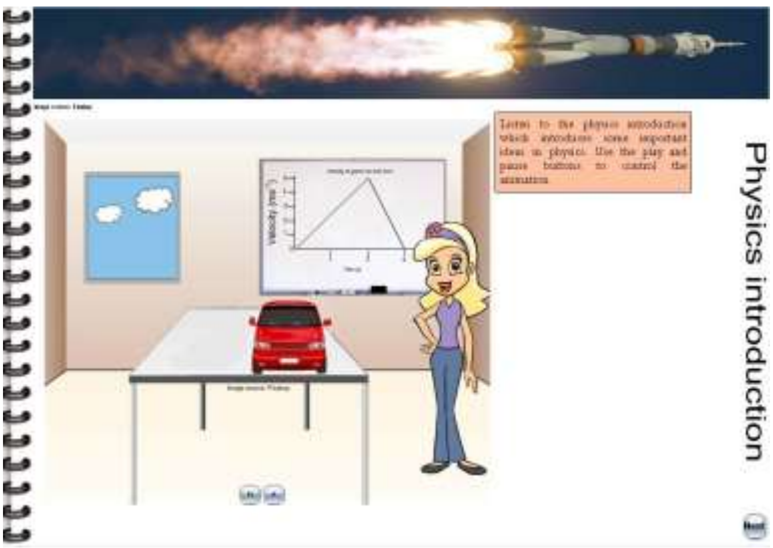


Figure A2.15. Screen shot from the Newton's Laws topic showing the introduction of graphing skills in cycle three, intervention one.

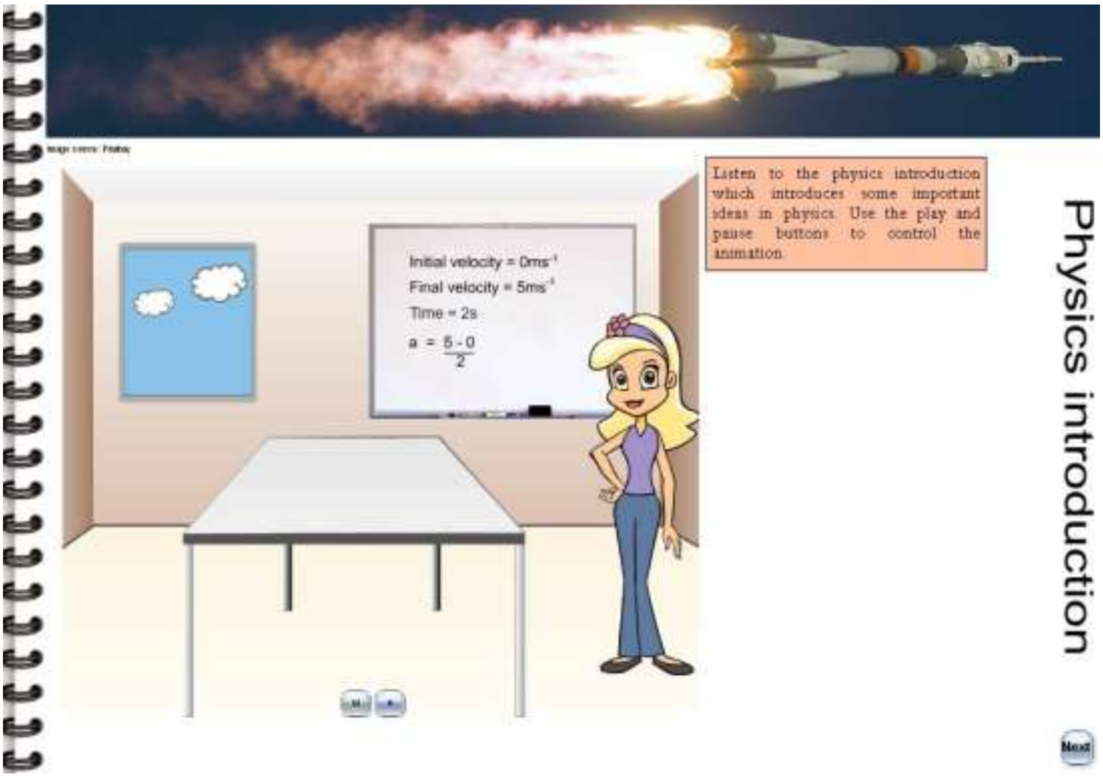


Figure A2.16. Screen shot from the Newton's Laws topic showing the introduction of mathematical skills in cycle two, intervention one.

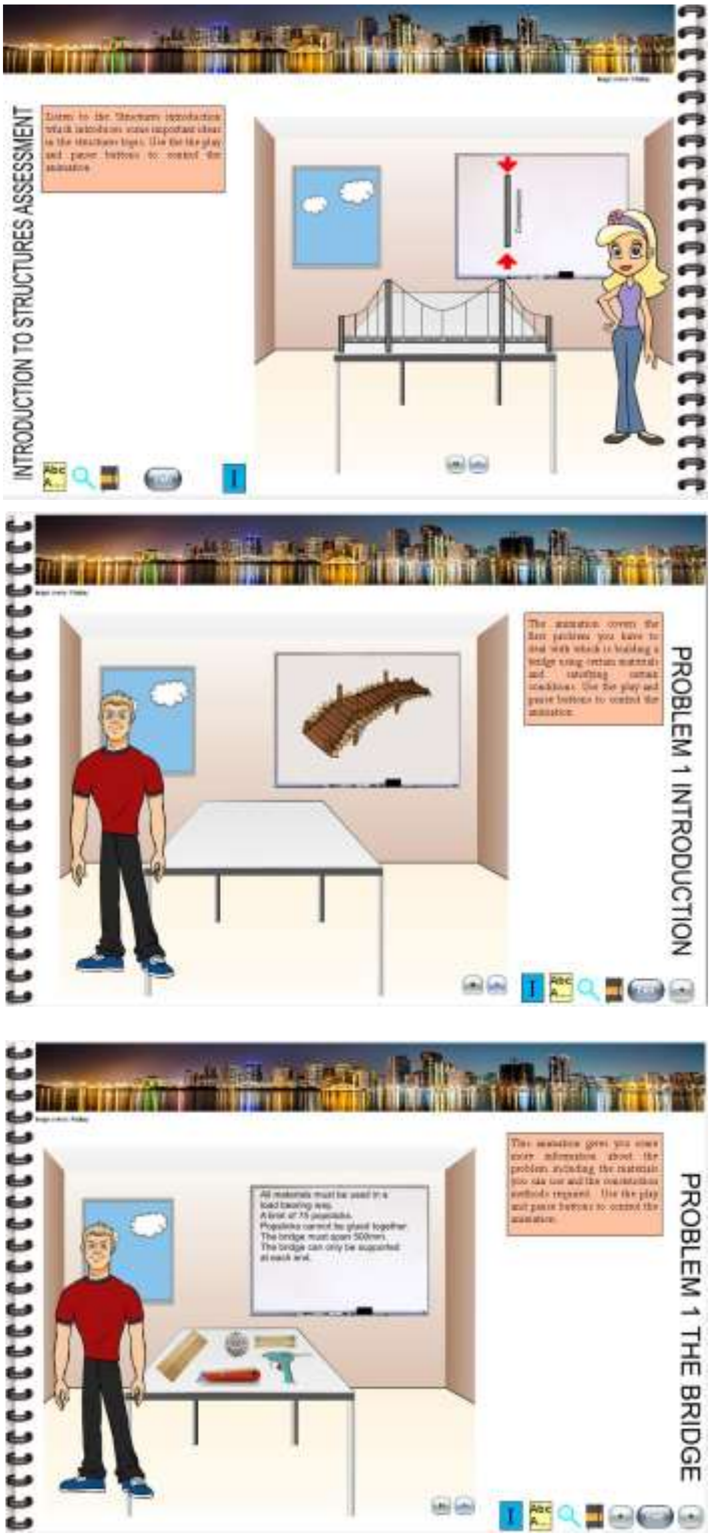


Figure A2.17. Screen shot of the Compression and Tension intervention showing presentation of the concepts, application of the concepts and the problem in cycle two intervention two.

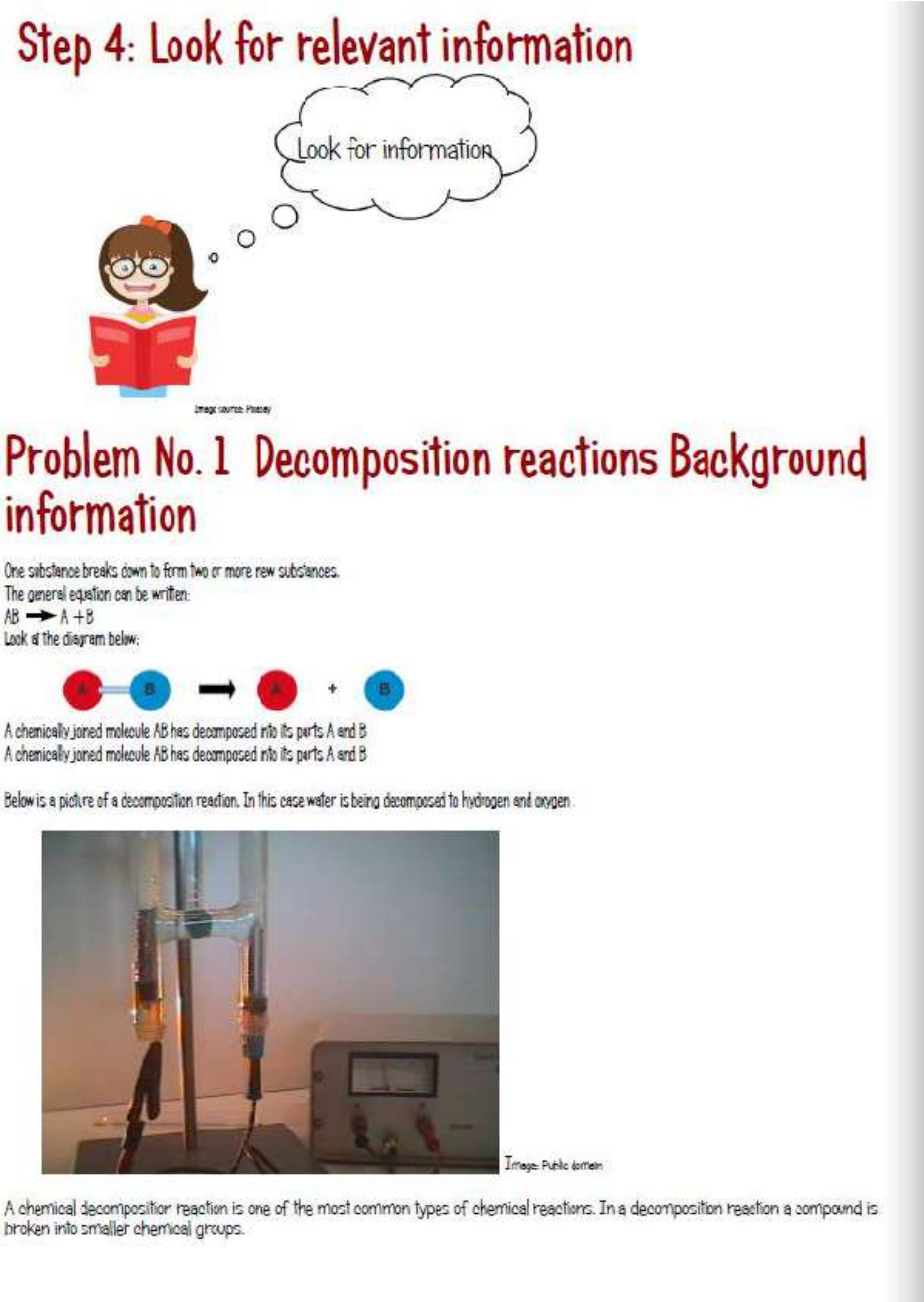


Figure A2.18. Screen shot from the Chemical Reactions topic showing the information provided to students in Cycle one, intervention two.

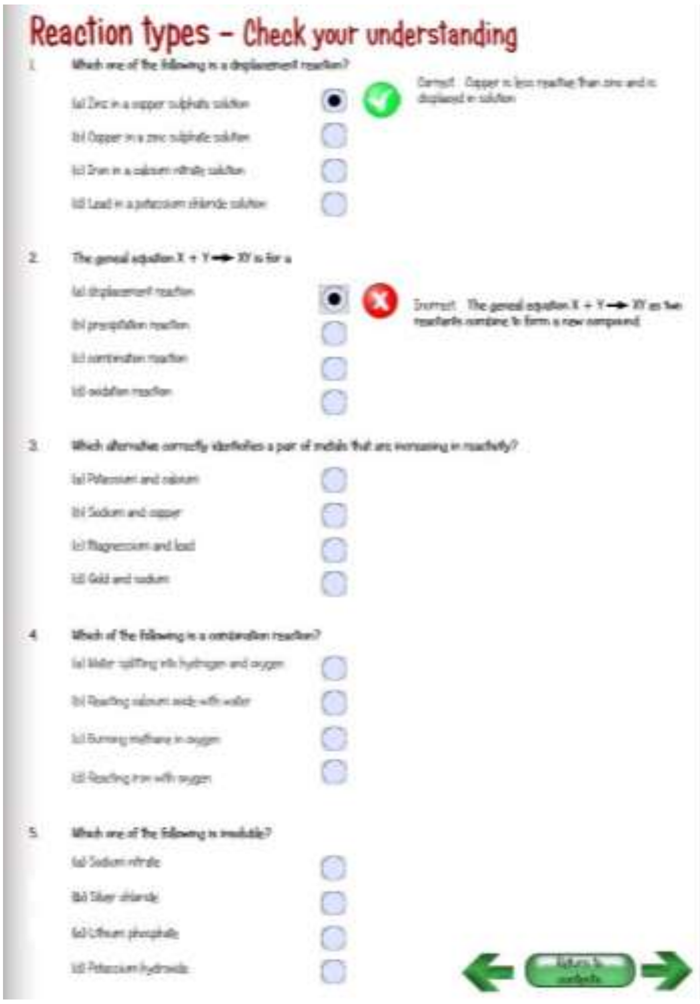


Figure A2.19. Screen shot showing the feedback provided to students in the Chemical Reactions topic in Cycle one, intervention two.

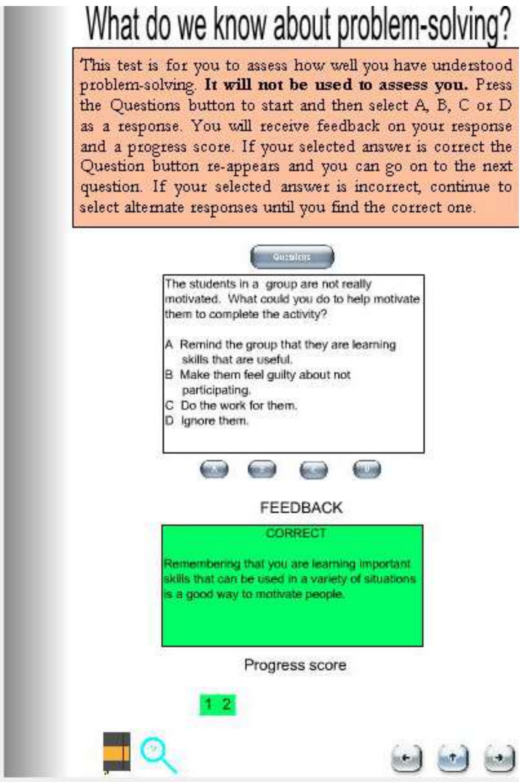


Figure A2.20. Screen shot showing the PBL feedback provided to students in the Newton's Laws topic in cycle two, intervention one.

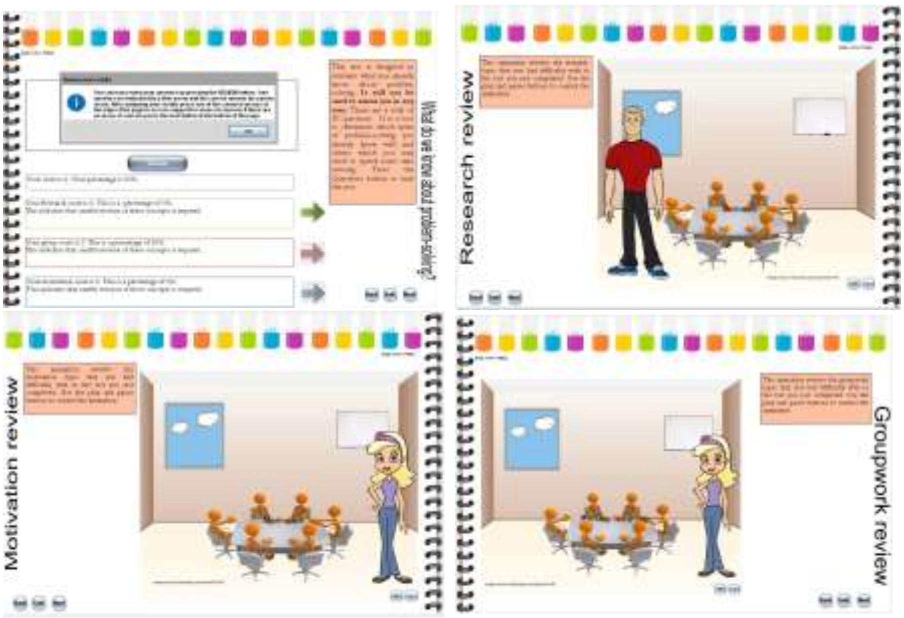


Figure A2.21. Screen shot showing the PBL feedback and needs based support provided to students in the Chemical Reactions topic in cycle three, intervention two.

Figure A2.22. Screen shot showing problem analysis support provided to students in the Newton's Laws topic in Cycle one, intervention one.

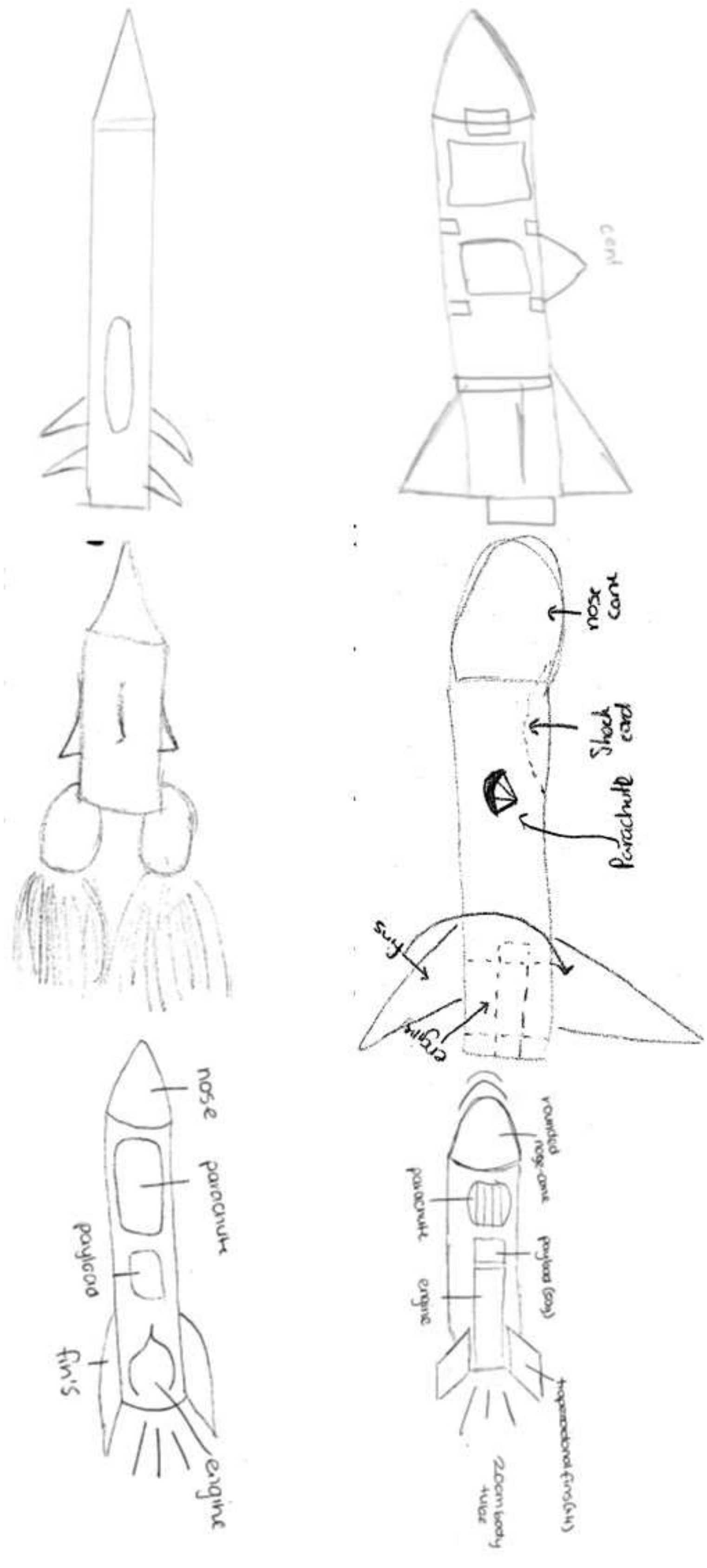
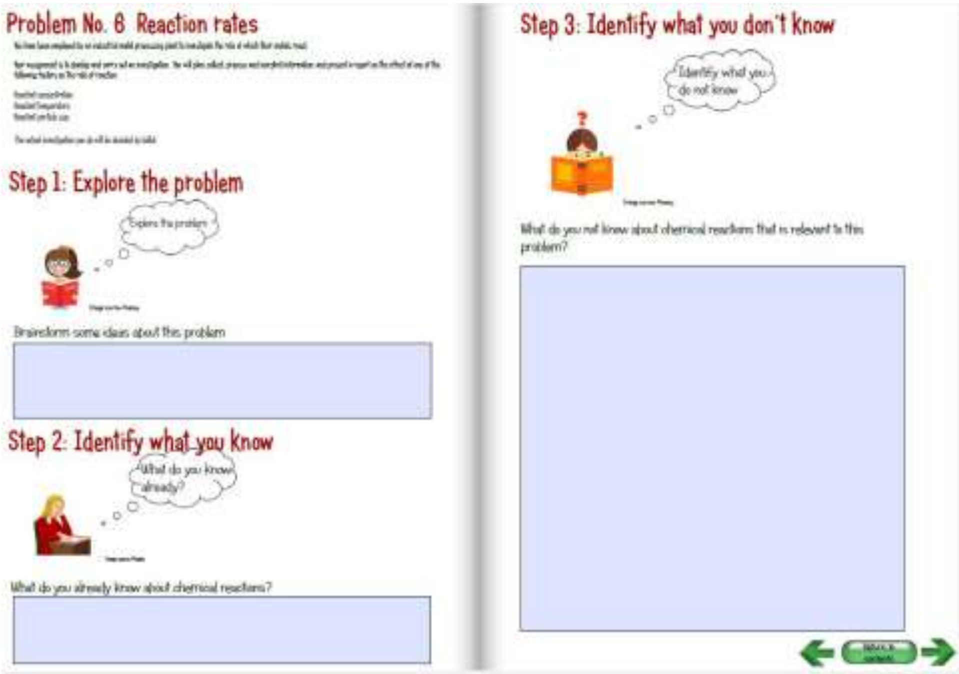


Figure A2.23. Student model rocket designs pre-intervention (left) and post- intervention (right) for the first (top), second (middle) and third (bottom) interventions.



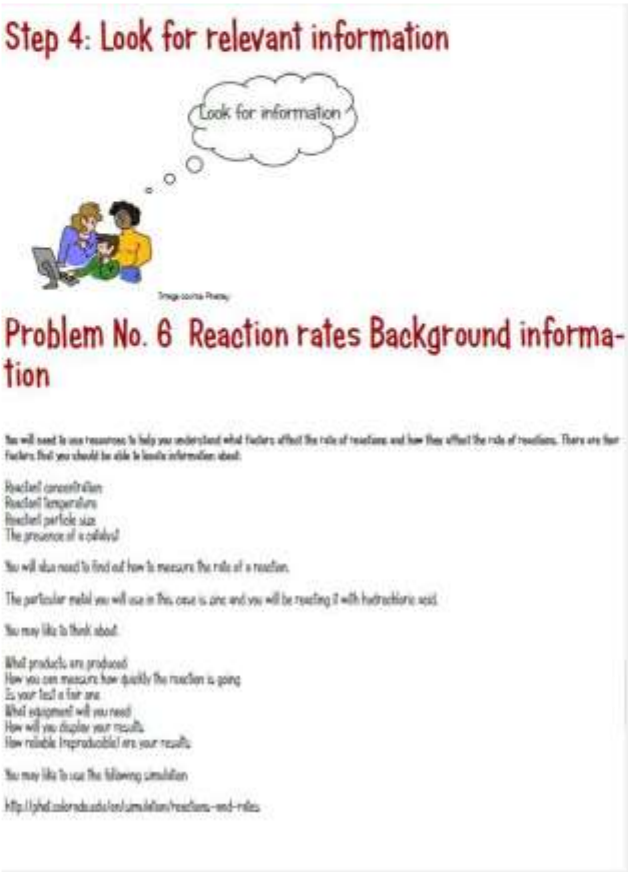


Figure A2.24. Screen shot showing problem six (rates of reaction) support provided to students in the Chemical Reactions topic in Cycle one, intervention two.

Figure A2.25. Screen shot showing problem five (rates of reaction) support provided to students in the Chemical Reactions topic in cycle three, intervention two.

Appendix 3 Participant Information Sheet and Consent Forms

THE UNIVERSITY OF NOTRE DAME AUSTRALIA

ICT Enriched Problem Based Learning in Secondary High School Science Classrooms.

PARTICIPANT INFORMATION SHEET-PARENT

CHIEF INVESTIGATORS: **Associate Professor Jean Macnish and Dr Frank Bate, The University of Notre Dame University Australia**

STUDENT RESEARCHER: **Mr Nigel Stewart** **DEGREE: Doctor of Philosophy**

Dear Parent,

Your child is invited to participate in the research project described below.

What is the project about?
The research project is a study that investigates the use of Information and communications technology (ICT), specifically in the form of purpose-built e-textbooks, to support problem-based learning in secondary high school science classrooms. The aim of this study is to determine if students' problem-solving skills in science will improve through the use of technology including e-textbooks. Problem based learning (PBL) involves students being presented with a problem and, by working in teams to solve it, learn by acquiring new information relevant to the problem.

Who is undertaking the project?
This project is being conducted by Nigel Stewart and will form the basis for the Doctor of Philosophy degree at The University of Notre Dame Australia, under the supervision of Associate Professor Jean Macnish and Dr Frank Bate.

What will my child be asked to do?
Students who take part in this study will

- Complete one Problem Based Learning (PBL) evaluation tool at the start and completion of two topics in science this semester. The PBL evaluation tools will not be used for assessment purposes and may be completed anonymously.
- Be assessed on how well they work as part of a team during the task using team member assessment.
- Be observed at regular times during each week that they undertake the topics in science related to this study. The observers will be either employees of the school or academics from the University of Notre Dame Australia. The observations will be taken every five minutes during the lesson and will focus on what students are doing, with whom they are interacting and how they are interacting. Individual students will **not** be identified in these observations.
- Be asked to volunteer for a focus group discussion at the conclusion of each topic. Approximately six students in each class will be asked to volunteer. Focus groups will be conducted by the researcher's supervisors to provide an impartial perspective. The focus group discussions will be audio-taped solely for the purposes of accurate transcription.

The PBL evaluation tools will contain a variety of different question types. In some cases, students will be asked to indicate their preference on a number scale ranging from strongly agree to strongly disagree. In other cases, students may need to select a response from a list of alternatives or write a short (two to three sentences) response to a question. The focus group questions will relate to how the students worked during the study, what problems they encountered and how they felt working during the study.

How much time will the project take?

This study will take place during normally scheduled science lessons at the school. The focus group questioning will take place at lunchtime at a time convenient for the students.

Each topic in this study will run for approximately five weeks. Each of the four PBL evaluation tools will take 60 minutes and will be conducted in class time. The focus group meetings will take approximately 30 minutes.

Are there any risks associated with participating in this project?

There are no foreseeable risks to students undertaking this study and there is no cost involved in participating. This study is aimed at determining whether the use of technology assists students with their problem-solving skills in science and to monitor any change in their problem-solving ability.

Can my child withdraw from the study?

Participation in this study is completely voluntary. Your child is not under any obligation to participate. If you agree for your child to participate, you or they can withdraw from the study at any time without adverse consequences, however, the information collected prior to withdrawal may still be used as participants will not be identifiable in the data. Students who refrain from participation or withdraw from the study will not be disadvantaged as they will receive the same educational experience by the same teacher at the same time as the other students under what would be considered a teacher's natural right of tuition style. The students will also receive the same formal assessment. The students will complete the same pre and post evaluations for formative assessment purposes. It is appreciated that there is a dependant relationship between the teacher and your child, however, you can be assured that non-participation or withdrawal will not affect your child’s ongoing enrolment, assessment or treatment.

Will anyone else know the results of the project?

Information gathered about your child will be held in strict confidence. This confidence will only be broken in instances of legal requirements such as court subpoenas, freedom of information requests, or mandated reporting by some professionals. Information collected from students, with the exception of the team member assessment, will not identify particular students. All data will be held securely at the school in password word protected files on the school’s server. Data will also be stored securely in the School of Education at The University of Notre Dame Australia for a period of five years after which it will be destroyed. It is anticipated that the data collected will be published in a thesis at the end of the study and may be published in peer reviewed journals prior to the thesis being published. In either case only aggregate data will be used and students will not be identifiable in any way. Students who wish to see their own results from the study will be shown those results.

Who do I contact if I have questions about the project?

If you want any more information about the project you should contact Mr Nigel Stewart at the School on 9581 6777. The study has been approved by the Human Research Ethics Committee at The University of Notre Dame Australia (approval number 013110F). If participants have any complaint regarding the manner in which a research project is conducted, it should be directed to the Executive Officer of the Human Research Ethics Committee, Research Office, The University of Notre Dame Australia, PO Box 1225 Fremantle WA 6959, phone (08) 9433 0943, research@nd.edu.au. Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

I want my child to participate!

In order for your child to participate in this study the accompanying Consent Form needs to be signed and returned to me.

Yours sincerely,

Nigel Stewart
Email:
Nigel.Stewartl@my.nd.edu.au
Phone: 9581 6777

A/Prof Jean MacNish
Email:
jean.macnish@nd.edu.au
Phone: 9433 0165

Dr Frank Bate
Email:
frank.bate@nd.edu.au
Phone:9433 0944

THE UNIVERSITY OF NOTRE DAME AUSTRALIA

ICT Enriched Problem Based Learning in Secondary High School Science Classrooms.

PARTICIPANT INFORMATION SHEET-STUDENT

CHIEF INVESTIGATORS: **Associate Professor Jean Macnish and Dr Frank Bate, The University of Notre Dame University Australia**

STUDENT RESEARCHER: **Mr Nigel Stewart** **DEGREE: Doctor of Philosophy**

Dear Student,

You are invited to participate in the research project described below.

What is the project about?

The research project is a study that looks at the use of Information and communications technology (ICT), specifically in the form of specially designed e-textbooks, to support problem solving in science classrooms. The aim of this study is to determine if your problem-solving skills in science will improve through the use of technology including e-textbooks. Problem based learning (PBL) involves you being presented with a problem and, by working in teams to solve it, learn by gaining new information relevant to the problem.

What will I be asked to do?

If you take part in this study, you will:

- Complete one Problem Based Learning (PBL) test at the start and completion of two topics in science this semester. The PBL tests will not be used for assessment purposes and may be completed without using your name. Each topic in this study will run for approximately five weeks. Each of the four PBL tests will take 60 minutes and will be conducted in class time.
- Be evaluated on how well you work as part of a team.
- Be observed at regular times during each week that you work on the topics in science related to this study.
- Be asked to volunteer for a focus group discussion at the conclusion of each topic. Approximately six students in each class will be asked to volunteer.

Can I withdraw from the study?

This study will take place during normally scheduled science lessons at the school. The focus group questioning will take place at lunchtime at a time convenient for you. You may bring your lunch to these interviews. Participation in this study is completely voluntary. If you do not take part or withdraw from the study, you will not be disadvantaged as you will receive the same educational experience by the same teacher at the same time as the other. You will also receive the same formal assessment. You will complete the same pre and post evaluations. You can be assured that non-participation or withdrawal will not affect your ongoing enrolment, assessment or treatment. Information gathered about you will be kept private.

I want to participate! How do I sign up?

Please feel free to talk to me, Mr McFetridge or Mrs Robertson if you have any questions about this study. In order for you to participate in this study, you need to discuss this with your parent/guardian and the accompanying Consent Form needs to be signed and returned to me.

Yours sincerely,

Nigel Stewart	A/Prof Jean MacNish	Dr Frank Bate
Email:	Email:	Email:
Nigel.Stewartl@my.nd.edu.au	jean.macnish@nd.edu.au	frank.bate@nd.edu.au
Phone: 9581 6777	Phone: 9433 0165	Phone:9433 0944

CONSENT FORM-PARENT

ICT Enriched Problem Based Learning in Secondary High School Science Classrooms

Informed Consent Form for Parent or Guardian

I, *(Parent/Guardian's name)* ____________________________hereby consent to my child,

(Child's name) ______________________being a volunteer participant in the above project.

- I have read and understood the Information Sheet and any questions have been answered to my and my child's satisfaction.
- I understand that my child may participate in this study, realising that I, or my child, may withdraw at any time without prejudice.
- I understand that all information gathered by the researcher will be treated as strictly confidential, except in instances of legal requirements such as court subpoenas, freedom of information requests, or mandated reporting by some professionals.
- I understand that the protocol adopted by the University of Notre Dame Australia Human Research Ethics Committee for the protection of privacy will be adhered to and relevant sections of the *Privacy Act* are available at http://www.nhmrc.gov.au/
- I agree that any research data gathered for the study may be published provided my name or my child's name and other identifying information is not disclosed.

Parent/Guardian's signature:		Date:	

Researcher's full name:	Nigel Stewart		
Researcher's signature:		Date:	

If participants have any complaint regarding the manner in which a research project is conducted, it should be directed to the Executive Officer of the Human Research Ethics Committee, Research Office, The University of Notre Dame Australia, PO Box 1225 Fremantle WA 6959, phone (08) 9433 0943, research@nd.edu.au.

CONSENT FORM-STUDENT

ICT Enriched Problem Based Learning in Secondary High School Science Classrooms

Informed Consent Form for Student

I, *(Student's name)* ___________________________________ hereby consent to being a volunteer participant in the above project.

- I have read and understood the Information Sheet and any questions have been answered to my satisfaction.
- I understand that I may participate in this study, realising that I may withdraw at any time without any disadvantage to myself.
- I understand that all information gathered by the researcher will be treated as strictly private, except in instances of legal requirements such as court subpoenas, freedom of information requests, or mandated reporting by some professionals.
- I understand that the protocol adopted by the University of Notre Dame Australia Human Research Ethics Committee for the protection of privacy will be adhered to and relevant sections of the *Privacy Act* are available at http://www.nhmrc.gov.au/
- I agree that any research data gathered for the study may be published provided my name and other identifying information is not disclosed.

Student signature:		Date:	

Researcher's full name:	Nigel Stewart		
Researcher's signature:		Date:	

If participants have any complaint regarding the manner in which a research project is conducted, it should be directed to the Executive Officer of the Human Research Ethics Committee, Research Office, The University of Notre Dame Australia, PO Box 1225 Fremantle WA 6959, phone (08) 9433 0943, research@nd.edu.au.

Frederick Irwin Anglican School

A School of The Anglican Schools Commission (Inc.)

Mr N Stewart
36 Caledonia Close
HERRON WA 6211

Dear Mr Stewart

Permission to Conduct PhD Research

I write to formally give permission for you to conduct research in lower school Science classes at Frederick Irwin Anglican School during 2013, 2015 and 2016 in a study entitled *e-Textbook Systems as a Learning Tool to Support Problem Based Learning in Secondary High School Science Classrooms: A Qualitative Study* to fulfil some of the requirements of your PhD through Notre Dame University.

As indicated in your formal request to conduct the research, the participation of individual students will be subject to parental permission being granted.

I wish you well with your research and look forward to your sharing your findings and expertise with us.

Yours sincerely

Kerry Robertson
Principal

14 May 2013

Gordon Road, Mandurah, Western Australia. Postal Address: P.O. Box 687, Mandurah, Western Australia 6210
Telephone (08) 9581 6777 Facsimile (08) 9581 6323
ABN 18 708 185 908

Appendix 4 PBL Evaluation Tool

PBL EVATUATION TOOL (PRIOR INTERVENTION) YEAR 10 PHYSICS

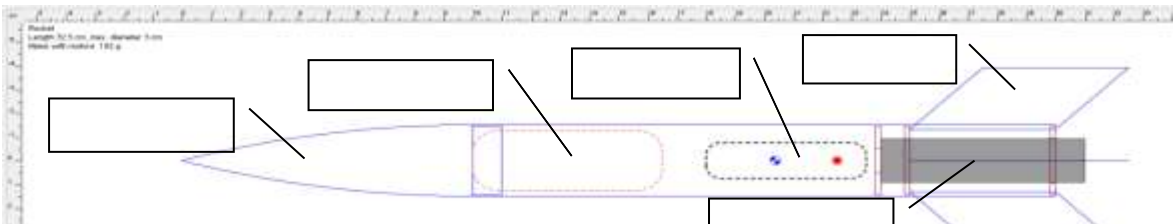
ID No:

The purpose of this PBL Evaluation Tool is to see how you would go about solving a problem in science. It is not going to be used to assess you in any way, but it is hoped that you will answer each question as well as you can. Don't worry if you cannot answer a question; make an attempt to answer it based on what you know or think. You are not required to provide your name on this PBL Evaluation Tool.

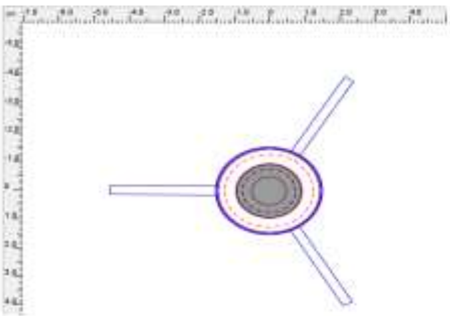
Please read the problem below and then answer the questions that follow.

Recently NASA (the National Aeronautics and Space Administration) has been trying to improve the efficiency of the rockets it uses. The main way they want to do this is to achieve higher altitudes with less fuel. There are many factors that affect the efficiency of a rocket. Some factors include; the weight of the payload (cargo), the shape of the rocket, the fins on the rocket and its size.

Your problem is to take a current rocket that can achieve an altitude of 75m with a payload of 100g and a standard motor and improve it. The design of the rocket is shown below.



Side



End

Knowledge structure

1. Which example best illustrates Newton's second Law? | Answer | |

   (a) A rocket leaving the launch pad

   (b) A passenger pushing against a seat belt when a car brakes

   (c) A truck taking longer than a car to stop when travelling at the same velocity

2. Which relationship best illustrates Newton's second Law about force and acceleration? | Answer | |

   (a) Objects with more mass require more force to move

   (b) Objects with more mass require less force to move

   (c) An objects mass does not affect the force needed to move it

3. To reduce the amount of force needed to launch a rocket you should: | Answer | |

   (a) reduce the mass of the payload

   (b) increase the power of the engines

   (c) increase the mass of the payload

4. What issue do think is important in this activity regarding Newton's second Law? | Answer | |

   (a) Rocket mass

   (b) Recovery systems

   (c) Rocket design

5. To calculate acceleration which one of the following is not required? | Answer | |

   (a) Final velocity

   (b) Initial velocity

   (c) Mass

6. To calculate force needed to accelerate an object which one of the following is not required? | Answer | |

   (a) Final velocity

   (b) Acceleration

   (c) Mass

7. The property of an object to resist change is called:

(a) mass

(b) inertia

(c) force

Answer	

8. Newton's third Law states that actions and reactions are:

(a) equal, but opposite

(b) unequal, but opposite

(c) equal, but similar

Answer	

9. An object in motion that is not acted on by a force will:

(a) eventually slow down as it runs out of energy

(b) stay in motion in the same direction

(c) stay in motion, but change direction

Answer	

10. The SI unit for mass is:

(a) kg

(b) g

(c) m

Answer	

11. Circle the pieces of information below that you do not know about but may be relevant to the problem of designing a rocket.

Nose cone shape	Fin shape	Rocket mass
Engine size	Engine thrust	Recovery system

12. Newton's second law of motion states that the acceleration of an object is proportional to the force applied and inversely proportional to its mass. Describe a situation where the mass of an object affects its acceleration.

____

____

____

____

13. Explain why only one person is needed to push the car, but several people are needed to push the truck.

Image source:
https://en.wikipedia.org/w/index.php?curid=23859384

Image source:
https://commons.wikimedia.org/wiki/File:Men_Pushing_Loaded_Truck_-_Phulbagan_-_Kolkata_20180223161038.jpg

____

____

____

14. Describe how to improve the efficiency of a rocket in terms of altitude gained using Newton’s second Law.

____

____

____

____

15. In trying to improve a rockets efficiency in terms of altitude gained write down all the factors you know of that will affect it.

____

____

____

____

16. How would you decide which members of your group would be assigned to the different tasks required to complete this task.

____

____

____

____

17. Explain why increasing the payload weight of a rocket increases the force needed to lift it to a certain altitude.

____

18. Explain how you would increase the efficiency of the rocket.

19. Sketch the design of a rocket that improves its efficiency in terms of payload lift.

20. What information will you need in order to improve the efficiency of the rocket?

Planning, Monitoring and Evaluation

21. Rate the importance of each aspect of planning such a task on a scale from 1 – 7:
1 = not important 4 = important 7 = very important

Reading some background information about the task	Answer
Prioritise the learning needs	Answer
Set learning goals and objectives	Answer
Allocate resources	Answer
Identify which task each group member will do	Answer

22. How important is it that all group members contribute equally to the task? Answer

1 = not important 4 = important 7 = very important

23. Rate each of the tasks below in terms of their importance to completing the task from 1 to 7

1 = not important 4 = important 7 = very important

Reading some background information about the task	Answer
Prioritise the learning needs	Answer
Set learning goals and objectives	Answer
Allocate resources	Answer
Identify which task each group member will do	Answer

24. Describe how you would divide up your time in this task between planning and carrying it out. You have approximately five weeks.

____

____

____

____

25. Describe how you would evaluate each step in your progress towards a solution to the task you are working on.

____

26. Describe, in as much detail as possible, how you would search for information on this task.

27. Explain how your group would know how well they were performing on the task.

28. How would you assess the information you found for your group?

Student Engagement

29. How confident are you that you could complete this task without help on a scale of 1 to 7.

    1 = not confident 4 = confident 7 = very confident

Answer	

30. How useful do you think this task would be to you on a scale of 1 to 7.

    1 = not useful 4 = useful 7 = very useful

Answer	

31. Describe how you would motivate yourself to complete such a task.

    ____

    ____

    ____

    ____

32. Describe how you think you would respond to problems that are easy compared to those that are difficult in this task.

    ____

    ____

    ____

    ____

33. Describe how you respond to problems that are interesting to you compared to those that are not of interest in this task.

    ____

    ____

    ____

    ____

34. If there is insufficient information on the problem you are working on, describe what your next steps would be in order to solve this problem.

    ____

    ____

    ____

    ____

35. Explain why you think this task would be enjoyable or not enjoyable.

____

____

____

36. How would you make sure the information you collected was reliable and relevant?

____

____

____

37. How difficult do you think you would find this task. Explain with specific examples

____

____

____

____

Appendix 5 Strobe Observation Protocol

CLASSROOM ACTIVITIES

(Fill this out as you are observing classes.)

5-Minute Observation Cycle Form

Record your observations at the start of each 5-minute cycle for the categories on the form in the following order:

1. Observe the whole group and note if the activity involves the whole group (large or small) or sub-groups.
2. Observe on-task behaviour, based on a panoramic view of the classroom.
   Indicate what you think represents the on-task behaviour of all of the students in the classroom.

Half or less	More than half	Almost All	All

On-task behaviours might include eye contact with a speaker, body language that indicates engagement in the task, note-taking, reading, and/or involvement in small group or individual discussions.

3. **Off-task behaviours** may include the appearance of being disengaged from the instructional activity such as isolation from sub-groups, sleeping, reading unrelated material, or chatting with friends. Observe on-task behaviour, based on a panoramic view of the classroom. Indicate what you think represents the type of behaviour most students are engaged in:
   - Individual work
   - Reading/writing
   - Using netbook
   - Working with materials
   - Interacting with other students
   - Verbally
   - Passing/presenting information
   - Responding to information
   - Organising roles
   - Monitoring progress
   - Physically helping
   - Other
   - Describe
4. Observe the instructor/facilitator and using the following description, write the word that most closely represents their behaviour:
   - Talk
   - Listen or Monitor
   - Organise (Includes personal organization, classroom management or transitions)
   - Other (Describe the behaviour in the space provided)
5. Record to whom the teacher behaviours are directed using the following:
   - Entire Class
   - Subgroup

Start time_____________

Time interval	Group activity	On task behaviour	Type of on task behaviour	Teacher behaviour	Teacher interaction
0					
5					
10					
15					
20					
25					
30					
35					
40					
45					
50					
55					
60					
65					
70					
75					
80					

Appendix 6 Focus Group Questions

THE UNIVERSITY OF NOTRE DAME AUSTRALIA

FOCUS GROUP QUESTIONS

Good afternoon and thank you for agreeing to be part of this Focus Group. My name is ________________ and I am a researcher at Notre Dame University Australia. I am here to ask you some questions about the problem-based learning topic that you have just completed with Mr Stewart. The answers that you provide are important but will only be made available to members of the research team and will not be used to assess you in any way. You will also be provided with a transcript of your responses so that you can check that what you said was recorded properly. Before we begin are there any questions?

What did you especially like or dislike about the topic you just completed? Explain why you feel this way?

Have you learnt anything, or not, about problem solving that you did not know before? Try to give specific examples.

Why is this way of teaching better or worse than other methods you have experienced?

Do you think you have learnt more or less about the topic using this method of teaching?

Did the questions in the PBL Evaluation Tool you completed at the start of the topic guide you, or distract you, in any way?

Think about how you worked in your team. What were some of the good and bad points about team work?

Now think about the e-textbooks you used in this topic.

Do you think they are better or worse than the normal textbook you used? Try to give specific examples.

Did they help or hinder you with the problem-solving tasks? Try to give specific examples.

Did they help or hinder you with learning the content of the topic? Try to give specific examples.

Thank you for your participation today. Do you have any final questions or anything you would like to add?