Investigating if working collaboratively through an online environment can support problem-solving skills of post-primary mathematics students

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Declaration

I declare that the work described in this document is, except where otherwise stated, entirely my own work and has not been submitted as an exercise for a degree at this or any other university.

Signed: ___________________________ **Date: ____________________**

Irene Stone

Permission

I agree that Trinity College Dublin may lend or copy this project upon request.

Signed: ____________________________ Date: ____________________

Irene Stone

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Abstract

Problem solving is an important skill needed in today's world. It is recognised as such by the National Council for Curriculum and Assessment; problem-solving skills should be embedded in the teaching and learning of mathematics in Irish post-primary schools. The Project Maths syllabus was introduced to the post-primary curriculum in 2008. One of the aims of the syllabus is to empower students to develop problem-solving skills. However, these skills are still lacking in classrooms despite the introduction of Project Maths and many students are still taught mathematics through a traditional, didactic model. This research investigated if working collaboratively through an online environment can support problem-solving skills. Google Docs, the online environment used for this research, allows for collaborative editing of a document. An exploratory case study was carried out which involved 30 post-primary students from a 2nd year Mathematics class, ages 13-14 years. Working in groups of 4 or 5, students were given problems to solve on the Google Doc environment over a two week period. The research employed mixed methodologies. Analysis of the findings demonstrated that in the Google Doc environment, students were reflecting and attempting problems, they were using words to describe what they were doing and applied a multi-representational approach to problem solve. The environment facilitated collaboration between students and scaffolding by the teacher. As these are all key components of problem solving, the research paper concludes that working collaboratively through an online environment can support problem-solving skills of post-primary mathematics students.

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Abbreviations

DES: Department of Education and Skills

NCCA: National Council for Curriculum and Assessment

OECD: Organisation for Economic Co-operation and Development

PISA: Programme for International Student Assessment

PMDT: Project Maths Development Team

SEC: State Examinations Commission

TIMSS: Trends in International Mathematics and Science Study

1 Introduction

1.1 Background and Context

“Problems are situations with no obvious solution, and solving problems requires thinking and learning in action” (OECD, 2014, p. 26). Problem-solving skills are in demand in today’s workplaces. Consequently, in education, there is a shift towards teaching students to solve problems (OECD, 2014, p. 26).

Problem solving is an integral part of mathematics learning, a view shared by the highly regarded problem solver George Polya (DES, 2013; Polya, 1957). It is at the “core of mathematician’s work” (Boaler, 2010, p. 26). There is a strong correlation between problem solving and mathematical performance (Perkins & Shiel, 2014, p. 23).

The Project Mathematics syllabus, known as ‘Project Maths’, was introduced to the post-primary curriculum in Ireland in 2008 after growing concerns that students were lacking in problem-solving skills (NCCA, 2012b). Problem solving permeates all strands of the Project Math syllabus (DES, 2013, p. 35) and a collaborative approach to problem solving is encouraged (DES, 2013, p. 11). In addition, mathematics students need technology skills to be able to function in society (DES, 2013, p. 6). Collaborative and digital skills also feature strongly in the new junior cycle post-primary curriculum (DES, 2015a, 2015b).

However, numerous reports published since the introduction of Project Maths suggest that problem-solving skills are still lacking in mathematics classrooms (Bray & Tangney, 2016; Jeffes et al., 2013; SEC, 2015a, 2015b).

It is clear, therefore, that problem-solving skills are needed by learners in today’s world and in particular, in a mathematics classroom. As there seems to be a lack of problem-solving skills evident in mathematics classrooms, this research will look at how problem-solving skills can be supported through a digital environment. The study will be looking at how these skills can be supported through students working collaboratively in the online environment of Google Docs.

1.2 Research Question(s)

It is the aforementioned background and context that helped form the research question for this research. This is summarised in Figure 1. The research attempts to answer the following question and sub-questions:

Can working collaboratively through an online environment support post-primary mathematics students' problem-solving skills?

> Did working through the online environment influence students' willingness to reflect on what they were doing and/or try again?
> Were students using words when solving problems?
> Did working through the online environment allow students to demonstrate different ways to solve a problem?
> How did the online environment support the scaffolding process?
> Was the online environment conducive to collaboration?

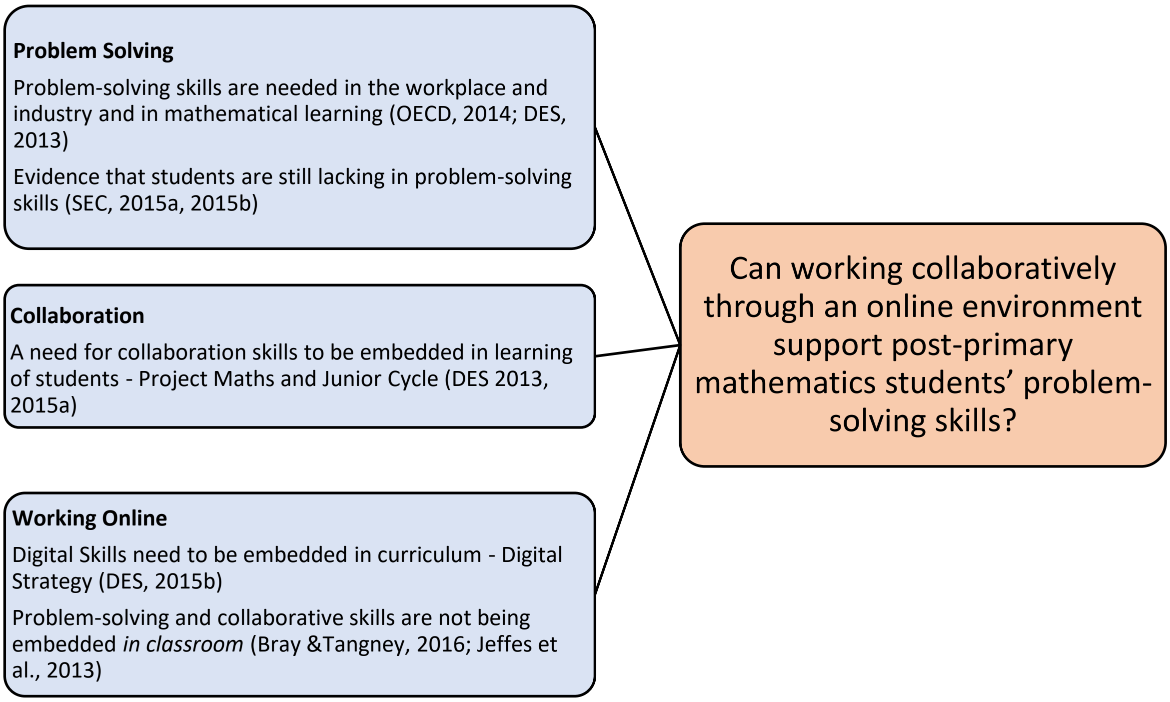

Figure 1: How the background informed the research question

1.3 Chapter Outline

In Chapter 2, the literature review focuses on the background and context regarding problem solving in the Irish education system, the problem-solving process, collaboration and problem solving, and online environments.

Chapter 3 describes the design of the learning experience and how it's broken up into 2 phases. It will be shown how the literature informed this design. Also, the rationale for using the chosen online environment are presented.

The design of the research is explored in Chapter 4. The chosen methodology, research and sub-questions, and how data was collected and analysed are presented. The rationale behind each research instrument will be explained. The implementation section looks at the participants, ethical concerns, validity and limitations of the study.

Chapter 5 examines the findings through analysing the data. The sub-questions of the research will be linked to the data collected.

Finally, in chapter 6, conclusions are drawn from the analysis, from which the main research question is answered. Limitations of the study are further discussed and recommendations are made for further developing research in this area.

2 Literature Review

A systematic search of the literature was conducted using Scopus[1] and the Stella search engine through the author's TCD Library account. An initial search term of "problem solving" produced too many results. The search had to be narrowed to "problem solving mathematics". The author found that there is a paucity in research in the fields of problem solving through an online environment. The following search terms were used "problem solving asynchronous", "problem solving collaborative", "constructivism", "real world problems". The categories for the literature review informed the search terms; these categories are listed below.

In order to give context to the research study, the literature review is divided into sections:

Background and context

The introduction briefly touched on the importance of problem solving in mathematical learning and the problems evident in the Irish education system. The literature review will further explore these issues.

The problem-solving process

This section will look at defining problem solving and how it can benefit mathematical learning. The process of problem solving will be explored and the steps that can be taken to improve problem-solving skills.

Collaboration and problem solving

This section will look at literature supporting the view that problem solving can be enhanced through collaboration.

Pedagogical approaches that can help with problem solving

The pedagogy of constructivism, and in particular the scaffolding process will be explored and how they can help improve problem-solving skills.

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[1] Scopus is the largest abstract and citation database of peer-reviewed literature: scientific journals, books and conference proceedings. Accessed on 16th November 2016 https://www.elsevier.com/solutions/scopus

Online environments

> There is a paucity in research around problem solving in online environments. Nonetheless, this section will take a brief look at research surrounding collaboration and constructivism in an online environment, in particular, the Google Doc environment.

At the end of this chapter, the author will extract common themes from the different sections of the literature review. It will be these themes that will form the basis for informing the design of the learning experience. These themes are also linked to the sub-questions as will be shown in the methodology chapter.

2.1 Background and Context

A report published in 2005 by the National Council for Curriculum and Assessment (NCCA) highlighted many concerns within the post-primary mathematics curriculum (NCCA, 2005). While international trends were pointing toward developments in problem-solving skills, mathematics in Ireland was taught in a highly didactic fashion where there was an "over-emphasis on procedural skills and rote learning to the detriment of understanding and application to problem solving" (NCCA, 2012b, p. 5). The OECD's Programme for International Student Assessment (PISA) assesses the skills and knowledge of 15-year-old students in mathematics, reading and science (Cosgrove, Perkins, Shiel, Fish, & Mcguinness, 2012, p. 1). During the period 2003 and 2009, Ireland recorded a significant decline in mathematics performance in the PISA assessments. This worrying trend underlined the importance of the Project Mathematics syllabus which was introduced in 2008 (Cosgrove et al., 2012, p. 6).

Informed by consultation and commissioned research, the NCCA set out a phased introduction (Appendix A) of the Project Maths syllabus in 2008 (NCCA, 2012b, p. 5). One of the aims of the new syllabus was to embed problem-solving skills amongst students; to steer them away from the procedural approach which dominated the "traditional" mathematics classroom (NCCA, 2005, p. 18). Since the rollout of Project Maths, there have been numerous reports evaluating the impact of the new syllabus; some of which point to a failure to embed problem solving in the learning of mathematics (Jeffes et al., 2013; SEC, 2015a, 2015b).

Jeffes et al (2013) explored the impact of Project Maths on student achievement, learning, and motivation. It was found that students struggle providing written explanations for their solutions and they find word-based problems "challenging and difficult to interpret". It was not apparent in students' written work that they were making connections between topics and they find it challenging to apply their learning to unfamiliar contexts. They find the unpredictability of questions challenging, even at higher level (Jeffes et al., 2013, p. 25). The report states that "students need to be regularly given high quality tasks…including: problem solving" (Jeffes et al., 2013, p. 32). It should be noted that only a small sample of students' written work was analysed in this report and it is recognised that the research was carried out at the early stages of the implementation of the new syllabus.

The Chief Examiner's Reports[2] published in 2015 were the first full examiner reports launched since the introduction of the new Project Maths syllabus. It was found that candidates struggled with non-routine questions, often giving up after one attempt and had difficulty drawing from multiple areas of the syllabus (SEC, 2015a, pp. 24, 32). The author contends that these are constituent components of problem solving (This will be explored in the next section). An inference can be drawn that that the reports suggest students struggle with problem solving.

In particular, students had difficulty solving problems that required algebra (SEC, 2015a, p. 25, 2015b, p. 17). Jeffes et al concur with this view; they found that students had lowest confidence in solving algebra problems and struggle with broader, open-ended questions that involve algebra (Jeffes et al., 2013, pp. 46, 57).

The chief examiner makes recommendations for teachers to engage their students in non-routine questions, draw from multiple strands of the course, and practice different ways of solving problems (SEC, 2015a, 2015b). It seems teachers are still teaching using traditional ways, a point highlighted in Jeffes et al's report; "traditional approaches to mathematics teaching and learning continue to be widespread" (Jeffes et al., 2013, p. 27).

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[2] Chief Examiners' Reports provide a review of the performance of candidates in the Junior and Leaving Certificate State examinations and detailed analysis of the standards of answering. Accessed on 20th November 2016 https://www.examinations.ie/?l=en&mc=en&sc=cr

Furthermore, Bray & Tangney (2016)'s paper points to continuing trends in mathematics teaching; where content and procedure are emphasised over a more skill-based (including problem-solving skills) approach to pedagogical practice.

While the results of PISA 2012 show an increase in the mathematics performance of Irish 15 year-olds compared with the period 2003-2009, Ireland's ranking has not changed. The country is still ranked just above the OECD average at 13th out of 34 OECD countries (Perkins, Shiel, Merriman, Cosgrove, & Moran, 2013). PISA 2012 highlights a strong correlation with problem solving and mathematics and indicates a need to improve the general problem-solving skills of Irish students (Perkins & Shiel, 2014, p. 23). Furthermore, it was reported that higher achieving students in Ireland are underachieving and teachers should be focusing on the types of learning that these students would benefit from including problem solving and collaborative learning (DES, 2016b, p. 11; Perkins & Shiel, 2016, p. 9). The results of the TIMSS[3] 2015 study report that Ireland was the 4th highest Non-East Asian country (DES, 2016a). However, the gap between East-Asian and the rest of the world has widened and Irish 2nd year students showed a relative weakness in Algebra (DES, 2016a, pp. 4, 5).

A report published by the NCCA in 2012 reviewed feedback from teachers in the initial 24 schools who rolled out the syllabus as a pilot (NCCA, 2012a). Teachers feel pressure of the terminal exam (the Leaving Certificate examination) and this makes them reluctant to using "more student-centered methodologies such as open-ended tasks, discussion and group work" (NCCA, 2012a, p. 11). In the next section of the literature review it will be shown that these methodologies can all contribute to an environment that is more favourable for problem solving.

Cosgrove et al (2012) found that teachers were concerned about the phased implementation and rate of implementation of the Project Maths syllabus (Appendix A). It could be inferred, therefore, that this may be why the aforementioned problems (outlined by teachers in the NCCA 2012 report) existed. Again, it must be highlighted that it is still early days in the Project Maths implementation; "it will be 2017 before the first full cohort of students will have experienced Project Maths all the way through post-

[3] TIMSS (Trends in International Mathematics and Science Study) is an international study which provides an international comparison of student achievement in maths and science at Fourth Class in primary and at Second Year of post-primary. – Accessed on 20th November 2016: http://www.education.ie/en/Press-Events/Press-Releases/2016-Press-Releases/PR2016-29-11.html

primary education" (Cosgrove et al., 2012, p. v). However, international research concurs with some of these views. Kim & Hannafin (2011, p. 403) describe how challenging it is for teachers to promote problem solving because of competing curriculum and assessment pressures, while Schoenfeld argues that teachers sacrifice problem-solving goals because of the pressures of content coverage (Kim & Hannafin, 2011; Schoenfeld, 1992).

In addition to changes made in the Project Maths syllabus, a focus on collaborative learning is proposed in the new junior cycle curriculum (DES, 2015a, p. 7). Collaboration is well recognised as key in the learning of mathematics (Boaler, 2010, p. 27; DES, 2013, p. 11; Tanner & Jones, 2000, p. 124) . One of the key points of the Digital Strategy for Schools is to embed digital skills within all subjects of the curriculum (DES, 2015b). The Minister of Education in 2015, Jan O' Sullivan, encouraged all teachers to use technology "to give learners the tools to collaborate and to examine engaging problems".[4] The junior certificate mathematics syllabus states that learners need essential skills in technology. One of the 24 statements of learning in the new junior cycle is that the student "uses technology and digital media tools to learn, communicate, work and think collaboratively and creatively in a responsible and ethical manner" (DES, 2013, p. 6, 2015a, p. 12).

With the need for problem solving, collaboration and digital skills to be embedded in the curriculum, this research will look at how problem solving can be supported through students working collaboratively in an online environment.

[4] The Press Release for the launch of the 'Digital Strategy for Schools is available at (Accessed on 20th November 2016): http://www.education.ie/en/Press-Events/Press-Releases/2015-Press-Releases/PR15-10-07A.html

2.2 The problem-solving process

"Problem solving is at the core of mathematician's work" (Boaler, 2010, p. 26). This section of the literature review will look at problem solving and how it applies to mathematical learning.

The problem-solving process as defined by Polya involves 4 steps (1957, p.xvii):

1. Understanding the Problem
2. Devising a Plan
3. Carrying out the Plan
4. Looking Back

This process is akin to the OECD's definition of problem solving: "identify the problem, plan and carry out solution, then monitor and evaluate progress" (OECD, 2014, p. 30).

1. Understanding the Problem

In problem solving, the problem can be identified for mathematical purposes however the solution should not be immediately obvious (DES, 2013, p. 10; Lazakidou & Retalis, 2010, p. 3; OECD, 2014, p. 30). Problem solving is "concerned with non-routine tasks" where one "can't apply previously learned procedures" (OECD, 2014, p. 30). As discussed in the last section, the chief examiner reports recommend that teachers engage students in non-routine tasks (SEC, 2015a, 2015b).

Tanner & Jones (2000, p.105) argue that one needs a knowledge base before they start. This view is supported by Carson; problem solving requires "a great deal of specific content knowledge" (Carson, 2007, p. 10). Problem solving is a process through which one uses previously acquired knowledge in unfamiliar situations (Krulik & Rudnick, 1988, p. 3). Problems should be "proportionate to their knowledge" (Polya, 1957, p. v). In order for a teacher to see if a student understands the problem, students should be encouraged to describe what the problem means to them in their own words (SEC, 2015a, p. 33).

2. Devising a Plan

When devising a plan to solve a problem one requires conceptual understanding. This is where one knows what to do and why, i.e. where one can not only apply a procedure to a problem but also be able to explain why or how the procedure works (Muir, Beswick, & Williamson, 2008, p. 229). One objective of the junior certificate mathematics syllabus, is that students become proficient in the skills of conceptual understanding (Boaler, 1998; DES, 2013; SEC, 2015b).

3. Carrying out the Plan

A recurring theme of problem solving is the multi-representational approach. This involves using a range of representations such as symbols, words, pictures, tables and diagrams, including making guesses or estimates (Boaler, 2010, p. 29). As discussed earlier, the chief examiner makes recommendations for teachers to draw from multiple strands of the course and practice different ways of solving problems (SEC, 2015a, 2015b). Tanner & Jones (p. 33) also recommend exploring connections as a problem-solving strategy. Mathematicians should be flexible in their thinking and use a broad range of techniques to solve problems (Schoenfeld, 1992, p. 2). This discussion should occur throughout the problem-solving process; as recommended by the chief examiner; students should "get used to … explaining… " and "showing supporting work" (SEC, 2015a, p. 33).

4. Looking back

An effective problem solver will look back at the strategy they employed to solve a problem and apply an alternative approach to solve the problem (Kim & Hannafin, 2011, p. 404). This technique would be useful for those who fail to solve a problem. The chief examiner reports described how students often gave up on a problem after the first attempt, thus failing to do as Kim & Hannifin advocate (SEC, 2015a, p. 24). Students should discuss alternative ways to solve a problem (Hurme & Järvelä, 2005, p. 53). By discussing alternative ways, reflecting and trying again, a student's productive disposition will be developed; a belief that they can persevere with a problem (DES, 2013, p. 6).

At the end of this chapter, the themes that emerge from Polya's 4 step process will be linked with the other literature that will now be explored.

2.3 Collaboration and problem solving

Collaborative learning involves "groups of learners working together to solve a problem, complete a task, or create a product" (Laal & Laal, 2012, p. 491). The OECD defines collaboration as a process where individuals "join their understandings and efforts and work together on solving" (OECD, 2013, p. 3). As previously mentioned, collaboration is an important aspect of mathematical learning (Boaler, 2010, p. 27; DES, 2013, p. 11; Tanner & Jones, 2000, p. 124). Jeffes et al (2013) found that there was little evidence that students were working collaboratively to solve problems. Collaboration supports the constructivist pedagogy as will be explored in the next section.

2.4 Pedagogical approaches that can help with problem solving

Tanner & Jones (2000) advocate a constructivist approach when problem solving, where learners are given significant autonomy as they construct the knowledge for themselves. They believe this process should not happen in solitude, a view supported by Gupta (Gupta, 2008, p. 1; Tanner & Jones, 2000, p. 124). A constructivist classroom is filled with discussion and is based on social interactions between individuals (Gill, Ashton, & Algina, 2004, p. 183; Palmer, 2005, p. 1854). Thus constructivism and collaboration go hand in hand. Students need to be motivated to make the effort to work collaboratively in a constructivist environment (Palmer, 2005, p. 1874). This motivation can stem from the sense of ownership of the learning that can be developed through the learning process (Laal & Laal, 2012, p. 494).

A study by Tan et al found that scaffolding plays an important part in the problem-solving process (Tan Yeen-Ju, Mai, & Selvaretnam, 2015, p. 845). Scaffolding is where teachers do not tell students too much but instead guide them by asking stimulating questions (Polya, 1957, p. v; Tanner & Jones, 2000, p. 29). It enables one to solve a problem, which one could not do on their own (Wood, Bruner, & Ross, 1976, p. 90).

> "Through a process of scaffolding, a teacher can gradually guide students to develop their knowledge and skills while making connections with students' existing schemes" (Palmer, 2005, p. 1855).

Vgotsky (1978) emphasises this role of the teacher as the more knowledgeable learner who supports students by making good use of questioning particularly to scaffold their learning (Tanner & Jones, 2000, p. 85). As discussed earlier in this chapter; students need a knowledge base before they start (Carson, 2007, p. 10; Tanner & Jones, 2000, p. 33). From a constructivist view, learners learn most when given tasks that are within their range of learning. This Zone of Proximal Development (ZPD) is the difference between learners trying to problem solve alone as opposed to under the guidance of a teacher or more capable peers (Vygotsky, 1978, p. 86).

A recent inspector report highlighted the need for teachers to provide "regular written formative feedback, with clear directions for improvement" (DES, 2016c, p. 6). Feedback is the most important thing a teacher can do to enhance student achievement; it's about helping students knowing how and why they understand or misunderstand, "what directions the student must take to improve" and "matching the next teaching act to the present understandings of the student" (Hattie, 1999). A constructive approach with appropriate scaffolding allows for one to give formative feedback. They go hand in hand; giving students directions to improve and matching the next teaching act (Hattie, 1999) are akin to scaffolding and students working in their ZPD (Polya, 1957; Vygotsky, 1978).

2.5 Online environments

There is limited research in the area of solving problems in an online environment and in particular, through the Google Docs environment. Hurme & Jarvela (2005, p.50) showed how collaboration was facilitated through socially-shared discussions that occurred on an online environment. The environment, however, was not Google Docs. Nonetheless, a study concerning Google Docs by Liu & Lan (2016) concurs with this view; they found that the Google Doc environment can promote collaboration. However, their study, which focused on Teaching English as a Foreign Language, was limited in size and was not concerned with problem solving (Liu & Lan, 2016). Meudec (2016) carried out a longitudinal study on the use of Google Docs to deliver a blended, collaborative, cloud-based approach to learning. While his research was not focused on problem solving, he found that constructivism can be supported through the use of the commenting tool in the Google Docs environment (Meudec, 2016). As collaboration and constructivism can support problem solving (as discussed in last two sections); the author contends that the

Google Doc environment has the potential to support problem solving (Tan Yeen-Ju et al., 2015; Tanner & Jones, 2000; Wood et al., 1976)

The idea of the "flipped classroom" receives attention in both popular media and research literature (Bergmann & Sams, 2012; Gerstein, 2011). This pedagogical approach is where typical classroom and homework elements are reversed, thus freeing up class time for more learning (Tucker, 2012). While the focus of this research is not on flipped classrooms, the online environment has the potential to free up class time as students problem solve and collaborate at home.

As was discussed, it has been recognised that students' exposure to problem-solving skills in a *classroom* environment is limited (Bray & Tangney, 2016; Kim & Hannafin, 2011; Schoenfeld, 1992). It follows, that the online environment has the potential to offer an *additional* way of engaging students in problem-solving activities.

Furthermore, in response to the results of PISA 2012, Perkins & Shiel (2016, p.10) recommend some strategies for assisting students including; providing opportunities for them to engage with problems in novel contexts, exploring new ways, and to be more reflective in their mathematical thinking through dialogue and working in small groups. They suggest students should engage with technology. This research will explore if Google Docs has the potential as an environment to support these recommendations.

2.6 Summary - Themes that emerge from the literature

There was a recurrence of themes within the literature. It was decided to map out these themes to ascertain and to demonstrate their relationship with each other and where they fit into the general theories of problem solving. These are shown in figures 2 and 3 on the following pages.

In summary;

At the beginning of the problem-solving process (figure 2):

- Problems should be **identifiable and non-routine.**
- Students should have an appropriate **knowledge base** before attempting to solve a problem.

During the process (figure 3):

- **Constructivism** as a pedagogy, is a conducive environment for problem solving.
- **Scaffolding** by a teacher can enhance problem-solving skills.
- When problem solving, one should **use words** to describe, explain, or justify what they're doing.
- Problem solving should be **collaborative.**
- Students should aim for a **multi-representational** approach when problem solving.

It will be these themes that will inform the design of the learning experience as discussed in the next chapter.

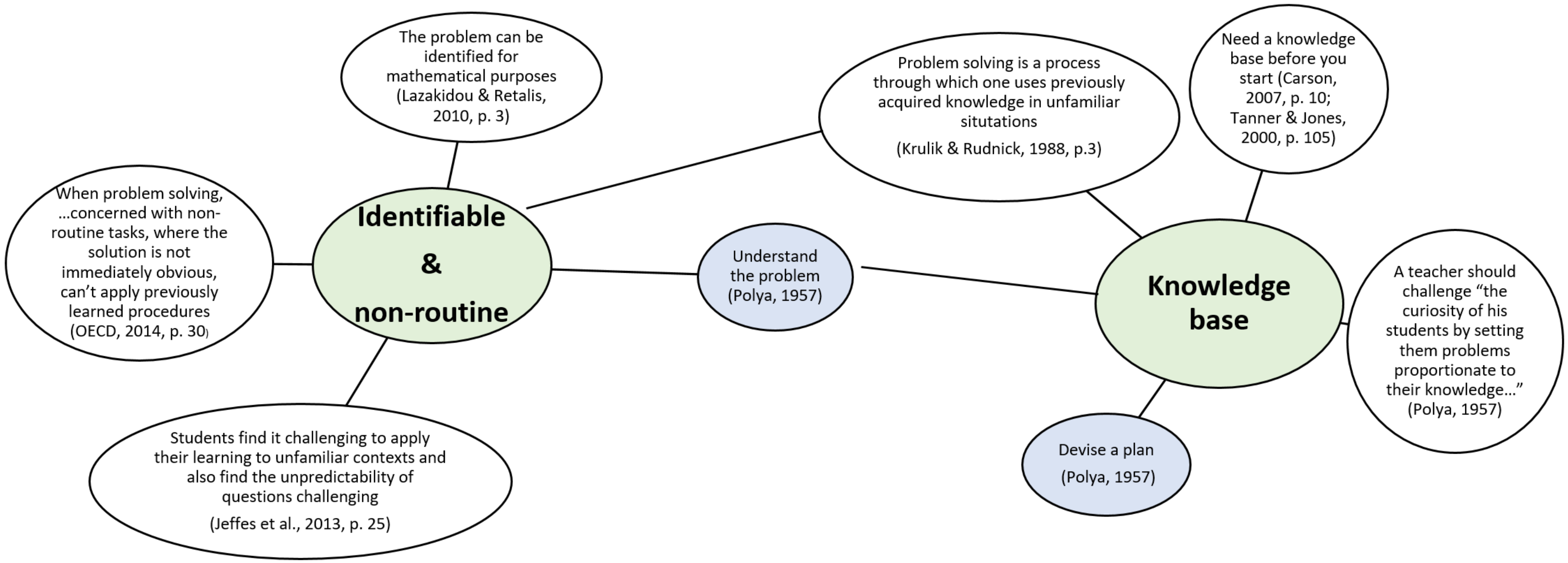


Figure 2: Common themes that define the problem-solving process – Before the process

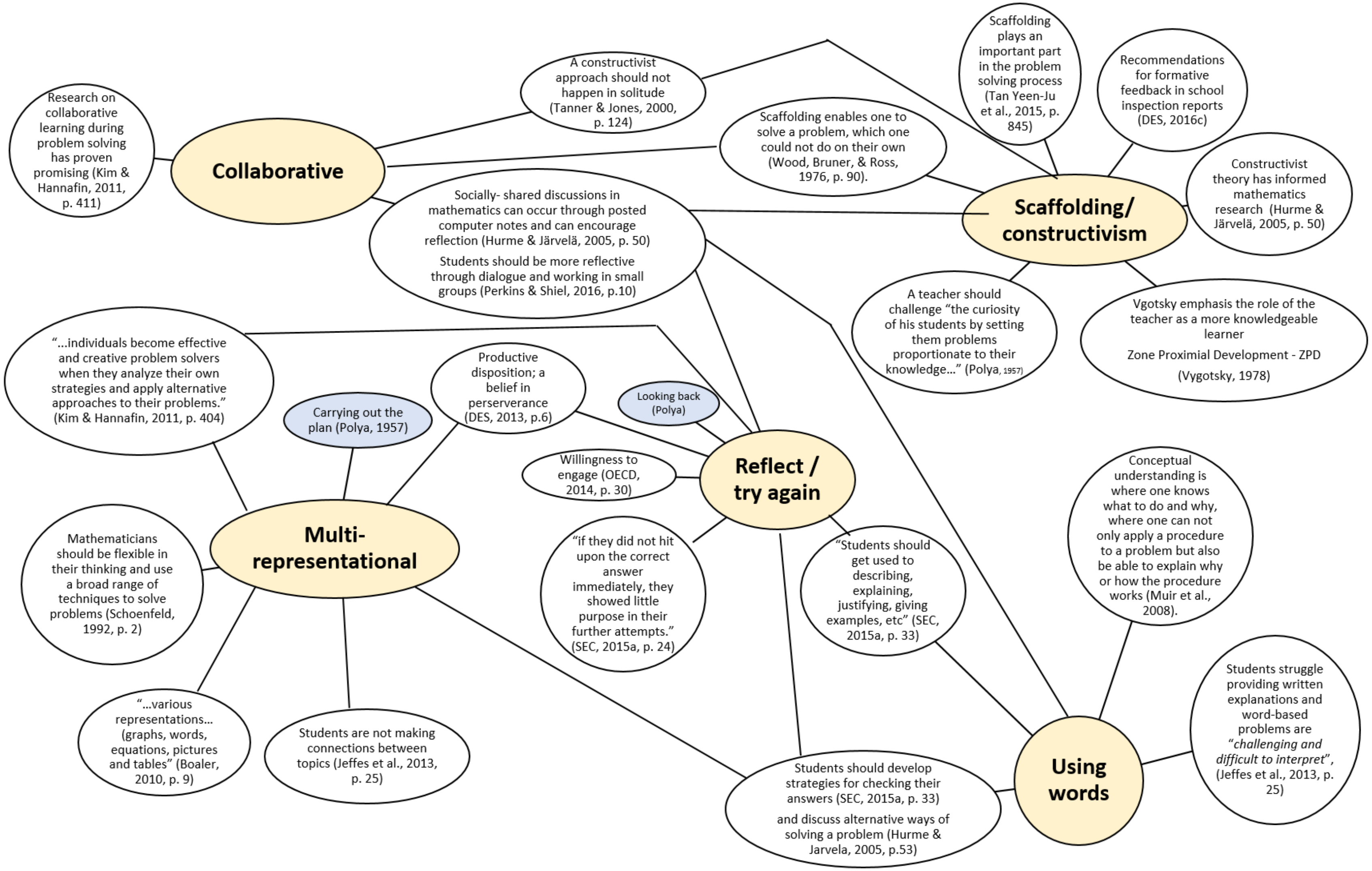


Figure 3: Common themes that define the problem-solving process – During the process

3 Design

3.1 Introduction

This chapter will describe how the learning experience was created. It will be shown how the literature informed this design. The rationale for using the chosen online environment will then be presented.

3.2 Learning experience

The overall aim of the learning experience is that students will solve problems through working in groups of 4 or 5 in an online environment. The learning experience is designed for junior cycle students who have prior experience of drill type exercises in algebra (including simplifying and factorising expressions and solving linear and quadratic equations). Typically students in their 2^{nd} year of junior cycle would be at this level.

As described in the literature review, the problems will be identifiable and non-routine. The problems could be solved using algebra, however this will not be explicitly stated at the beginning. So, while it is clear from the start what result is expected from solving the problem (identifiable) it is not obvious which method to employ to solve the problem (non-routine). Students have the appropriate prior knowledge or knowledge base as they will have studied some algebra as part of their curriculum. The five themes of “Collaboration”, “Describe using words”, “Scaffolding”, “Reflect/ try again” and “Multi-representational” will inform the design of the problem-solving process (figure 3, previous page).

The learning experience is divided up into two phases as shown in figure 4.

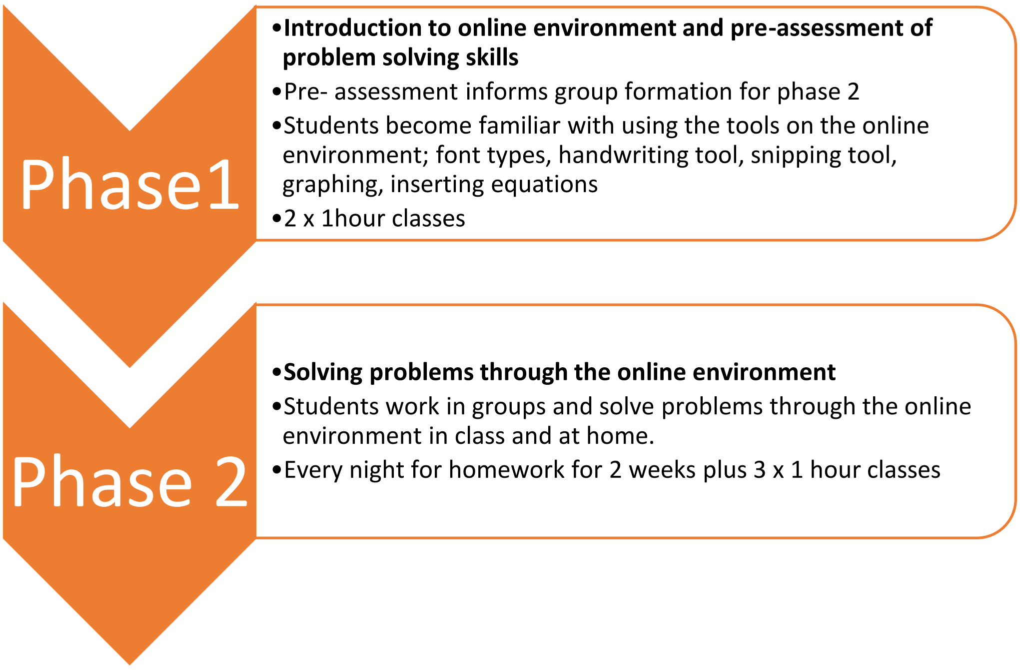


Figure 4: Phases of the learning experience

Phase 1 – Introduction to the online environment and pre-assessment

Students are familiarised with the technology to be used during the learning experience. They will work through an online environment that allows for collaborative editing of a document. The design of the online experience assumes users can view each other's' edits on the document and allow for commenting. Learners should be able to work synchronously and asynchronously on the document. Examples of such software are Word Online[5] or Google Docs[6]. The chosen environment for this intervention is Google Docs, the rationale for which will be discussed later.

[5] Word Online allows for multiple users to collaborate on a document. Everyone's changes can be seen as they happen. Accessed 11th February 2017 https://support.office.com/en-ie/article/Collaborate-on-Word-documents-with-real-time-co-authoring-7dd3040c-3f30-4fdd-bab0-8586492a1f1d

[6] "Google Docs is an online word processor that lets you create and format documents and work with other people." Learners can access, edit and collaborate wherever they are. Accessed 22nd January 2017 https://support.google.com/docs/answer/7068618?co=GENIE.Platform%3DDesktop&hl=en

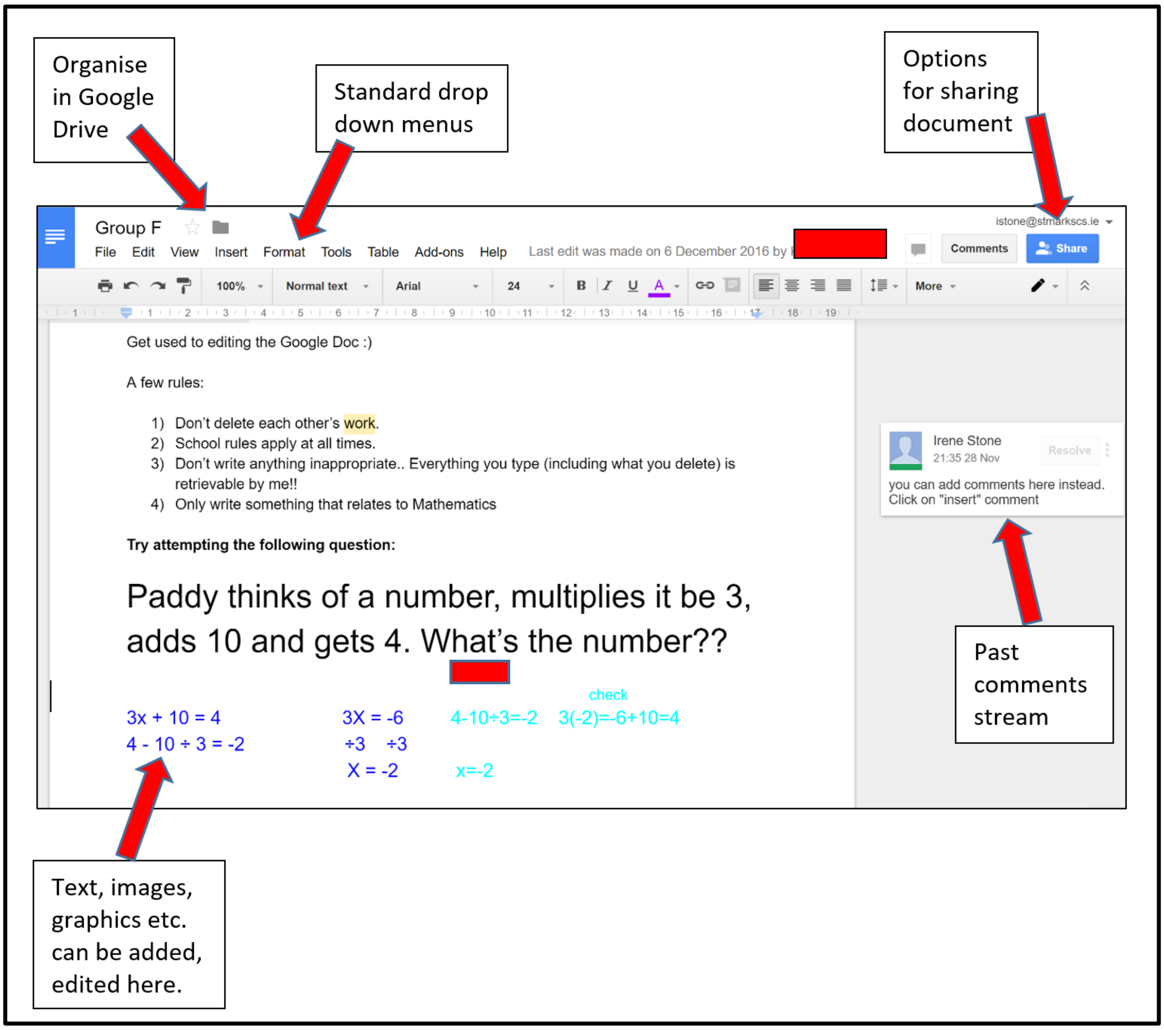


Figure 5: Overview of the Google Docs environment

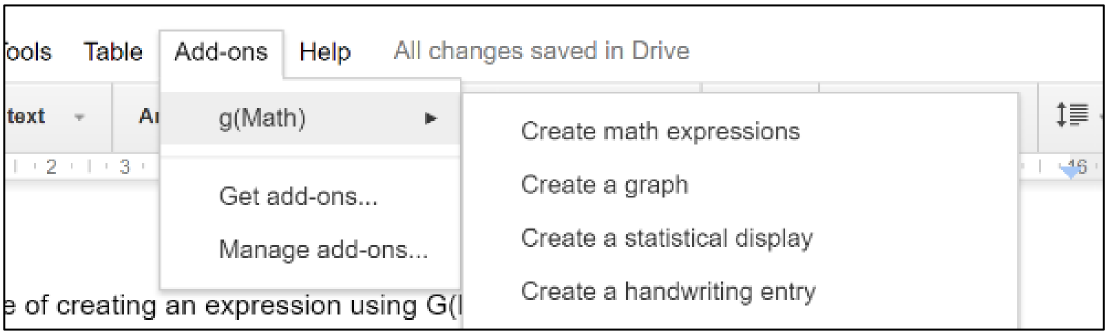
Students will be brought down to the computer room as they need a suitable device to work on for the activities; e.g. a tablet, laptop or computer. The device will have to allow for editing of documents created online. They will be put into groups of 4/5, randomly chosen. The teacher is a member of each group.

By the end of this session students will be able to…

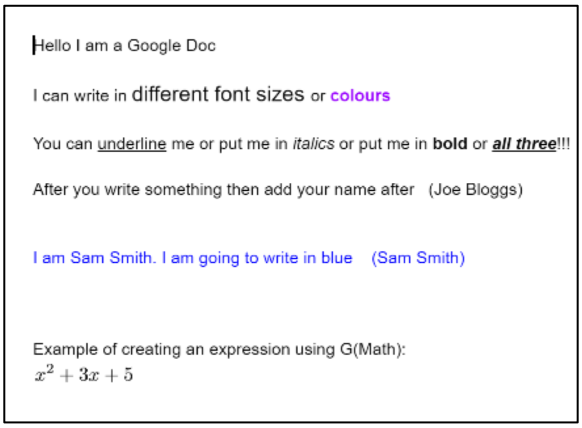
- Write an introduction in the Google Doc
- Use different text styles and colours
- Use the g(Math)[7] add-on tool in Google Docs to create formulae and algebraic expressions

[7] G(Math) is an add-on tool that allows one "to create equations, graphs, stats displays and math quizzes to insert in Google Docs or Sheets"

- Draw tables
- Use the handwriting entry tool in g(Math)
- Snip an image and post it
- Take a photograph of hand written work from their copy and post it up.
- Examples of all these features can be seen in figure 6, below.



g(Math)


Hello I am a Google Doc

I can write in different font sizes or colours

You can <u>underline</u> me or put me in *italics* or put me in **bold** or ***all three***!!!

After you write something then add your name after (Joe Bloggs)

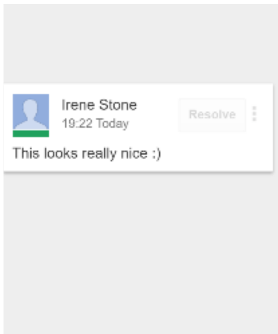
I am Sam Smith. I am going to write in blue (Sam Smith)

Example of creating an expression using G(Math):
$x^2 + 3x + 5$

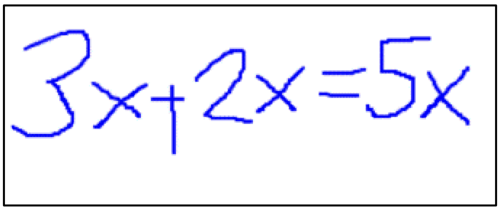
Font sizes, colours, styles and mathematical expressions

Example of a Table

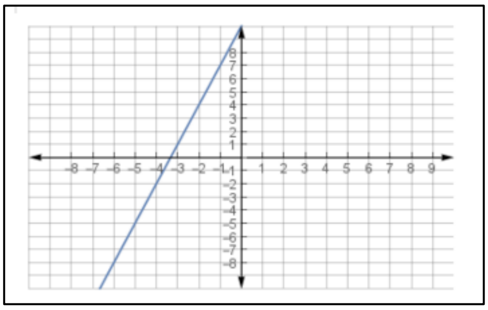
x	y
1	7
2	10
3	13
4	16
5	19
6	
7	



Tables and comments



Handwriting Tool



Graphing

Figure 6: Some features of the Google Doc online environment

During phase 1, the problem solving “pre-assessments” are handed out, see Appendix B. The purpose of these individual assessments is to categorise students as naïve, routine and sophisticated problem solvers (Muir et al., 2008). This can be achieved through the use of a rubric (table 1). This informs the group formation for phase 2, based on the results of the pre-assessment. As discussed in the literature, weaker students can learn and develop from more knowledgeable others in their group (Vygotsky, 1978). When forming the groups for the next phase; at least one sophisticated problem solver and at least one naïve problem solver is to be placed in each group. Students should be given approximately one hour to complete these problem-solving tasks.

	Naïve (0)	**Routine (1)**	**Sophisticated (2)**
Stages of Problem Solving **1. Understanding the Problem** **2. Devising a Plan** **3. Carrying out the Plan** **4. Looking Back**	Errors occur at some or all stages Problem not even attempted	No attempt made to verify solution Problem attempted but then “gives up”	Scores highly for each of the 4 steps of Polya’s heuristic plan and verifies solution
Multi-representational	Relies on one or two strategies/methods when solving all problems	Does not switch or adapt to another strategy/method if one is not working	Uses a variety and combination of strategies Identifies alternative ways to solve problem
Conceptual understanding – Justification Explaining Communication	Inadequate Cannot explain their working	Clear	Scores highly for written communication Can explain why or how a particular strategy works
			Total (max) = 6

Table 1: Rubric for assessing problem-solving ability

Adapted “Problem Solving Continuum” (Muir et al., 2008, p. 230)

Students will be presented with 10 problems in the pre-assessment (Appendix B). It was highlighted in the literature review that students need to feel motivated to attempt problems (OECD, 2014; Palmer, 2005). The first 4 problems involve using algebra skills that students have prior knowledge of; they would have used these skills in non-routine questions before. These problems will therefore, be familiar to students. By feeling confident that they can tackle the first few problems, they will feel motivated to attempt the rest of the problems in the assessment.

Questions 5, 6, 7 and 8 are types of problems students would not have seen before. While they would have practised routine exercises involving the algebra required for these problems, they would not have encountered any non-routine problems that require this algebra. As discussed in the literature review, problem solving is a process through which one uses previously acquired knowledge in unfamiliar situations (Krulik & Rudnick, 1988, p. 3). It is important that students are presented with problems they have never seen before as one of the research questions is asking if they will attempt more questions after the intervention. If they had experience of all the problems before then they probably will attempt them all. Q9 involves Algebra they have not done in class before. Q10 is a question from the 2015 Junior Certificate Examination. Table 2 on the next page shows a breakdown of the problems in the assessment.

Problems	Description	Rationale	Expected outcomes
Q's 1-4 Problems involving linear patterns, solving linear equations	Students have the **knowledge base** – they have solved routine exercises **and** similar non-routine problems before.	To give students confidence in tackling the problem set, helping them feel like they will succeed (Keller, 2010, p. 44)	They would attempt the problems and use algebra. They would be successful in their attempts.
Q's 5-8 Problems involving quadratic equations	Students have the **knowledge base** – they have solved routine exercises in solving quadratic equations. However they have **not** solved non-routine problems with a context that involve quadratics.	To ascertain who would/wouldn't attempt and what methods they would employ to solve. To assess who is a naïve, routine, or sophisticated problem solver. To inform the types of problems that would be asked during the intervention.	They would attempt problems but maybe not use algebra.
Q 9 Generalising a quadratic patterns	Students do **not** have the knowledge base (i.e. Algebra – generalising quadratic patterns) to solve this problem however it could be solved by trial and error.	To ascertain if they would even attempt this question and to find out who the "sophisticated" problem solvers were.	Very few will solve this problem. Any student who did was categorised as a "sophisticated" problem solver.
Q 10	A higher level Junior Certificate question from 2015.	This particular question was highlighted in the SEC report (SEC, 2015a)	Students would attempt but few would complete.

Table 2: Breakdown of problems in pre-assessment

Phase 2 – Solving Problems through the online environment

Students are put in groups of 4 or 5. The groups are chosen such that there is a more knowledgeable other in each group, a "sophisticated" problem solver. Over the course of 2 weeks, groups are given approximately 8 problems to solve (Appendix C). A problem is given on average every 2 days. Students are asked to log in to their Google accounts for homework and attempt to solve the problem. The design of the learning intervention needed adjusting as it became apparent that not all students had access to a suitable device at home. The learning experience, therefore, should include some sessions during timetabled class where learners have access to a tablet, laptop or desktop computer. This design is based on 3 timetabled class sessions.

Examples of the type of questioning and comments the teacher can use are shown in table 3, below. These were informed by the literature (Hattie, 1999; Muir et al., 2008; NCCA, n.d.; Wood et al., 1976).

Literature	**Examples of questioning / scaffold prompts**
Seek feedback from students as to what they know, understand (Hattie, 1999)	*"Can you explain how you did that?"*
Look for conceptual understanding (Muir, Beswick, & Williamson, 2008)	*"Can you explain why you did that?"*
Reminder prompt • More suitable for able students (National Council for Curriculum and Assessment, n.d.)	*"Explain why you think this"* *"You have solved this correctly, is there another way you could solve this?"* *"Go back and read the question again"*
Scaffold prompt • More suitable for students who need more support (National Council for Curriculum and Assessment, n.d.)	*"If you try putting the numbers in a table, it might help you"* *"I have drawn the table for you"* *"Have a look at what X did"*
Example prompt • Can be used with all students, but in particular those who need the most support (National Council for Curriculum and Assessment, n.d.)	*"Think back to when we solved X in class"*
Wood et al (1976) suggest emphasizing certain aspects of the problem to help with solution. Different aspects of the problem could be emphasised to different groups depending on needs of that group.	*"I've highlighted some of the problem for you"*

Table 3: Types of questioning and comments

3.3 Literature informing design

The design table below (table 4) shows how the themes that emerged from the literature were used to shape the design and implementation of the learning experience. The first two themes "Identifiable and non-routine" and "Knowledge base" set the scene for the process. The remaining themes guide the design of the process.

The final column shows the first problem that is set for the students to solve. The problem is: *"Farmer Joe has 20m of fencing. What is the maximum rectangular area he can make with the fencing?"*

Themes that emerged from literature	Design principle	Implementation	Example *Farmer Joe has 20m of fencing. What is the maximum rectangular area he can make with the fencing?*
Identifiable and non-routine	Problem should be identifiable (Lazakidou & Retalis, 2010) Should be non-routine in nature (OECD, 2014) Unfamiliar contexts (Krulik & Rudnick, 1988)	It will be clear from the start what the students have to do. Students won't have seen the problem before. It will not be clear what method to employ to solve the problem	It is clear that students have to find the maximum area – it is not clear what method students should employ. (This problem can be solved using tables, trial and error, drawing diagrams, using algebra and/or graphing)
Knowledge base	Students need a knowledge base and problems should be proportionate to their knowledge (Carson, 2007; Polya, 1957; Tanner & Jones, 2000)	Students will have the maths tools to solve the problems or at least attempt them, i.e. appropriate prior knowledge.	Students know how to construct tables, find the area of a rectangle and are familiar with generalising linear patterns. They have not graphed a quadratic pattern before (not necessary for problem). Through appropriate scaffolding and teacher guidance some students could be challenged to draw graph.
Constructivism	Learners are given significant autonomy in problem solving (Tanner & Jones, 2000) Constructivist classroom is filled with discussion and is based on social interactions between individuals (Gill, Ashton, & Algina, 2004; Palmer, 2005)	Students will not be told how to solve the problem. They are free to choose whatever method they wish. They will be encouraged to solve a problem a different way to others in their group. They will be encouraged to explain what they're doing – to have online discussions.	If one student solves problem drawing diagrams, another student will be encouraged to use a table.
Scaffolding	Making good use of questioning to scaffold the learning (Polya, 1957; Tanner & Jones, 2000) Zone of Proximal Development (Vygotsky, 1978) Formative Feedback (DES, 2016c)	Students are given tasks within their range of learning. The teacher can give hints if they encounter difficulties. The teacher can set more challenging problem to those who are not being challenged.	Some students may need the start of the table drawn for them; this is giving them a hint to try other values for the length and width of a rectangle. For those who need an extra challenge; they can be encouraged to draw a graph. Through guided questioning can they see that it is a quadratic pattern?

<table>
<tr><td>Using words</td><td>Students can retrace their thoughts on online environment
(Hurme & Järvelä, 2005, p. 50)

Students should get used to “describing, explaining, justifying, giving examples, etc.” (SEC, 2015a, p. 33)

Conceptual understanding is one where one knows what to do and why (Muir et al., 2008)</td><td>When a student makes an attempt on a problem on the Google Doc, the teacher will encourage them to explain what they are doing. They will also be encouraged to ask each other questions as to why they did something.

Students will be asked to explain what the problem means in their own words. They will be asked to justify their chosen method, and verify their result.</td><td>The teacher can ask: ‘Can you explain how you did that?’

‘What do you think the problem means in your own words?’</td></tr>
<tr><td>Collaborative</td><td>Collaboration is key in the learning of mathematics (Boaler, 2010; DES, 2013, 2015a)

Constructivist approach should not happen in solitude (Tanner & Jones, 2000)</td><td>A Google Doc will be shared with 4/5 students and the teacher.

Students will be working together to solve a problem. They will have the opportunity to work from home or at the same time during class.</td><td>Teacher can remind students to explain and justify their thinking to the others in their group. They will be encouraged to ask questions of each other.</td></tr>
<tr><td>Multi – representational</td><td>Students should use different methods/ representations/ techniques for solving problems
(Boaler, 2010; Kim & Hannafin, 2011; Schoenfeld, 1992; SEC, 2015a)</td><td rowspan="2">Students will be encouraged to attempt the problem using different techniques.

If they successfully solve the problem they will be asked to try solve again a different way.

If they are unsuccessful, they will be encouraged to try again - the teacher can apply appropriate scaffolding; i.e. make the problem a little bit easier for example.</td><td rowspan="2">Problem can be represented in many different ways; diagram (picture), table, graph, algebra.

A student may not know the difference between area and perimeter and may give up at first. The teacher can either define area and/or perimeter or ask another student to explain these keywords.

If a student is unsuccessful, the teacher can draw the first few rows of a table.

A student may solve this problem drawing a table and find that$5 \times 5 = 25m^2$, i.e. the correct solution. In this instance they could be asked to graph the Area vs Length of Rectangle.</td></tr>
<tr><td>Reflect and/or try again</td><td>Students should be encouraged to solve problems again using alternative strategies, or try again if they are unsuccessful
(Hurme & Järvelä, 2005; Kim & Hannafin, 2011; SEC, 2015a)

Provide written explanations as to how they solved a problem; explain their thought process
(Muir et al., 2008; SEC, 2015a)</td></tr>
<tr><td>Motivation</td><td>Students need to be motivated to make the effort to work collaboratively and to solve a problem (OECD, 2014, p. 30; Palmer, 2005, p. 1874).
Interlinking of algebra with other mathematics topics increases students’ motivation and interest (Jeffes et al., 2013, p. 61).</td><td>Students are given autonomy over how they can solve the problem.

Encouraging students to use different methods/ representations to solve the problem.</td><td>ARCS motivation model used (will be explored later in this chapter).</td></tr>
</table>

Table 4: Design table

3.4 Rationale for using the Google Docs online collaborative environment

The literature review highlighted the reasons why teachers may be reluctant to employ methodologies that facilitate problem solving, such as group work, discussion, open-ended tasks, etc. Teachers feel the pressure of content coverage and the terminal exam, e.g. the Junior Certificate and the Leaving Certificate examinations in the case of the Irish education system (Kim & Hannafin, 2011; NCCA, 2012a; Schoenfeld, 1992). Using an online collaborative environment can allow for students to work in their own time. Homework that is normally set for students can be replaced with work that involves collaboration, something that is not normally possible for students to do from their own home environments.

As mentioned in the literature review, students are required to improve on their digital skills, in particular to "communicate, work and think collaboratively" (DES, 2013, p. 6, 2015a, p. 12, 2015b). Through working on the online environment, it is envisaged that students will be improving their digital skills while working collaboratively.

It is envisaged that the online platform, will allow students to discuss their work 'using words' through typing or using the handwriting tool in the main editing area or through the comments. This can occur during any of the stages of the problem-solving process; explaining what the problem means to them, justifying why they choose a particular method, asking questions to others, going back and trying again. All of these are important elements of problem solving as discussed in the literature review (Jeffes et al., 2013; SEC, 2015a; Tanner & Jones, 2000).

It is hoped that the online environment can support scaffolding where the teacher, as member of each group, can intervene at any stage to guide discovery (Palmer, 2005; Polya, 1957; Tan Yeen-Ju et al., 2015; Tanner & Jones, 2000). Scaffolding, in turn, allows for formative feedback to be given to students (DES, 2016c).

Google Docs was chosen as the online platform because the school uses a "Google for Education/ G Suite for Education"[8] platform. This platform has enhanced security

[8] Google for Education … G Suite core services contain no advertising and do not use student data for advertising purposes. (more information about G Suite for Education security features: https://www.google.com/edu/trust/index.html#howdo-you-know-were-keeping-our-word)

features and all students have school domain google accounts which are specifically set up for school related work.

One aspect of problem solving is using different methods to solve problems (Boaler, 2010; Jeffes et al., 2013; Kim & Hannafin, 2011; Schoenfeld, 1992; SEC, 2015a) . Google Docs should allow the students to show each other different methods they may use to attempt a problem. For example, one student may draw a table, another student may draw a graph, and another student may use algebra. They can take photographs of their work (in their maths copies for example) and post it up on the Google Doc. There are also mathematical functions in Google Docs, for example inserting equations and drawing tables and graphs. Examples of all these tools were explored in the learning experience section.

3.5 ARCS model

As discussed in the literature review, motivation is required in order for the collaborative constructivist experience to be successful (OECD, 2014; Palmer, 2005). The ARCS motivational model is used to improve the motivational appeal of instructional materials and involves 4 steps – Attention, Relevance, Confidence and Satisfaction (ARCS) (Keller, 1987, 2010). Table 5 shows the ARCS model and its relevance to the learning experience.

	Definition	How
Attention	Capturing the interest of learners Stimulating the curiosity to learn	Google Docs is new to the students. This novel learning environment should capture their interest as they have never used it in their maths class. They are used to solving problems in their copies.
Relevance	Meeting the personal needs/goals of the learner to effect a positive attitude	Students will be made aware that problem solving skills are necessary for their mathematical learning. They will be told that it is envisaged that this learning experience will improve these skills as well as their collaboration and digital skills.
Confidence	Helping the learners believe/feel that they will succeed and control their success	Students will have the appropriate prior knowledge to solve the problems. They will be given ownership of the process as they can choose whichever method they wish to solve the problems. The teacher will be there to support them should they have difficulty. There are other students to help them too. It will be re-iterated to them throughout the process that it's acceptable to make mistakes.
Satisfaction	Reinforcing accomplishment with rewards (internal and external)	Positive feedback can be given through the comments on the Google Doc; e.g. "well done", "keep going".

Table 5: ARCs model

(Adapted from Keller's ARCS model (Keller, 2010)

4 Research Design

4.1 Introduction

The research is investigating students' development of problem-solving skills through an online collaborative environment. As highlighted in the previous chapter, Google Docs was chosen as the platform to use. The researcher was an active part of the whole process; as a group member the researcher was observing and participating (through commenting) as the participants engaged in the activities. The research, therefore, takes the form of a case study; this is the "social research equivalent of the spotlight or the microscope" (Hakim, 2000). A case study investigates "a contemporary phenomenon" (problem-solving skills) within its "real-life context" (through Google Docs). The "boundaries between phenomenon and context are not clearly evident" (Yin, 2003, p. 13).

As the intervention being evaluated has "no clear, single, set of outcomes", it was decided to approach the research as an exploratory case study (Baxter & Jack, 2008, p. 548). Furthermore, a paucity in research on problem solving through an online environment merits an exploratory approach (Creswell, 2003, p. 22); one which allows for flexibility in the research design and the data collected (Creswell, 2014). The exploratory approach first explored the views of the participants through surveys and assessed their problem-solving abilities through an assessment. An initial analysis of this data informed the next phase of the intervention "phase 2"; it dictated the forming of the groups, what types of problems to ask on the Google Docs and the type of scaffolding needed by the teacher. Through observation of the activity during phase 2; this in turn fed into the types of questions that were asked during the interviews.

A case study relies on multiples sources of evidence and allows the researcher to look at many different variables of the learning experience (Cronin, 2014, p. 20; Yin, 2003, p. 13). Data sources for this research include surveys, interviews, participant observation, documentation (Google Docs records of students' workings), records of conversations made online and assessments of problem-solving skills. Case study research allows for the collection and integration of these different sources which produce qualitative and quantitative data (Baxter & Jack, 2008, p. 554).

Case studies also suit research which is conducted over a short period of time (Creswell, 2014). The timeframe for the intervention (phase 2) is short at just 2 weeks. The reasons for this will be discussed in the implementation section.

4.2 Research Question(s)

The purpose of this case study is to explore the problem-solving skills of the participants through the online environment of Google Docs. The research will attempt to answer the following question:

Can working collaboratively through an online environment support post-primary mathematics students' problem-solving skills?

The literature review looked at defining problem solving. The themes that emerged informed the design of the learning experience, these were discussed in the last chapter. Some of these themes inform the sub-questions.

Theme: "Reflect and Try Again"

Did working through the online environment influence students' willingness to reflect on what they were doing and/or try again?

Theme: "Using Words"

Were students using words when solving problems?

Theme: "Multi-representational"

Did working through the online environment allow students to demonstrate different ways to solve a problem?

Theme: "Scaffolding"

How did the online environment support the scaffolding process?

Theme: "Collaboration"

Was the online environment conducive to collaboration?

4.3 Research Methodology

The sample size of the study is small (n=30), thus a quantitative approach alone is not suitable to conduct meaningful statistical analysis (Creswell, 2014). However, it is argued that a qualitative approach alone is unscientific (Cronin, 2014). It was decided, therefore, to approach the research design as a convergent mixed methods approach. This approach analyses the qualitative and quantitative data collected; at first analysing them separately and then comparing their results to see if they converge (Creswell, 2014).

A constructivist pedagogy, which underpins the design of the learning experience, suits the collection of qualitative data allowing for capture of the “lived experiences of individuals; to understand the meaning of phenomena and relationships among variables as they occur naturally…” (Baxter & Jack, 2008; Ross & Onwuegbuzie, 2012, p. 87). Quantitative data collected from surveys and assessments will enrich the data collected (Johnson, Onwuegbuzie, & Turner, 2007). Triangulation i.e. “gathering data from different sources”, increases the scope for interpreting findings and allows for convergence of data (Creswell, 2014; Cronin, 2014, p. 26; Øvretveit, 1998).

4.4 Data Collection/ Instruments

Both quantitative and qualitative data was collected. The quantitative data came from the pre and post surveys and pre and post assessments of problem-solving questions. The qualitative data collected came from observation, documentation (students work on the Google Docs), conversations that occurred on the Google Docs and interviews. By collecting data from numerous sources, this allowed for the researcher to have greater confidence in the findings (Johnson et al., 2007).

Data collection method	Stage in process	Reason	Research question to be answered
Problem solving pre and post assessments	Before and after learning experience	To determine the number of attempts students will make to problems they have never seen before and to see if the number of attempts will change after the intervention	Did working through the online environment influence students' willingness to reflect on what they were doing and/or try again?
		To determine students use of words when solving problems before and after the intervention	Were students using words when solving problems?
		To determine the number of ways students will use to attempt to solve problems in particular, their use of Algebra	Did working through the online environment allow students to demonstrate more ways to solve a problem?
Pre and post Surveys	Before and after learning experience	To see if there is any change in students attitudes and feelings on problem solving after the intervention	All sub-questions
Researcher observation	During the intervention	To assess the levels of engagement, use of words and collaboration during the intervention.	Was the online environment conducive to collaboration? Were students using words when solving problems?
		The researcher is also an active participant in the research and will be acting as a guide to scaffold the learning of individuals so observation is key to this process.	How did the online environment support the scaffolding process?
Documentation of students workings - through the Google Doc	During the intervention	Three of the main themes that emerged from the literature can be assessed here: students' use of words, their willingness to attempt problems "reflect and try again" and their use of different methods "Multi-representational". Comments from teacher and students will be recorded. To assess the level of collaboration amongst students.	All sub-questions
Interviews	After the intervention	To understand more about the learning experience from the students' perspectives and to collect data that could not be collected otherwise.	All sub-questions

Table 6: Research instrument rationale

Problem-solving assessments

The pre and post assessments consisted of 10 problems to be solved (Appendix B). One of the reasons for the pre-assessment as outlined in the design chapter was to categorise learners as naïve, routine or sophisticated, so they could be grouped for the learning intervention. From a research methodology point of view, a post assessment was also given. The first 7 questions were different from the pre-assessment. The problems were still non-routine but students could use similar methods/approaches to solve these problems (refer back to table 2 on page 23 to see the breakdown of problems). After analysing the pre-assessment, it was decided to leave Q's 8, 9 and 10 the same due to the high level of non-attempts, incomplete or incorrect solutions. This will be discussed in more detail in the findings chapter.

The purpose of having a post-assessment, was to see if there was a change in the number of attempts students employed, when compared with the pre-assessment. This method of data collection produced quantitative data. It was not the purpose of the research to see if students' problem-solving ability had improved. This was due to the short time frame of the intervention. Therefore the number of naïve, routine or sophisticated learners was not established from the post-assessment.

Surveys

Paper surveys were handed out before and after the learning experience (Appendix D). The purpose of the surveys was to determine if there were changes in students' attitudes towards problem solving. The author failed to find a validated survey in the literature that would address the needs of this research. The survey was designed by the author with the themes of the research questions in mind. Some of the questions were adapted from the Professional Development for Teachers (PDST)'s 'Pupil Math's Survey' and also influenced by Schoenfeld's work in problem solving, in particular, on typical student beliefs about mathematics (PDST, n.d.; Schoenfeld, 1992, p. 27).

This data collection method allows for the measure of quantitative data by comparing pre and post responses. Bar charts offer an easy way to compare the data. A T-Test analysis is used to determine if the two data sets (pre and post) are statistically significantly different from each other. The questions were mainly closed with one open question. As will be highlighted later, this method is limited in its scope; the intervention is too short and the sample size too small for meaningful statistical analysis to occur. To avoid influence or researcher bias, the surveys were filled out anonymously.

Researcher observation

The researcher was an "active participant" in the research, having access to the Google Docs allowing for observation of interactions between students. The researcher could check for conceptual understanding; i.e. could students explain why they choose a particular strategy or method. As a participant observer, the researcher was able to be within the "world" of the situation. This allowed the researcher to scaffold the learning, a key theme that emerged from the literature as something that can improve problem solving. The researcher could also observe students approaches; were they using different methods to solve the problems? Were they justifying/explaining their methods/ answers to each other? This allowed for the collection of qualitative data.

Documentation of students' workings

During the 2 week intervention, all work students completed, and conversations between them and the researcher were documented on the Google Docs. This allowed for the collection of qualitative data; looking at students use of language (describe using words), looking at the different methods they employed to solve a problem (multi-representational), their attempts at trying again and reflecting on their work (reflect and/or try again). Examples of the Google Doc artefacts are in Appendix M.

Interviews

Group interviews were conducted after the intervention. There were six interviews in total. Students were in groups of 5 and each interview was of 6-10 minutes in duration. Interviews were semi-structured; there were 6 focused questions that came from the sub-questions (Appendix E). The other questions were open and exploratory; participants were asked to pursue issues that emerged from previous responses. Group interviews were conducted instead of individual interviews due to the size of the sample; interviewing 30 students in a school would not have been possible due to timetable constrictions. Also, students at this age (14-15) are likely to feel more confident speaking in a group and may feel intimidated speaking one-one to their teacher (Øvretveit, 1998, pp. 202–204). The interviews were recorded and then transcribed.

4.5 Implementation

4.5.1 Learners and prior knowledge

Learners were a convenience sample chosen from one of the researcher's Maths classes. The class consists of 30 2nd year Junior Cycle students, of mixed gender (13-14 years). The students were studying the higher level syllabus. During the run up to the intervention, the curriculum was focused on building up their algebra skills as set out in the subject plan and the sequence of teaching topics as recommended by the PMDT (Appendix F). Through prior summative and formative assessments, the participants were deemed to have the appropriate prior knowledge to enable them to attempt the problem-solving tasks. It also seemed appropriate to choose this particular class as this is the age group the TIMSS study focused on (DES, 2016a).

7 groups were created; 5 groups with 4 students, and 2 groups with 5 students. Over the course of 2 weeks, students were asked to log in to their Google accounts for homework and attempt to solve a problem. It quickly became apparent that not all students could access the Google Doc from home. Some of them were using their mobile devices (e.g. smartphones) and didn't know how to comment, or add to the Google Doc. They reported only being able to view the document. It was clear that students needed access to a tablet, laptop or desktop computer, and some students didn't have these devices at home. At this point, the researcher, decided to have 3 sessions in class time to spend on the Google Docs. During these 3 periods of 1 hour each, students were working collaboratively on the Google Docs. They were working synchronously solving the problems. During all stages of the activity, the teacher was periodically checking in on each group's work, adding comments and guiding the learners.

The timeframe for the intervention (phase 2) was 2 weeks. The reasons for this are multifaceted:

-The researcher is the participants' maths teacher and often includes problem solving activities during normal classroom teaching; this would be stepped up throughout 2nd year, in particular problems requiring algebra. The 2 week period chosen to run the study was just before the Christmas break. Students sit their 2nd year Christmas tests at the beginning of December and there is a 2 week window after their exams and before the Christmas break. It is the time when students are normally involved in project work.

It made sense to use this 2 week window as the researcher wanted to rule out any influence normal class time would have on students' problem-solving skills, when measuring the effect of the intervention.

- The school where the researcher works has limited access to devices. There are 2 computer rooms which are heavily used. The researcher was able to book the computer room for the 2 week intervention but this would not have been possible for a longer period.

4.5.2 Ethics

The ethical considerations are listed below and a brief synopsis is given as to how the researcher dealt with these issues.

- Participants under 18

As the participants were under 18, consent was sought from their parents/guardians. Parents/guardians and students were given information sheets about the project and were asked to complete consent and assent forms respectively. A letter detailing the study was sent to the board of management of the school who were also asked to complete a form of consent.

- Researcher was participants' teacher

Students were made aware that their responses during the interview were treated with the utmost anonymity. The survey was designed so that the questions were not biased towards working individually on problems or working collaboratively with someone else to solve a problem (Appendix D).

- Impingement on the curriculum

Students learned how to use the technology Google Docs before the intervention. This occurred during timetabled class time. This did not impinge on the curriculum as students were learning Mathematics content (they were given mathematical problems to solve) from the curriculum while learning these tools. Through Google Docs, students conversed online "to share, explain and justify their solution strategies" (DES, 2013, p. 11). While learning how to use the g(Math) and graphing tools in Google Docs, students were developing their skills in using computer graphing software, as recommended in the Junior Certificate syllabus (DES, 2013, p. 26). Students who choose not to participate in the study still attended the classes where they learned these relevant digital skills.

- Extra work for students

Students were not given any homework during the 2 week intervention to allow them the time to work online with their group members. All work was relevant to the maths curriculum. Students who choose not to participate in the study were given similar problems to complete in the usual format (i.e. homework copybooks). For students who had difficulty going online and/or had no suitable device at home, it was arranged to have a time for them to use a computer in school during lunch or after school.

- Privacy and Security issues using Google platform

The school uses G Suite for Education (formally known as Google Apps for Education). This is where all student and teachers use school domain google accounts. E.g. joebloggs@stmarkscs.ie. This Gmail domain has enhanced security features. G Suite for Education contain no advertising and does not use student data for advertising purposes. Parents and students were aware of the privacy and security feature of the G Suite for Education service by giving them the link to this website and a summarised printed copy of these features (Appendix G).

- Anonymity of students

Students were told that when they were working on their Google Doc that they should only discuss/ write about content related to the mathematics problem they were solving. They knew that the researcher/teacher was a member of the Google Doc group and that the teacher could contribute to the discussions. Students were identifiable on the Google Doc through their school google accounts. Any data used for the research was not identifiable. Open ended questions in the survey may have resulted in individuals being identified. To mitigate this risk, the following warning was added: “Please do not name third parties in any open text field of the survey. Any such replies will be anonymised.” If any individuals were named, the data that identified the individuals was deleted.

Ethical approval for the study was granted by the School of Computer Science & Statistics, Trinity College Dublin Ethics Committee. Consent was sought and obtained from

- Student participants
- Parents/Guardians
- Board of Management of the school

All information sheets and permission forms pertaining to this research are included in Appendix G. Ethical approval is included in Appendix H.

4.6 Limitations

The validity of the intervention is questionable due to the fact that the researcher was acting as a participatory observer. The participants knew that their teacher was observing and contributing to the discussions, this was likely to have an effect on the students (Øvretveit, 1998, p. 201). However, it was important that the researcher was part of the process, helping the students through scaffolding and guiding them with their learning; an important step in the problem-solving process (Polya, 1957; Tanner & Jones, 2000; Vygotsky, 1978). Also, observation in this way allows for "direct evidence of observed outcomes" (Øvretveit, 1998, p. 201).

The small sample size (n=30) creates a validity issue with the surveys. A quantitative analysis of the survey responses is not suitable to conduct meaningful statistical analysis (Creswell, 2014). The validity of the surveys themselves is also questionable due to the fact that they were designed by the researcher.

Validity issues with the interviews include the fact that the teacher acted as interviewer. This may have unintentionally influenced students' responses. The researcher aimed to appear neutral and non-judgemental during the interview (Øvretveit, 1998) . Each interview started with the words "There are no right answers to these questions". Students were assured that their responses would be completely anonymised and that all recordings, once transcribed would be deleted. It was important that the researcher carried out the interviews to allow for a semi-structured approach. This outweighed the potential validity issue.

There are weaknesses when using group interviews; it is less easy in a group situation to probe one person's views and there's the pressure of group conformity (Øvretveit, 1998, p. 204). However, the group interviews allow for gathering of a range of views more quickly.

5 Findings

The research set out to answer the question “Can working collaboratively through an online environment support post-primary mathematics students’ problem-solving skills?” It was decided to take each of the sub-questions and see if they could be answered by triangulating the data collected from the different sources.

The sub-questions were:

- Did working through the online environment influence students’ willingness to reflect on what they were doing and/or try again?
- Were students using words when solving problems?
- Did working through the online environment allow students to demonstrate different ways to solve a problem?
- How did the online environment support the scaffolding process?
- Was the online environment conducive to collaboration?

Data collected from the pre and post assessments and surveys was analysed quantitatively. Students were interviewed after the intervention; this data was analysed qualitatively. Qualitative data was also collected through observations of their work on the online environment.

Some of the sub-questions were answered through analysing all types of data collected (survey, interview, observation) while others could only be inferred from the interview responses and observations. The aim was to triangulate the data as much as possible to strengthen the conclusions made at the end.

An attempt will be made in this chapter to answer each sub-research question separately. Before that, a description of how the survey responses were analysed quantitatively, and how the interview responses were analysed qualitatively, will be presented.

5.1 Quantitative analysis of survey responses

The pre and post survey responses were analysed quantitatively. For questions 3 -17, students had to respond to questions by choosing one answer only from a Likert Scale that had 5 points, (Appendix D). Each point on the Likert Scale was assigned a value from 1 to 5 as outlined below.

Strongly Disagree = 1

Agree = 2

Neither Agree or Disagree = 3

Agree = 4

Strongly Agree = 5

The data was analysed using a Two Sample T-test. A T-test is commonly used when analysing and comparing 2 samples of quantitative data. The T-test was chosen because of the small sample size (n=29). The table in Appendix I shows the means, variances, standard deviations and p-values for each survey question. Questions that have a p-value < 0.05 indicate a statistically significant change in the mean. Questions that have a p-value > 0.05 indicate no significant change in the mean. From the table in Appendix I, it can be concluded that 18% of the survey questions (3 out of 17) showed a change in the mean. These 3 survey questions (table 7) will be analysed separately in this chapter when an attempt will be made to answer the sub-questions. The statistical significance of these 3 survey questions will help support the conclusions about the research intervention, in particular when triangulating data from different data sources. 14 survey questions showed no change in mean score. The intervention time of 2 weeks was short and could explain why there was no change.

		Pre			Post			
Q	**Survey Question**	**Mean**	**Variance**	**Std. Dev.**	**Mean**	**Variance**	**Std. Dev.**	**p value**
9	…I describe how I solve the problem using words.	3	1.142857	1.069045	3.551724	0.970443	0.985111	0.045687
12	Students who have understood the maths taught to them will be able to solve a problem in less than 5 minutes	2.793103	0.884236	0.940338	2.310345	0.578818	0.760801	0.036109
17	Reading a problem more than once is a waste of time.	1.827586	1.147783	1.071346	1.37931	0.243842	0.493804	0.047504

Table 7: Quantitative data - surveys

While the initial aim of the research methodology was to compare pre and post survey data, some interesting findings can be drawn from analysing the pre-survey data alone (Appendix I). It is clear from some of the survey responses that students already showed traits of problem-solving skills. The low mean scores for the 2 statements *"If I can't do a problem I give up straight away…"* (mean = 1.83, standard deviation = 1.04) and *"There is only one way to solve a maths problem"* (mean = 1.66, standard deviation = 0.67) indicate students disagreeing or strongly disagreeing with these statements before the intervention. This finding shows that they have a productive disposition, i.e. they know to persevere with a problem (DES, 2015c).

The high mean score (mean = 3.76, standard deviation = 1.02) for the question *"If I can't solve a problem one way I will try and solve it another way…"* indicates that students already knew to try other ways to solve problems. While it appears that students already know not to give up and that there are other ways to solve problems, the responses to the surveys don't indicate *how* they do this. This research is looking at *how* they can be supported to do this through the online environment.

5.2 Qualitative analysis of interview responses

The interview responses were recorded and then transcribed. The data was coded and themed to fit in with the sub-questions. As answers were being sought for particular sub-questions, it was logical to use pre-determined categories when coding the data. These pre-determined categories were "Scaffolding", "Working with others", "Different ways/methods", "Reflect/Try again", and "Communicate using words".

As the data was being analysed, other codes emerged: "Motivation", "Negatives", "Learning something new". Appendix J shows samples of coded interview transcripts. The word count of each of the coded responses was compared against the total word count of the interview transcripts (the researcher's questions were omitted for this exercise). The percentage occurrences of each coded theme are shown below (figure 7). It is clear from Appendix K, how these percentages were calculated.

The validity of working out these percentages is questionable. The reason why the percentage occurrence of some of the themes are so high are because certain interview questions were leading, for example "Working with others", "Different ways/methods" and “Communicate using words” (Appendix E). Targeted questions in the interviews led to some categories, however other themes such as “Scaffolding” emerged from the responses.

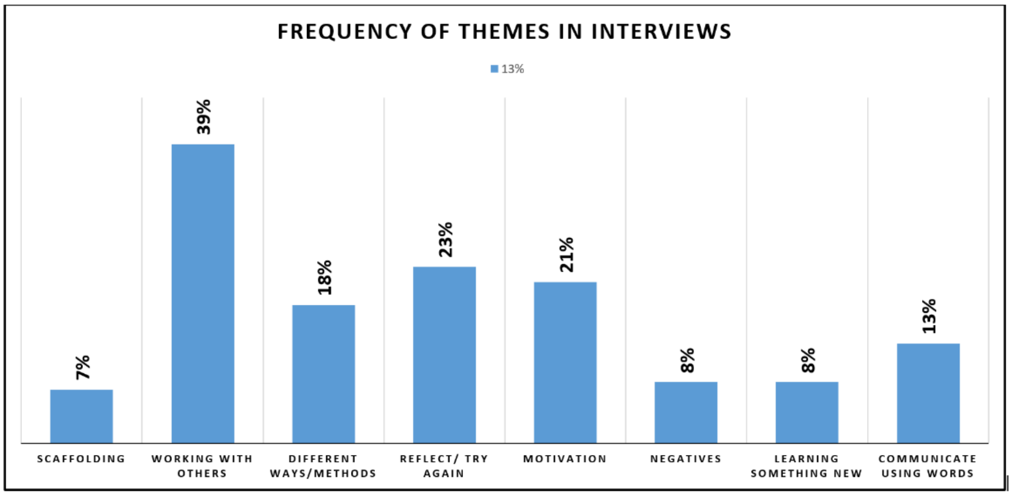


Figure 7: Frequency of themes in interviews

An attempt will now be made to answer each sub-question where data extracted from the interviews and surveys, as described above, will be triangulated with other data.

5.3 Did working through the online environment influence students’ willingness to reflect on what they were doing and/or try again?

Checking answers

Paper Surveys were handed out before and after the learning experience to determine if there was a change in students’ attitudes towards problem solving. In relation to the statement, *“When I get the answer to a problem, I look back and check if my answer makes sense…”* 7% (2 out of 29) of students disagreed pre intervention, this dropped to 0% after the intervention. Before the intervention 21% (6 out of 29) strongly agreed with this statement increasing to 34% (10 out of 29) after the intervention. While the t-test shows this data not to be statistically significant (p = 0.15 - Appendix I), there is a positive indication that the intervention encouraged reflection (figure 8, next page).

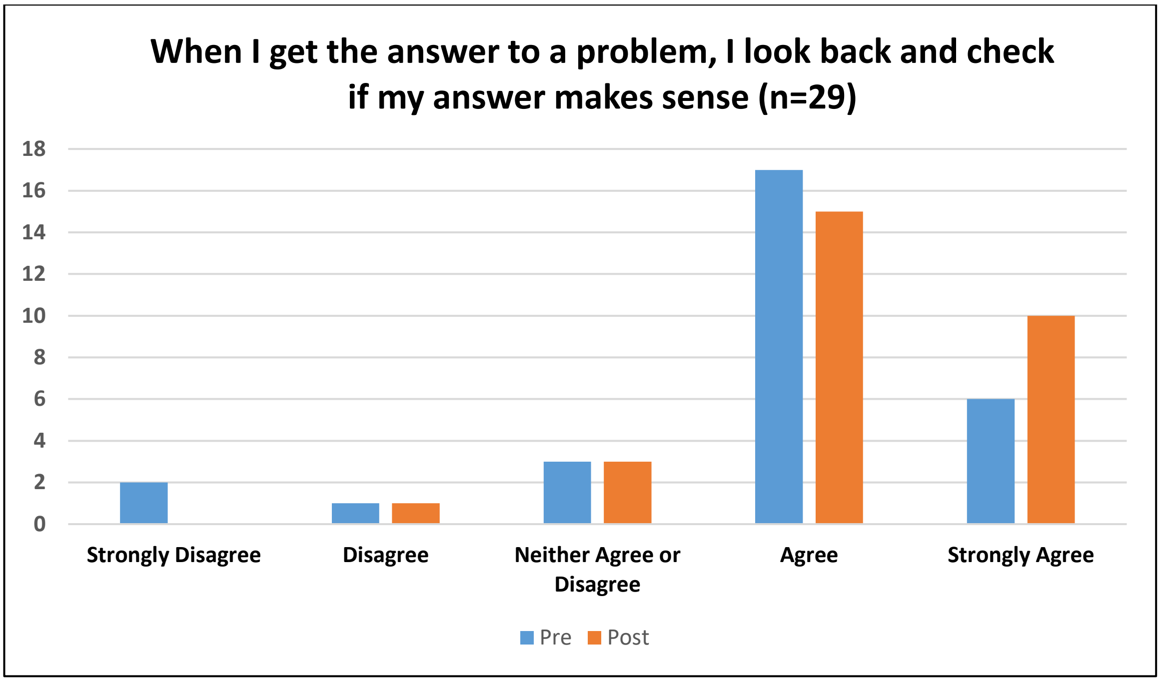
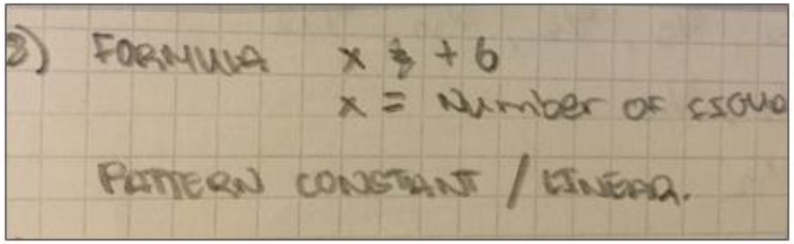
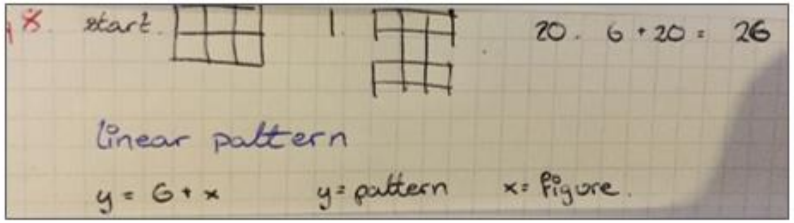


Figure 8: Survey – "checking my answer"

The post-assessment also demonstrated that students were checking (or verifying) their answers more after the intervention. Examples of checking answers are demonstrated on the next page (figure 9).

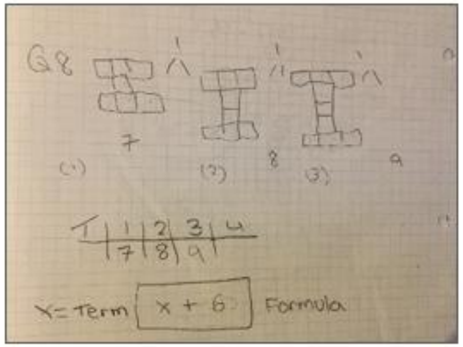
Pre-Assessment:
Q8 Correct formula but not checking or no work shown

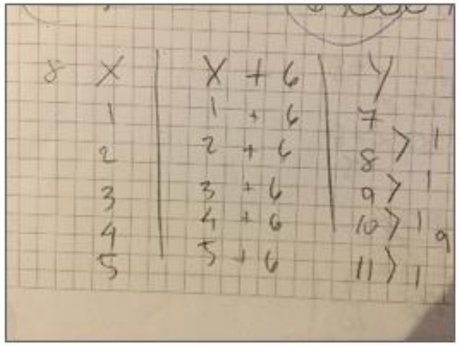




Although these students were correct in generalising the pattern they did not check their formula to see if it worked.

Post-Assessment:
Q8 Checking their formula





These students were checking their formula through a diagram and a table.

Figure 9: Assessments – "checking answers"

Evidence of increased occurrences of checking solutions occurred in 11 out of 14 questions[9]. The incidence of checking their correct solutions ranged from a 1% to an 11% increase (figure 10).

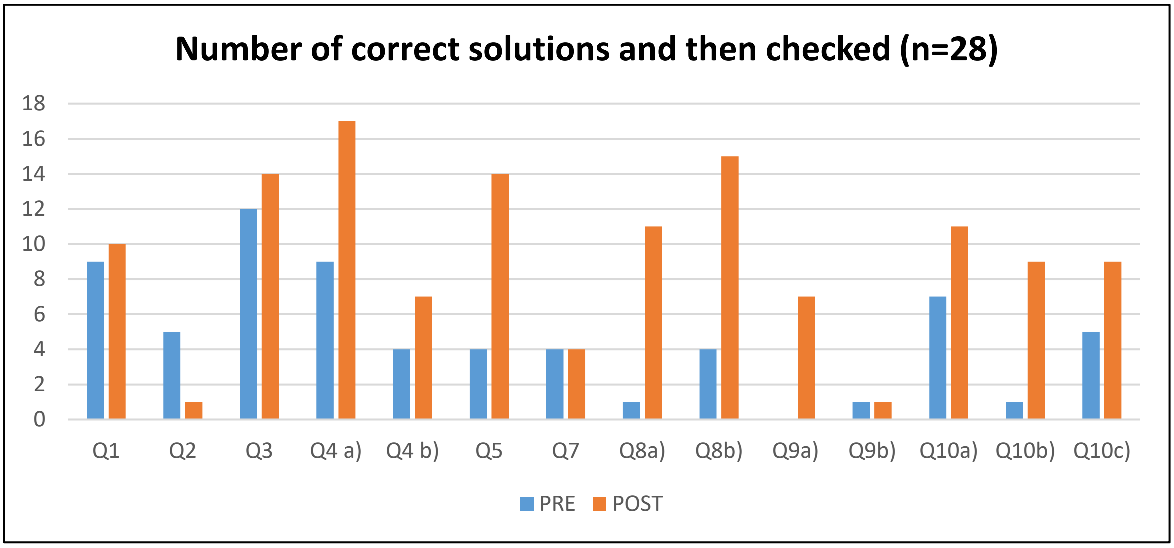


Figure 10: Checking correct solutions

Questions 5 and 8 demonstrated the largest changes in the amount of checking of correct solutions. Both these problems involved solving problems in unfamiliar or non-routine contexts (Krulik & Rudnick, 1988; OECD, 2014). It was interesting to note that in Q2, the incidences of checking their answers decreased; on reflection, the problem in the post assessment was relatively easier; that being the case, students may not have felt the need to check their answer (Appendix B).

Question 8 required students to generalise a linear pattern. Students had generalised linear patterns previously so it was therefore unsurprising that 16 students generalised the linear pattern correctly pre-intervention. However, only 25% of these students checked their formula to see if it worked. In the post-assessment 17 students generalised correctly but 88% of these checked their formula (figure 11).

[9] There was a typographical error for question 6, students were asked therefore to skip this question pre and post assessment. It was therefore not included in the analysis. Only 28 students completed the pre and post assessments.

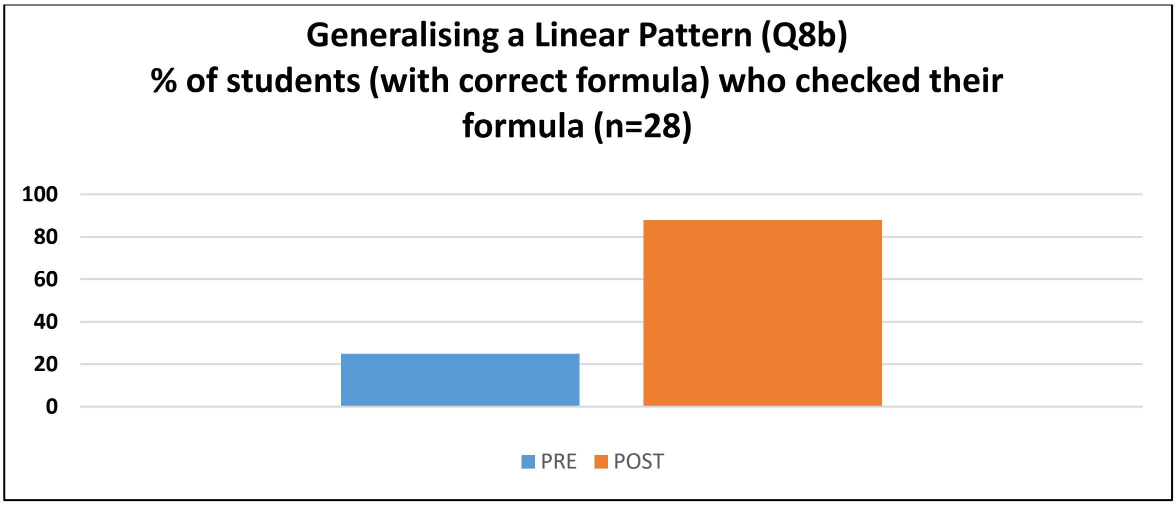


Figure 11: Checking a linear formula

It is clear therefore from analysing the data, that there was an increased occurrence of students checking their answers when solving problems. By looking back and checking if their answer makes sense, students are reflecting on their work. As outlined by Kim & Hannafin (2011); individuals are effective problem solvers if they analyse their own strategies. The chief examiner's report makes recommendations that students should develop strategies for checking their own answers (SEC, 2015a).

Attempting questions

When comparing pre and post assessments, it was evident that students attempted more problems after the intervention. This was clear when counting and comparing the number of non-attempts pre and post intervention. A non-attempt is where a student left their solution blank. It is worth noting here, that it was not important that students got the correct solution rather, that they attempted the question. This is in line with the OECD's view; a willingness to engage is an integral part of problem solving (OCED, 2014, p.30). Also, as discussed in the literature review, students are encouraged to attempt problems even if they do not hit upon the correct answer (SEC, 2015a, p.24). 10 out of 12 questions showed a decrease in the number of non-attempts (figure 12).

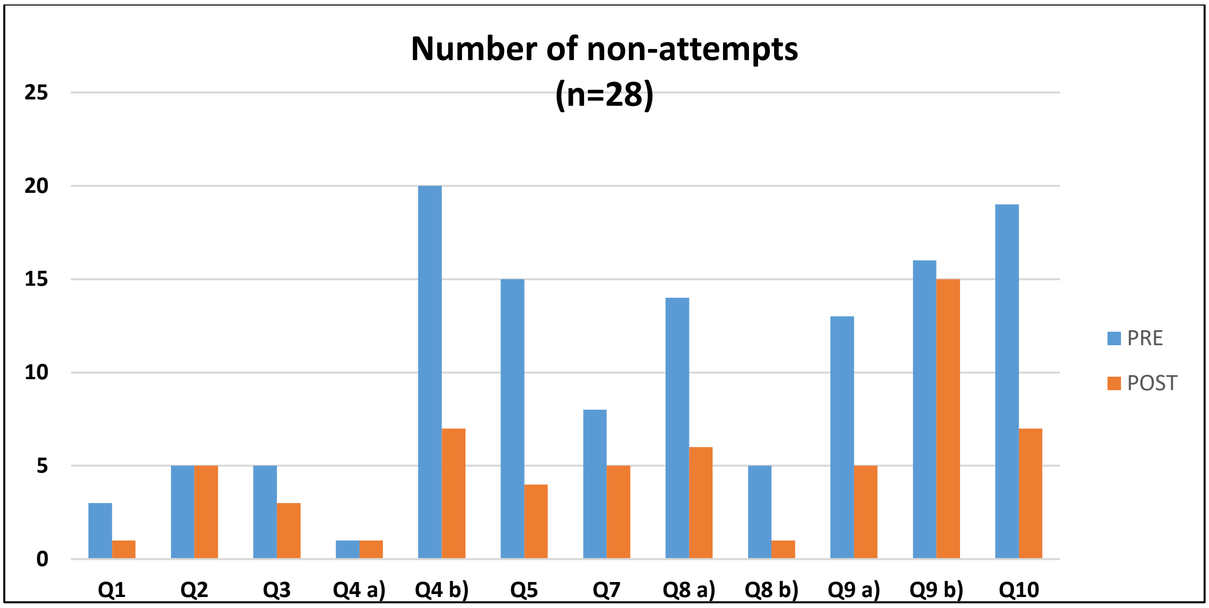


Figure 12: Assessments - number of non-attempts

The least amount of non-attempts occurred in Q's1, 2, 3 and 4. This was not surprising as these type of problems were familiar to the students. Q4 b) showed a significant drop in the number of non-attempts from 20 to 7, however the wording in the pre-assessment was confusing. It was clearer in the post assessment what was expected of students (Appendix B).

Questions 5, 7 and 8 were non-routine problems. Students had the appropriate prior knowledge (algebra skills) to solve these problems but have only used this algebra in drill type exercises. This is in line with Krulik & Rednick's (1980, p.3) view; problem solving involves solving problems in unfamiliar situations. The most significant change was observed in Q5. This problem involved forming and solving a quadratic equation. 54% of students did not attempt this problem before the intervention. However this had decreased to 14% post intervention (figure 13).

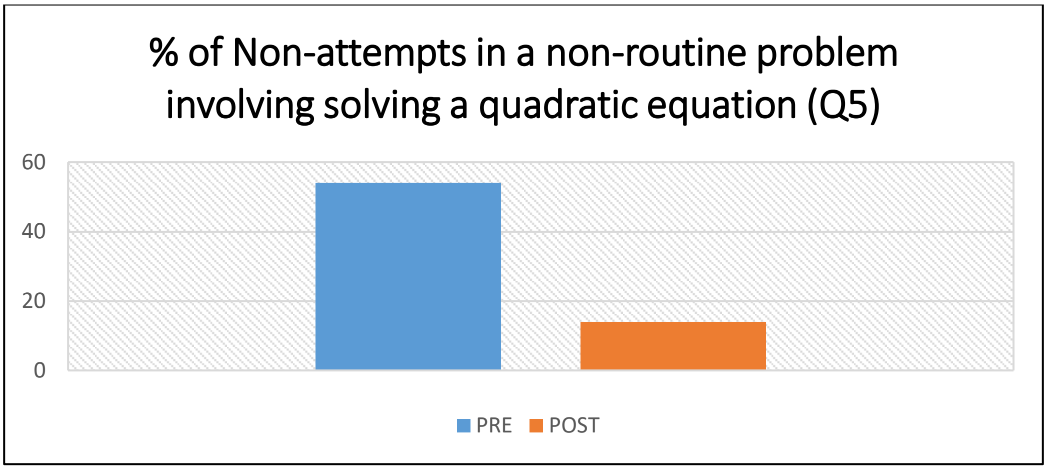


Figure 13: Non attempts in a non-routine problem

Questions 9 and 10 involved algebra students had not seen before. While it seems that there was an increase in attempts (i.e. decrease in non-attempts) this should be analysed with caution. As will be seen later, students used more algebra in the post-assessment; this was most apparent in Q1, 3, 4 and 5. This resulted in students requiring less time to solve these problems, therefore, having more time for Q9 and 10.

For the survey statement, *"Students who have understood the maths taught to them will be able to solve a problem in less than 5 minutes"*, it was evident that more students disagreed with this statement post intervention (figure 14). The results of the comparison of pre and post responses was statistically significant and showed a decrease in means from 2.79 to 2.31 ($p = 0.036$). This suggests a willingness to accept that solving a problem involves work and time; that it is important to reflect on a problem and persist with it (OECD, 2014). It shows a productive disposition if they know to persevere with a problem (DES, 2013).

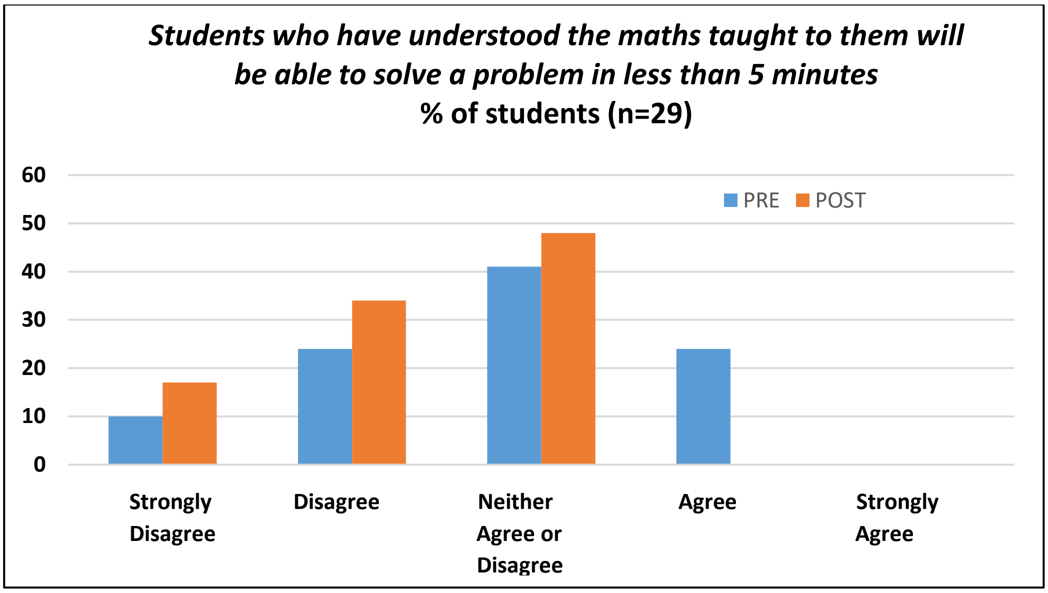


Figure 14: Solve a problem in less than 5 minutes

For the statement, *"Reading a problem more than once is a waste of time",* more students agreed with this statement pre intervention compared with post intervention (figure 15). Similarly, more students disagreed with this statement post-intervention compared with pre-intervention. The results of the comparison of pre and post responses was statistically significant and showed a decrease in means from 1.83 to 1.38 ($p = 0.048$). Disagreeing with this statement shows students would be more likely to read over a problem again; hence more likely to try again and reflect. They are showing a willingness to engage (OECD, 2014).

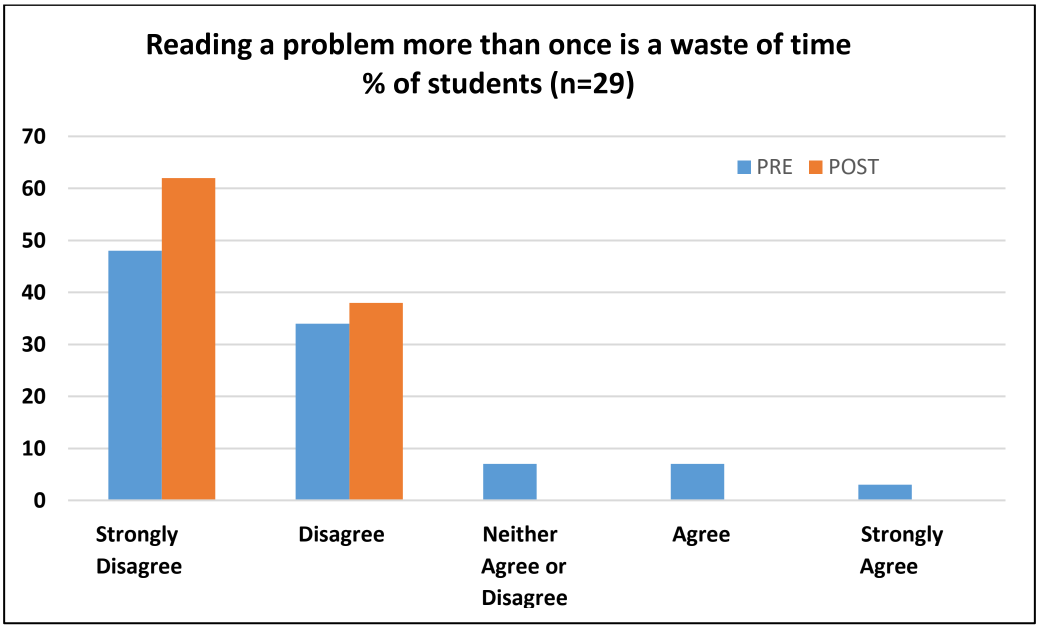


Figure 15: Reading a problem more than once is a waste of time

There was plenty of evidence on the Google Docs of students reflecting and/or trying again. In figure 16 below, two students came up with a formula and then check their formula to see if it worked:

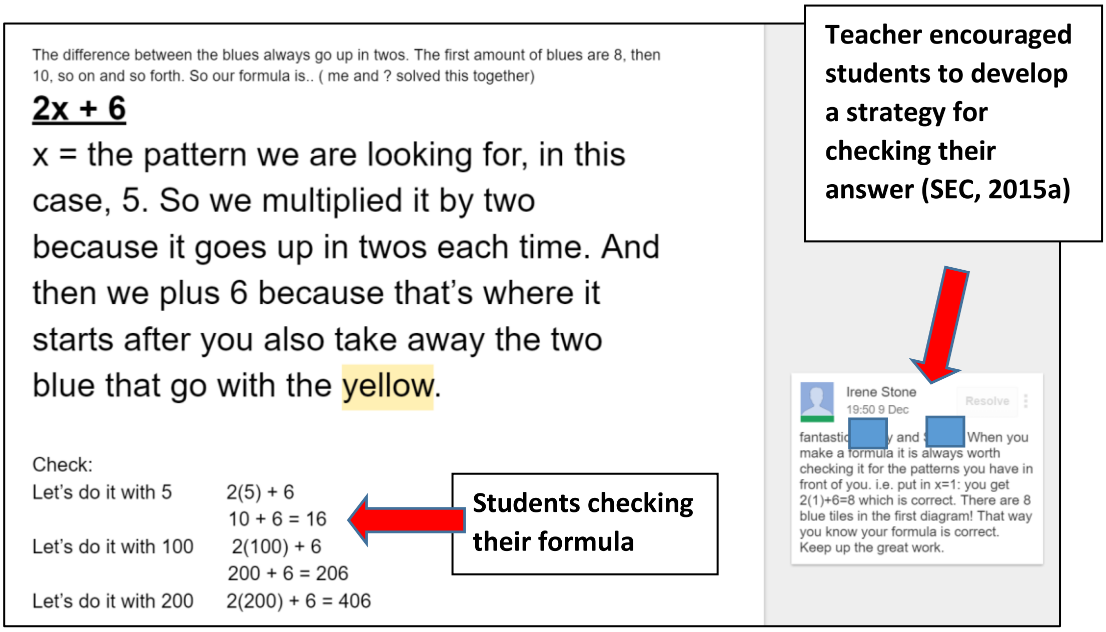


Figure 16: Students reflecting and checking their work

Figure 17 shows where a student recognises that he went wrong the first time he solved the problem but then tries again:

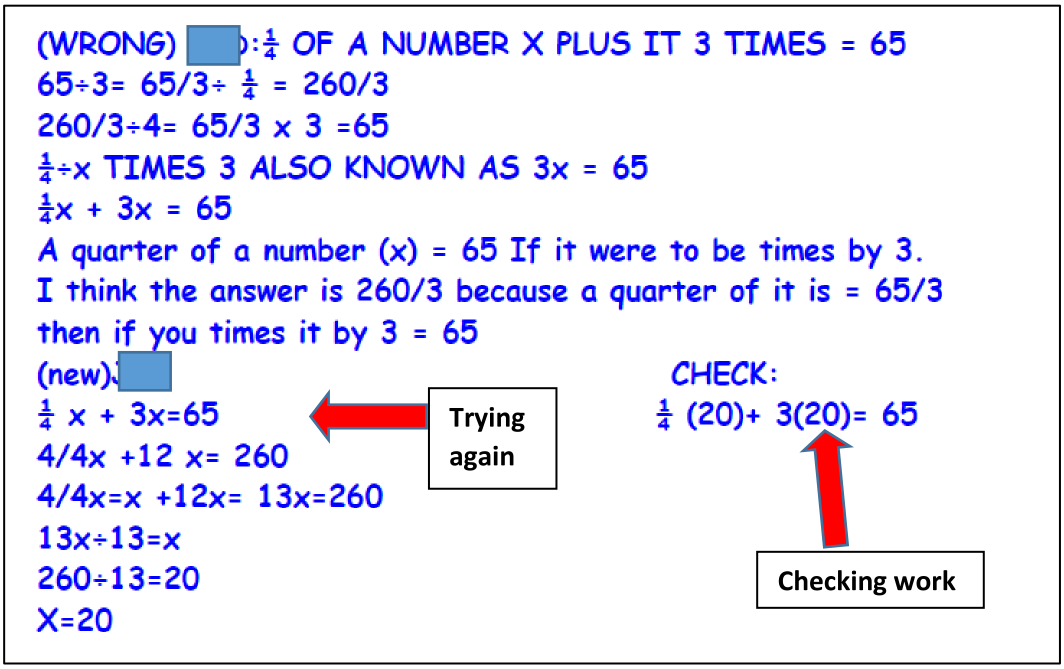


Figure 17: Student trying again and checking answer

To gain an understanding of *how* the online environment supported students reflecting and or trying again, it is necessary to look at the interview responses. The online environment allowed this student to see different ways others had created. He goes on to explain how he was encouraged to try another way himself; he is analysing his own strategy and applying an alternative strategy (Kim & Hannafin, 2011).

> *"It was kinda good to see all the different ways and if you got one way and still no one was on you'd try and find another way."*

There was plenty of evidence of students reflecting on what they were doing;

> *"On the google doc … I always wrote out a lot of information on why I was doing stuff"*

The online environment allowed for this reflection through the comments tool;

> *"The comments made a big difference cas you were able to like think about things more and if you explained it in words they could explain it in algebra for ye."*

Another student explains that the reason he wouldn't reflect on his work in his copy is because only he himself will see it.

> *"I was aware unlike in my copy that people were gonna be looking at it… it's just cas in your copy it's just you were as in the google doc its more people so you have to explain it to everyone so they know what you are doing ."*

Students were conscious that the others in their group would be looking at their work; this motivating factor causes them to reflect more through explaining the way they solved a problem. The online environment allowed for this to happen because it facilitated the students viewing each other's work, and therefore encouraging them to reflect on what they were doing. The comments tool allowed the teacher to remind students to check. This was clearly evident in figure 16; the teacher encouraged students to develop a strategy for checking their answer (SEC, 2015a).

In summary it can be concluded that working through the online environment did influence students' willingness to reflect on what they were doing and/or try again. Analysis of the data collected from the surveys and assessments clearly show that there were more incidences of attempting problems and checking answers after the intervention. This is clear evidence of students displaying a productive disposition where they are persevering with a problem by greater attempts and checking their answers (DES, 2013, p. 6). This is in line with the findings of Kim & Hannafin (2011, p. 404).

Evidence of students reflecting and trying again on the Google Doc was presented. The interview responses gave an insight into why students were reflecting and/or trying again; they were conscious of others in their group looking at their work, and they felt they had to explain what they were doing to them. Students were being more reflective in their mathematical thinking through working in small groups (Perkins & Shiel, 2016, p. 10). The online environment of Google Docs supported this change through its functionality as a document that's shared with others.

5.4 Were students using words when solving problems?

The survey statement *"When solving a problem, I describe how I solve the problem using words",* clearly showed a shift in attitude after the intervention. 31% of students agreed or strongly agreed before the intervention; this increased to 55% after the intervention (figure 18). The results of the comparison of pre and post responses was statistically significant and showed an increase in means from 3 to 3.551724 (p = 0.046).

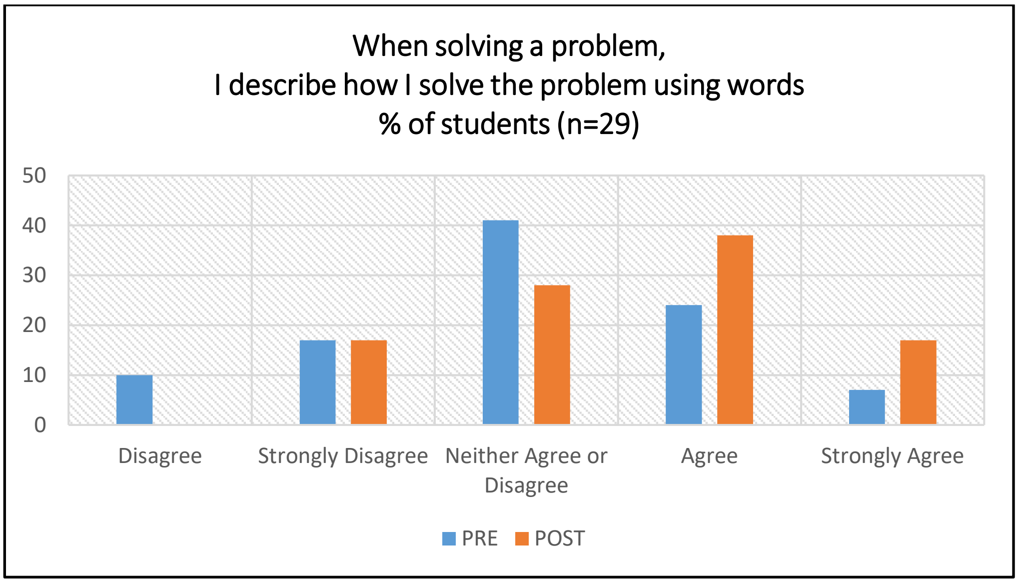
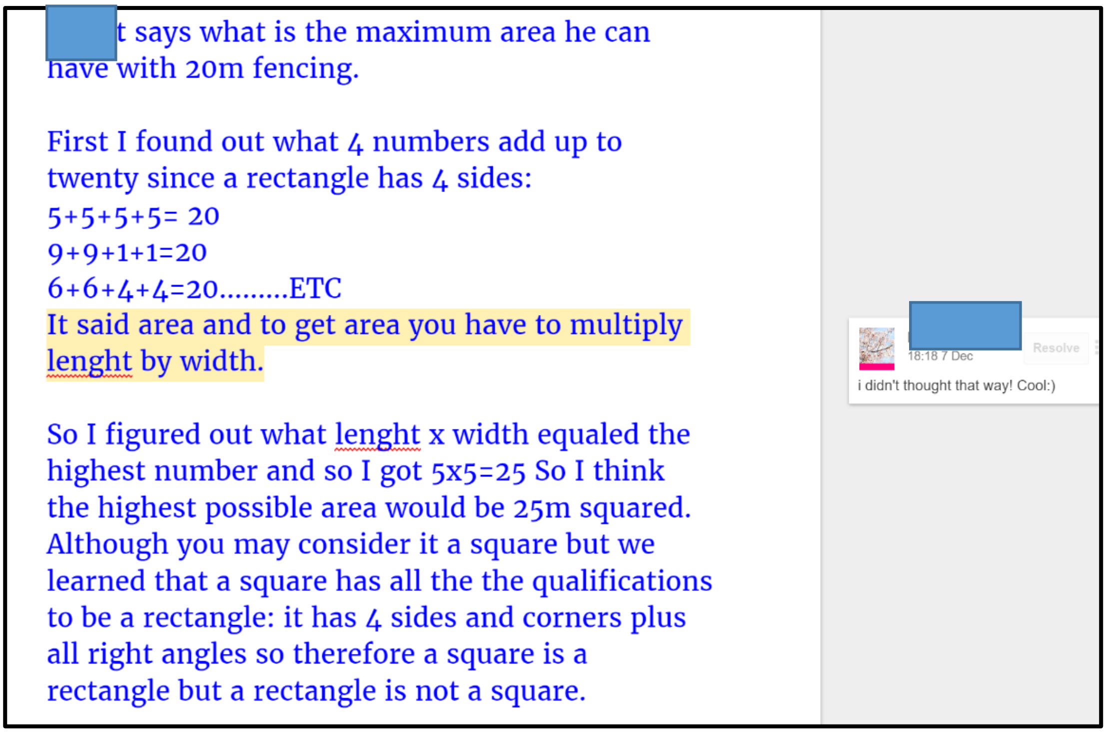


Figure 18: Survey – using words

There was plenty of evidence of students using words on the Google Docs. A student explains in detail (using words) how he solved the "Fencing problem". Another student comments that she is impressed with his explanation (figure 19).


[redacted]t says what is the maximum area he can have with 20m fencing.

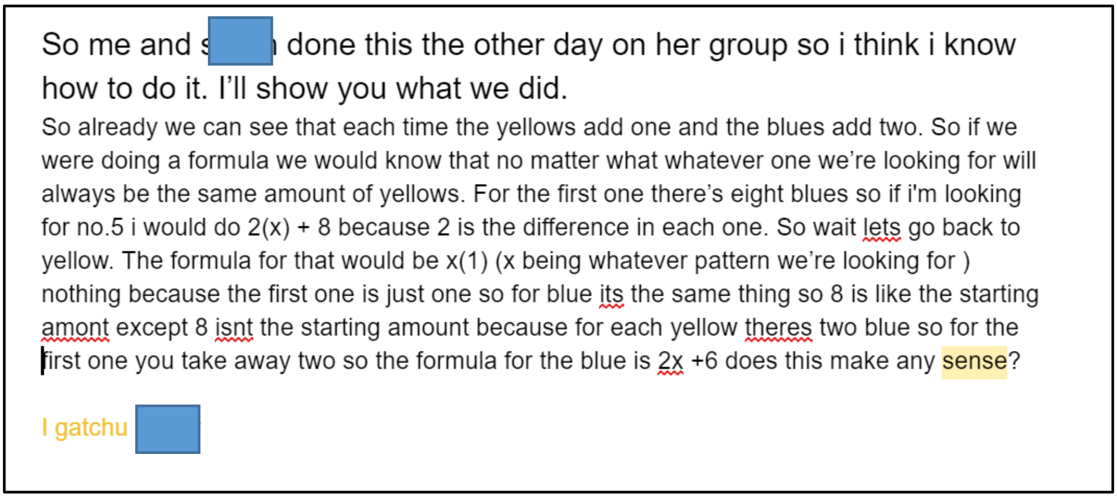
First I found out what 4 numbers add up to twenty since a rectangle has 4 sides:
5+5+5+5= 20
9+9+1+1=20
6+6+4+4=20.........ETC
It said area and to get area you have to multiply lenght by width.

So I figured out what lenght x width equaled the highest number and so I got 5x5=25 So I think the highest possible area would be 25m squared. Although you may consider it a square but we learned that a square has all the the qualifications to be a rectangle: it has 4 sides and corners plus all right angles so therefore a square is a rectangle but a rectangle is not a square.

[redacted] 18:18 7 Dec Resolve
i didn't thought that way! Cool:)

Figure 19: Student describing in words on Google Doc

The student below explains in words how she got the formula for one of the pattern problems.


So me and [redacted] done this the other day on her group so i think i know how to do it. I'll show you what we did.
So already we can see that each time the yellows add one and the blues add two. So if we were doing a formula we would know that no matter what whatever one we're looking for will always be the same amount of yellows. For the first one there's eight blues so if i'm looking for no.5 i would do 2(x) + 8 because 2 is the difference in each one. So wait lets go back to yellow. The formula for that would be x(1) (x being whatever pattern we're looking for) nothing because the first one is just one so for blue its the same thing so 8 is like the starting amont except 8 isnt the starting amount because for each yellow theres two blue so for the first one you take away two so the formula for the blue is 2x +6 does this make any sense?

I gatchu [redacted]

Figure 20: Student explaining in words how she got her formula

The interview responses give an insight into *why* the online environment encouraged students to use words. When students were asked *"When working on the Google Doc, did you find you had to explain what you were doing using words?"* many students described why they were using words. It was because other people were viewing their work, they felt the need to explain what they were doing.

> *"You're not going to write in your copy you are just write examples in your copy"*
>
> *"I think that using words helped to describe what I was doing and how other people can understood the problem better"*

This is clearly shown in figure 21.

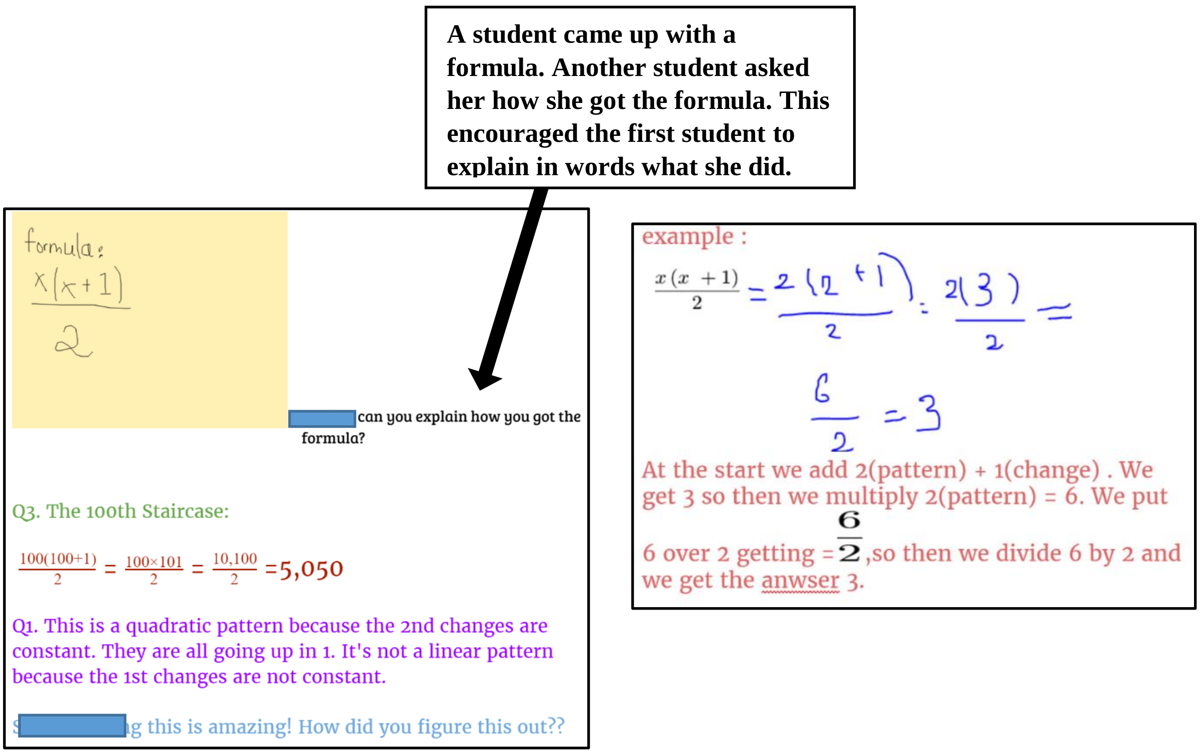


Figure 21: Students explaining to each other (using words)

From the examples above, it can be observed that students are improving their conceptual understanding as they are explaining how or why a procedure works (Muir et al., 2008).

One way the online environment allowed for this to happen was through the comments.

> *"You could see what people had said and the comments... what people had written down"*

In summary, it is clear that the online environment did encourage students to use words when solving problems. The survey response showed an increase in students agreeing to using words. There was plenty of evidence of students using words from observing the online Google Docs. The interview responses offered explanations as to why Google Docs supported this; students were using words because there were others in their group viewing their work. As highlighted in the literature review, using words is a key element of problem solving, whether it's to describe, explain, or justify their work (Boaler, 2010; Perkins & Shiel, 2016; SEC, 2015a).

5.5 Did working through the online environment allow students to demonstrate different ways to solve a problem?

A comparison of pre and post responses to the statement *"If I can't solve a problem one way I will try and solve it another way…"*, was of no statistical significance (figure 22). The t-test analysis showed no significant change in the mean response (pre: 3.76, post: 3.97, p=0.4). Nonetheless, it is evident that there was an increase of 2 students who strongly agreed to the statement.

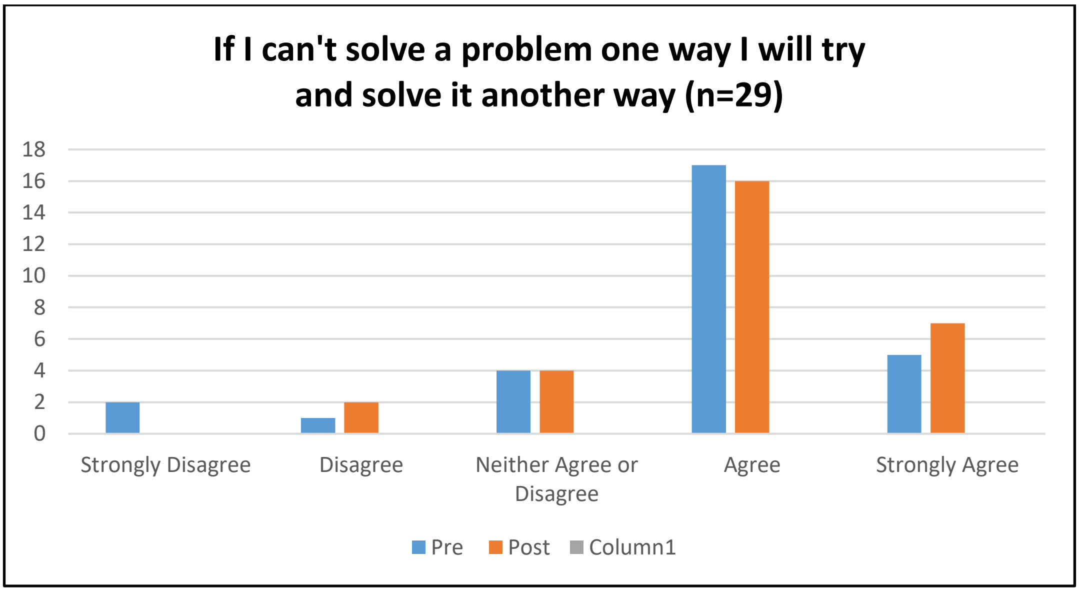


Figure 22: Survey – "trying other ways"

While this data was of no statistical significance, it is interesting to note that most students already agreed to the statement pre-intervention, i.e. they were aware that a strategy for solving problems was trying different methods. The intervention supported them to show these different ways and methods to solve problems. The different features of Google Docs (e.g. handwriting tool, g(Math), photographing, comments…) as described in the design section allowed them to do this. Examples of students' work demonstrating different methods are shown in figure 23 and 24.

Problem: ***One side of a rectangle is 4m bigger than the other side. The area of the rectangle is 60metres squared. What is the perimeter of the rectangle?***

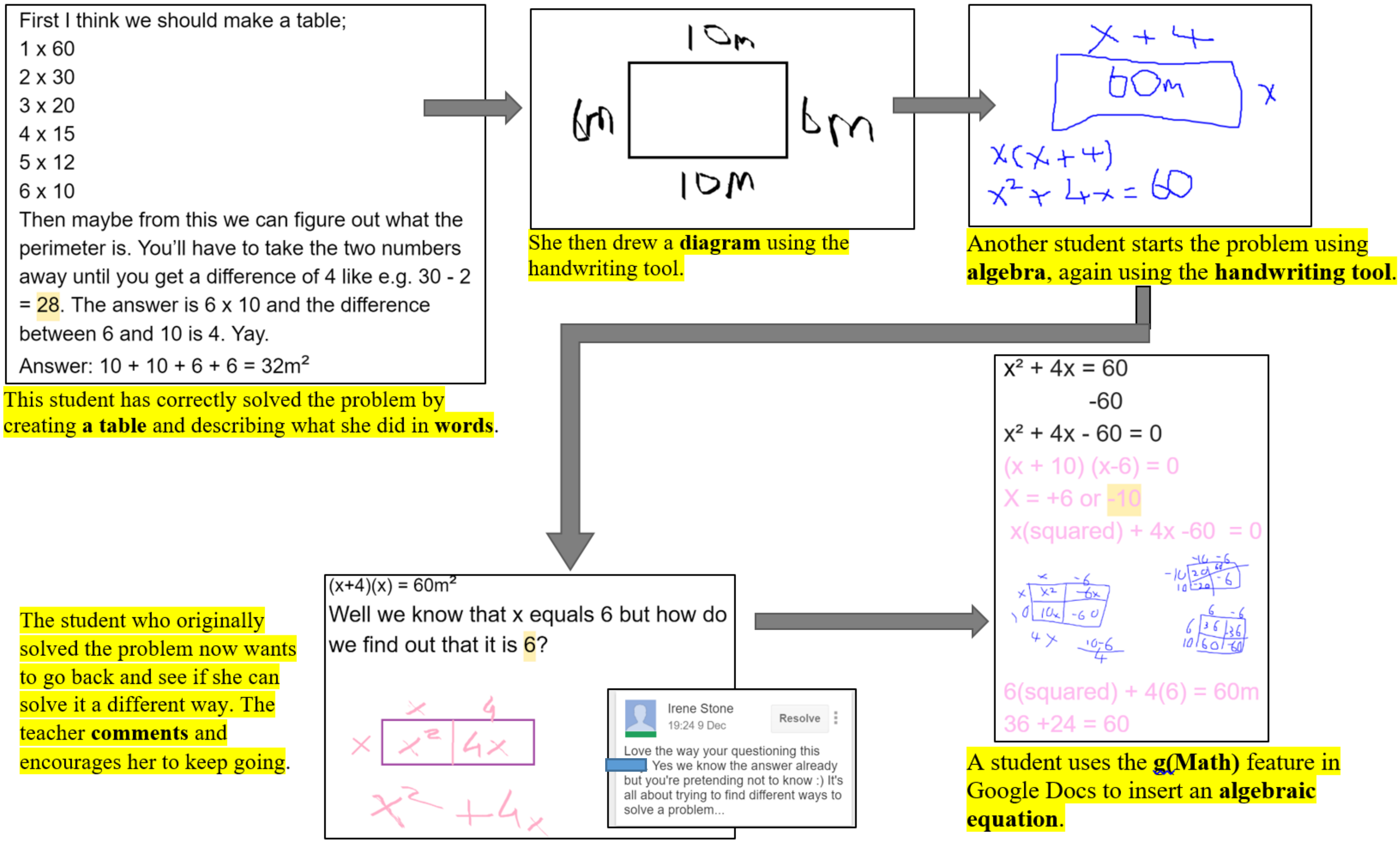
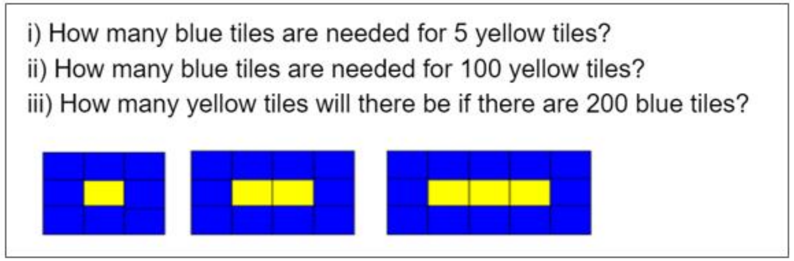
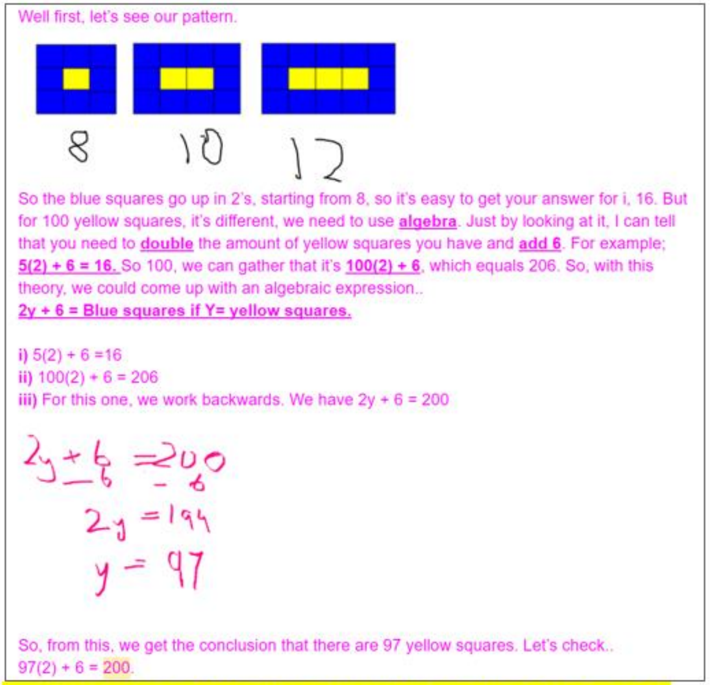


Figure 23: Examples of different ways to solve a problem – Google Docs

Problem: Blue and Yellow Tiles Problem





A student uses a **diagram**, **words** and **algebra** to solve the problem using **type** and the **handwriting** feature

This student decided to do the work in his copy. He **takes a photo** of it and posts it as an image on the Google Doc

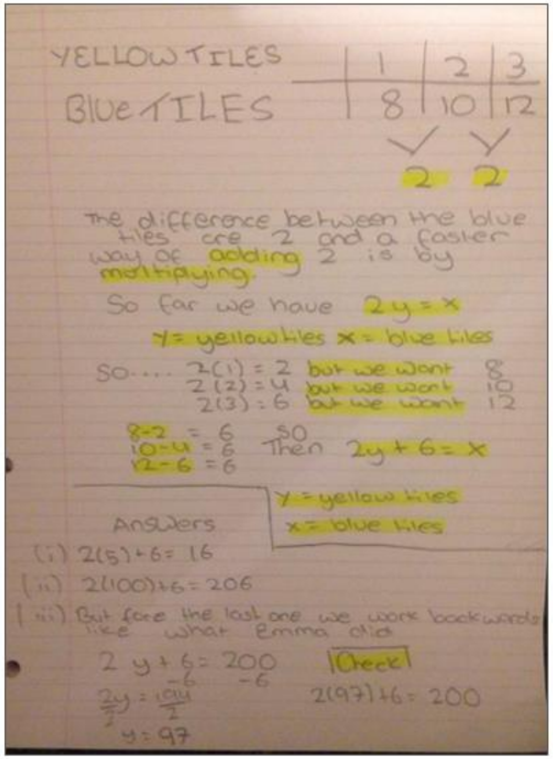


Figure 24: Examples of different ways to solve a problem – Google Docs

There was evidence in the interview responses of students using different methods;

> *"Well one person in our group would maybe write a paragraph and explain it and then another person would go and do like in a table and then another one would do in a graph so it was kinda good to see all the different ways and if you got one way and still no one was on you'd try and find another way"*

One student described how the Google Doc allowed her to see the different ways and how it helped her understand the problem more.

> *"Just kinda made you understand the problem more because you could see how other people done it and that there's not one way to solve every problem"*

It appears from student responses that working in groups encouraged them to solve problems in different ways:

> *"You got to see people's point of view of solving maths equations so you would solve something then another person would see it differently"*

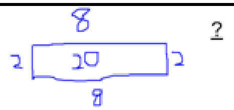
> *"Everyone just kind of did different things and then you just like clicked them together how it all worked."*

The quantitative data did not allow the sub-question to be answered with statistical significance. However, analysis of the Google Docs demonstrated use of the software's tools to solve problems in different ways (figures 23 and 24). The interview responses point to a consensus among students that the collaborative nature of the online environment encouraged them to demonstrate different ways to solve a problem. As discussed in the literature review, a collaborative environment supports alternative ways to problem solve (Hurme & Järvelä, 2005; Kim & Hannafin, 2011).

5.6 How did the online environment support the scaffolding process?

This sub-question cannot be answered through analysis of the survey responses. To answer this question, it is necessary to analyse the Google Doc work and the interview responses. As a member of each group, the teacher was able to intervene at any point during the process and guide students as appropriate. This could be done in the main text area of the Doc or through the comments feature. Students also provided scaffolding to each other. Figures 25 and 26 show how scaffolding took place in the Google Doc.

Figure 25: Scaffolding – Fencing problem: Farmer Joe has 20m of fencing. What is the maximum rectangular area he can make with the fencing?



does everyone agree with me on this? This is the area of a 20m rectangle but I'm not too sure what the maximum rectangular means. Does it mean the largest numbers you can multiply together to make the area? Or am I totally wrong?

Irene Stone
18:02 6 Dec
Resolve

[redacted] you are not wrong. Area is when you multiply the numbers together.. keep at it :)

[redacted]

Ok thank you

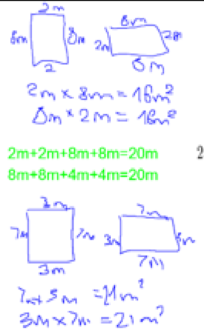
Student A does not undestand the problem. The teacher tells her she is correct about area (when you multiply the numbers). However the teacher holds back from telling her everything and waits to see if another student responds.

?: yes there are differen't way's try to look for more 4 numbers that add up to 20.

"Does it mean the largest numbers you can multiply together to make the area?"

In a way you are right, try to look for the ***largest area***, not numbers.

Student B responds to student A. She recognises the misconception that student A had with finding largest numbers, not area. This is an example of peer-peer scaffolding. She doesn't tell her the answer but instead points out the misconception and points her in the right direction.



2m+2m+8m+8m=20m

8m+8m+4m+4m=20m

$2m \; x \; 8m = 16m^2$

3m+3m+7m+7m=20m

7m+7m+3m+3m=20m

$3m \; x \; 7m = 21m^2$

Irene Stone
19:17 6 Dec
Resolve

[redacted] a well done you are on the right track.. keep going!! it might help to make a table..

Student B continues to draw different rectangles. Examples of some of the rectangles she drew are shown. The teacher scaffolds her learning by giving a tip to create a table.

Student B creates the table. The teacher challenges her to draw a graph. Students have not drawn quadratic graphs before. This is tapping into the ZPD of the student.

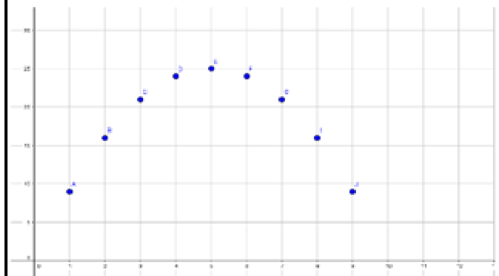
Lenth (m)	Width (m)	Total (m)	area (m2)	changes:
1	9	20	$9m^2$	+7m
2	8	20	$16m^2$	+5m
3	7	20	$21m^2$	+3m
4	6	20	$24m^2$	+1m
5	5	20	$25m^2$	-3m
6	4	20	$24m^2$	-1m
7	3	20	$21m^2$	-3m
8	2	20	$16m^2$	-5m
9	1	20	$9m^2$	-7m

Irene Stone
19:53 6 Dec
Resolve

This is amazing work girls. I'm very impressed well done!!!
Can you see what type of pattern these numbers are? (i.e. the Area numbers).

This is a big challenge: would you be able to GRAPH the area numbers against the length? (Put the length on the X axis)

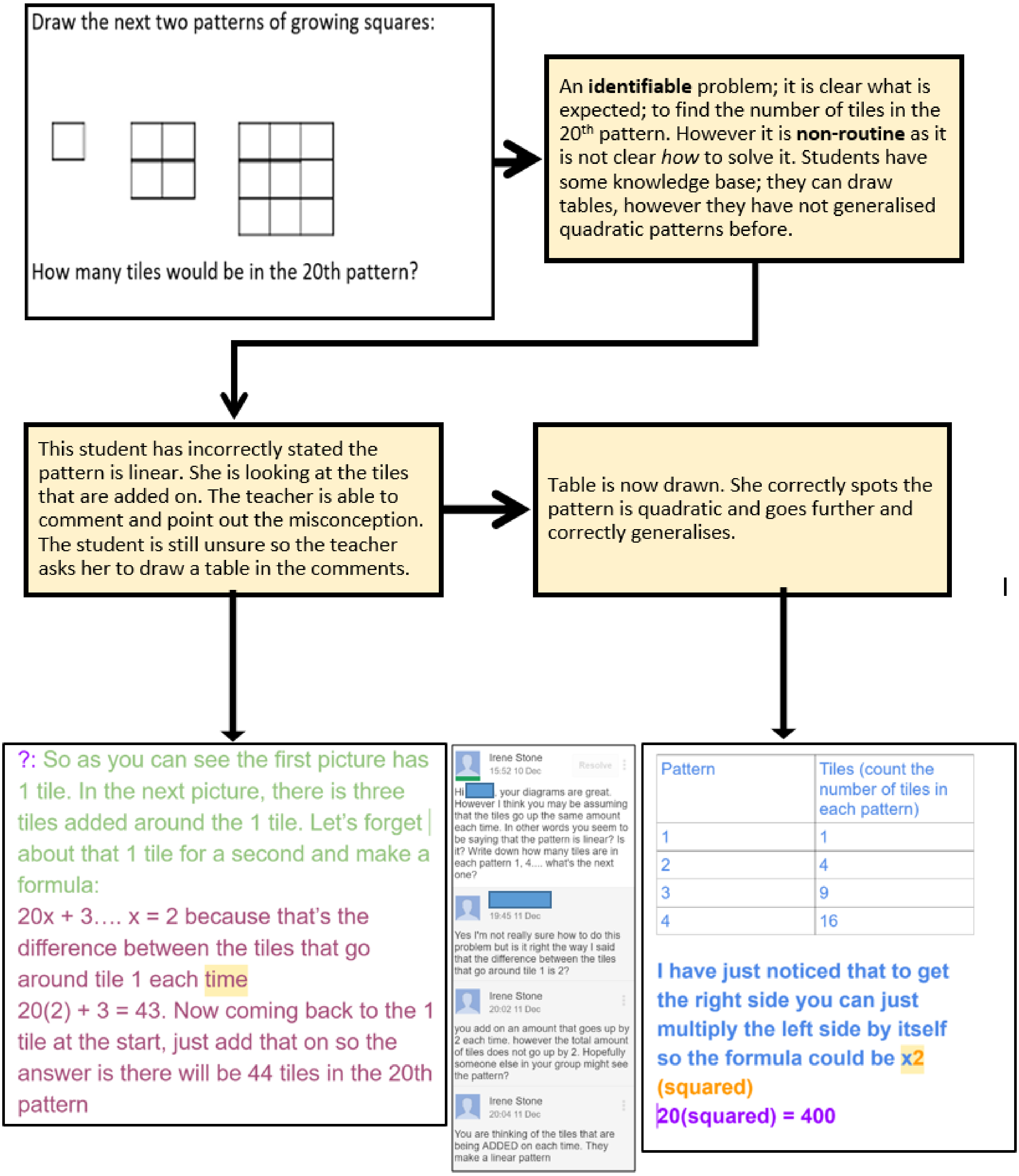
Student B figured out that the pattern was quadratic, something that wasn't required in this problem. This is clear evidence of further learning and would not have happened without intervention of more knowledgeable other – "the teacher" who asked her to draw a table. Student B draws the graph and explains what she has done. Student A comments underneath that she understands.



I noticed that this pattern is a quadratic pattern. After I made a graf I noticed that the maximum rectangular area That *Farmer Joe* can fence is $25m^2$. The changes would first Increase, but after I got to the maximum rectangular area, $25m^2$, the changes would decrease.

[redacted]: I get what you`re doing [redacted]a. It`s a good way to show all the different types of areas. I like it.

Figure 26: Scaffolding - Draw the next two patterns



Although the interviewer did not target the participants with a question about scaffolding, 7% of the interview responses were coded as "scaffolding". When asked, what they liked about the Google Docs, one student said:

> *"You gave us some eh like steps to drive us into the right direction"*

This enabled the student to start the problem, which one could not do on their own (Palmer, 2005; Wood et al., 1976).

Another student described how the Google Docs supported this; while she solved the problem herself in the end, it was the support of one of her peers that gave her the initial step of understanding the problem. She also mentions how she liked having the teacher at home;

> *"It was slightly confusing what to do on the 4th problem but then like X gave me a brief understanding of the problem so I managed to solve the problem on my own even having like you at home* (the teacher) *and it just felt more like we were learning more in-depth from the class"*

The online environment of Google Docs permitted students to see each other's work and build on it;

> *"Viewing each person's perspective like what they said and you can add on... add stuff to it… to make it better"*
> *"I think X started a problem and I finished it"*

This is in line with Tanner & Jones' (2000) view, a constructivist approach should not happen in solitude.

In summary, there was evidence of both teacher and student scaffolding in the Google Docs. The interview responses also support this. The Google Docs online environment allowed for scaffolding to take place through the general type section and comments tool.

5.7 Was the online environment conducive to collaboration?

While a comparison of pre and post responses to the statement *"When problem solving, I prefer to work with someone else…"* showed no significant change in mean (pre: 3.69; post: 3.86, p=0.54), the amount of students who strongly agreed with the statement doubled from 14% to 28% (figure 27).

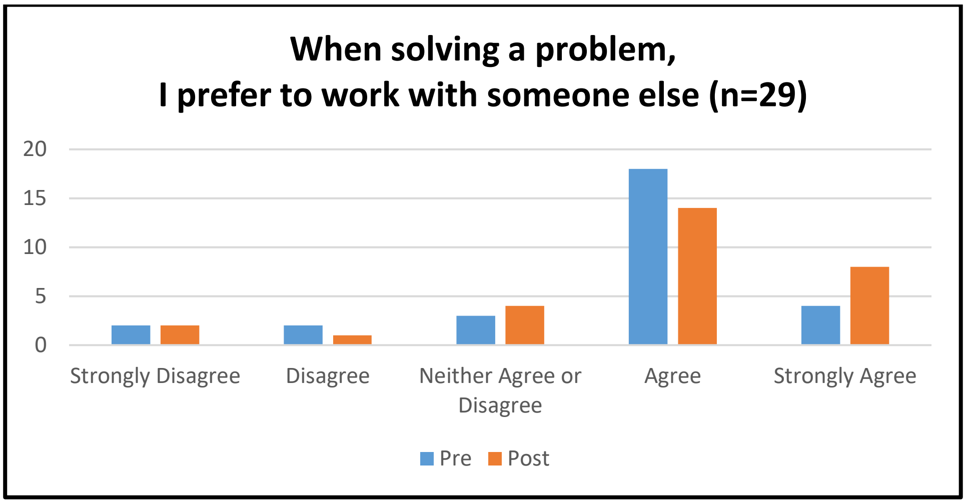


Figure 27: When solving a problem I prefer to work with someone else

Clearly, students already preferred working with someone else before the intervention. So while the intervention may not have increased this preference, the research question was seeking to look at *how* the Google Docs supported this collaboration.

There was plenty of evidence of collaboration in the Google Docs. Some examples (figure 28) show students working together and communicating to achieve a common goal of solving the problem.

¼ (x)+3x= 65
X all by 4
1(4x) +12x = 260 =
4x + 12x = 260
16x = 260
If x = 16 ½
¼(16 ¼)

[redacted] 11:38 1 Dec Resolve

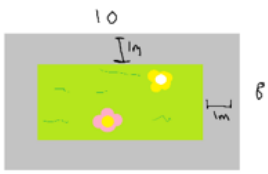
[redacted], I think you mean that X= 4 on your second line? If so, then, your 3rd line should be 1(4) + 12. You should get a completely different answer if you work it out

Irene Stone 14:06 1 Dec

This is amazing [redacted] well done to both of you. Fantastic you are trying to solve problem different ways and spotting mistakes in each other's work: true collaboration.. Keep at it :)

A student makes a mistake and another student helps her in the **comments**.

3) To do this one, we need to use our imaginations a bit.



Logically, because the grey area is Im wide, and it's a 4 sided shape, so to figure out the dimensions for the green area, we must take 2m from the width and length. So 10 and 8 turns into 8 and six.
8x6 = 48m^2

[redacted]: Hi [redacted], this is regarding your answer for question 3. I understand that have take away from the length and width but why do we have to take away 2 instead of 1?

[redacted] =i think it's because there is 2 sides so you have to take 1m from both sides. Basically what you do on one side you have to do on the other.

Students helping each other in the Google Doc – they are typing in different colours.

Well, I was thinking that maybe 20m is the total perimeter of the rectangle so if you were to divide it by four (because a rectangle has 4 sides) you would get 5 BUT it's a rectangle so it couldn't be 5.

A student thinks that a square is not a rectangle. Another students addresses her misconception.

Ms said that a square is also a rectangle since a rectangle and square are shapes in which the opposite sides are equal so we can use 5x5.

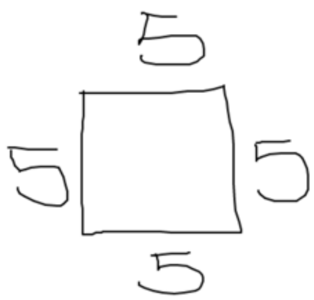


Figure 28: Collaborating on the Google Doc

Students described in their interview responses incidences of when they were working with others:

> *"If somebody didn't understand how you got the answer, we would have to explain how we did it and why we did it….. then I understand myself more how I did it."*

> *"I think we all helped each other. I think it was kinda equal in our group anyway."*

Students were getting used to explaining and justifying to each other (SEC, 2015a). The Google Docs made it easy to communicate with each other;

> *"It was easy to communicate and to work together solving a problem"*

The following student described how he learned how to make a formula (algebraic) because he was able to view another person's work on the Google Doc. He was then able to ask how they solved it.

> *"There was a question I had a problem with coming up with a formula, then ... ehhh. I saw that somebody solved it so I asked them how they do it so then I ... ehh... actually understood it and I knew how to do the formula then"*

Another student described how she found it easier getting the support of her peers rather than from the teacher. The Google Docs environment facilitated this peer-peer support.

> *"As a group say if someone did this, like people could say yeah that's right or that's not right, ye can do it this way. It's just like consulting between everyone else and it's easier than doing with a teacher I think, peer support."*

A student described how the Google Doc environment encouraged her to work with others. She felt it was beneficial for her and described how she could see other ways of solving problems.

> *"I think it was better for more independent learners that usually would study by themselves or write down everything in their copy, it was better for them to interact with other people and see that there is more than one way they do it"*

In summary, it is evident from observations and interview responses that the online environment was conducive to collaboration. As discussed in the literature review, collaboration supports problem solving (Kim & Hannafin, 2011; Tanner & Jones, 2000). The Google Doc online environment allowed students to communicate and help each other.

5.8 Other findings

5.8.1 Learning something new

While the intervention sought to look at how the online environment supported elements of problem solving, it was not the intention to improve algebraic skills of students. As discussed in the literature review, students struggle with problems that require algebra to solve them (Jeffes et al., 2013; SEC, 2015a, 2015b). The problems chosen for the pre and post assessments could all be solved using algebra, although it was not necessary to use algebra.

In 4 of the questions there was an increase in the use of algebra to solve problems post intervention (figure 29). Examples from the assessments are shown on the next page, (figure 30). Problem 1 involved forming a linear equation involving algebraic fractions. On first analysis, it seemed that there was no significant change in the amount of correct answers that were obtained. However, when analysing the methods for solving the problem, 10 more students used algebra in the post-assessment. In problem 3, also a familiar problem; the pre-assessment showed that 50% of students used algebra to solve the problem. This increased to 68% post-assessment. For problem 5, a non-routine problem involving solving a quadratic equation; 18% used algebra while post-assessment, this had increased to 43%.

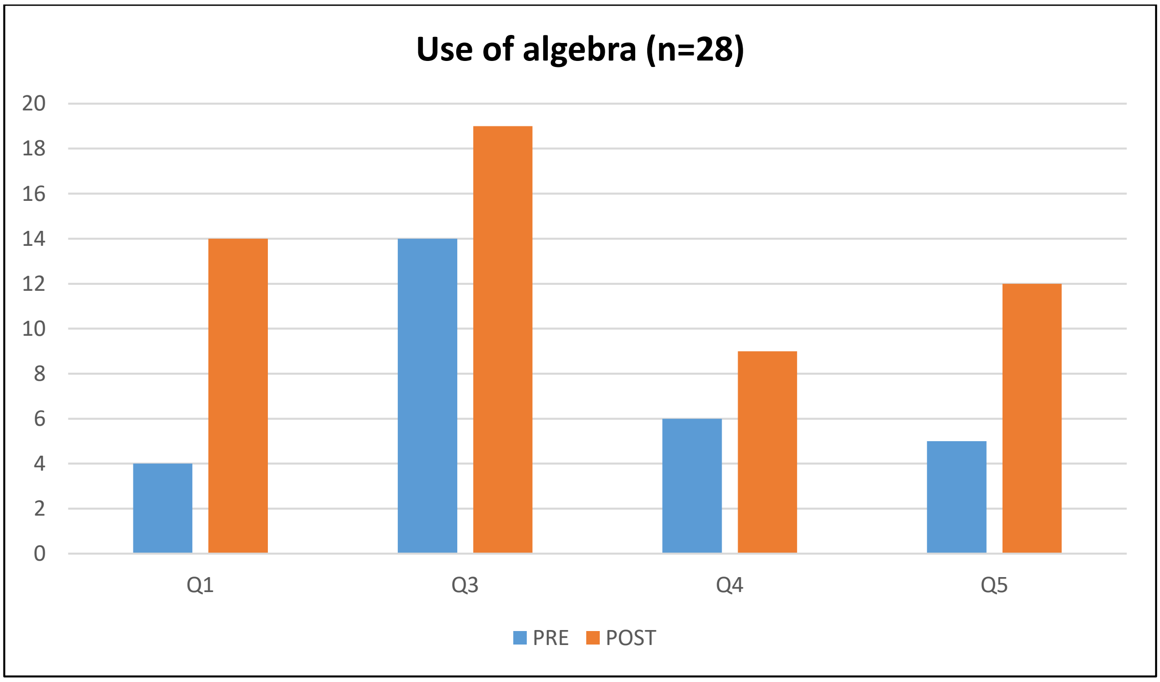
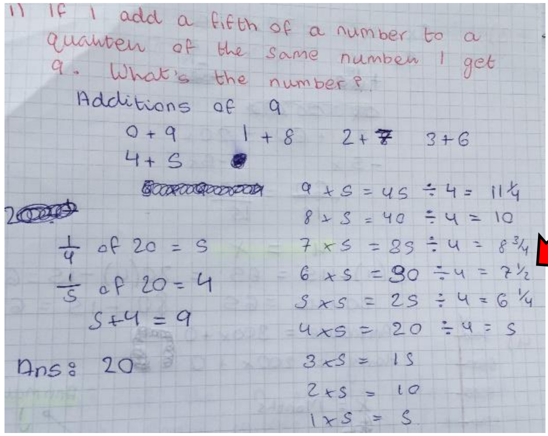


Figure 29: Use of algebra

Pre-Assessment: Example of no algebra	**Post-Assessment:** Examples of algebra used

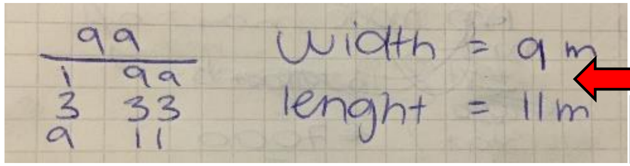
Pre-Assessment: Example of no algebra

Q1) ***If I add a fifth of a number to a quarter of the same number I get 9. What's the number?***



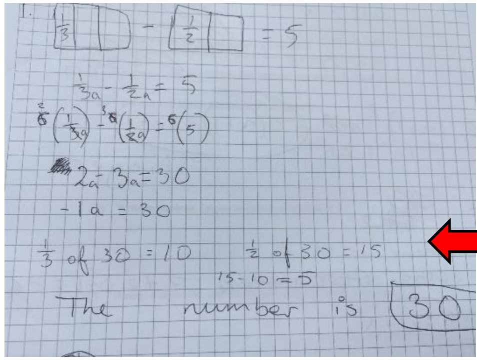
Problem involving fractions - solved using "Trial and Error"

Q5) ***A garden with an area of 99 m^2 has width x m and its length is 2m longer than its width. Write its area in term of x. Solve the equation to find the length and width of the garden.***



No algebra used

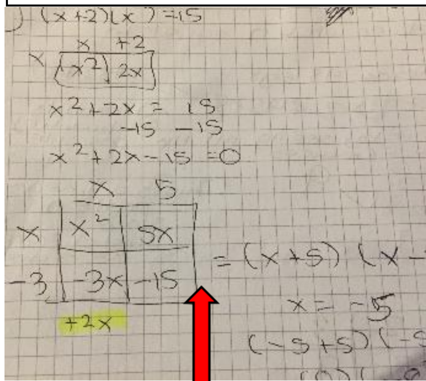
Post-Assessment: Examples of algebra used

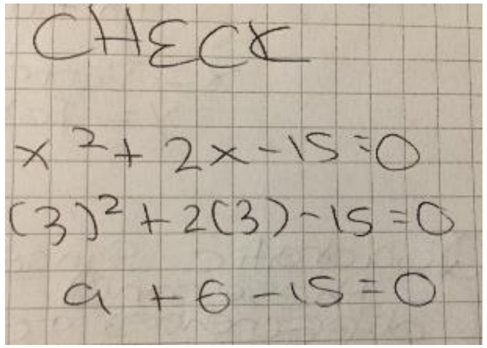


Q1) ***A third of a number subtracted away from a half of the same number is 5. What's the number?***

Problem involving fractions - solved using "Algebraic Fractions"

Q5) ***One number is 2 greater than another number. When these two numbers are multiplied by each other the result is 15. Represent this problem as an equation and solve the equation.***





Algebra used to solve problem; a quadratic equation is formed.

Figure 30: Use of algebra, pre vs post assessments

Observation of the Google Docs showed students learning new techniques (figure 31, next page). Student B used the operation of logarithms in the “Snowman problem”. Logarithms are mathematical operations that students are required to know at leaving certificate higher level. The teacher challenged the student through the comments tool on the Google Doc; a website link was posted that would allow students to investigate logs should they wish. Figure 31 shows where student A solved the problem through “Trial and Error” while student B decided to check out the website the teacher had posted.

It’s not clear why student B choose to solve the problem using Logs. As student A had already solved the problem using the “Trial and Error” method, student B may have felt compelled to try an alternative method. Analysis of findings showed (section 5.1), that students were encouraged to try an alternative strategy as they are conscious of others looking at their work (Kim & Hannafin, 2011). Also likely, is that the student was encouraged by the teacher’s comment. This is an example where student B is in the Zone of Proximal Development (Vygotsky, 1978).

Students described in their interview responses how they learned something new during the intervention;

“It helped me … to be able to get formulas for different harder problems”

It is clear therefore that students have learned new skills, in particular in algebra, through working on the Google Doc environment. One could infer that the collaborative environment introduced a level of competition and raised the level of expectation of what an individual can achieve. Students’ curiosity was challenged at a level proportionate to their knowledge (Polya, 1957, p. v).

Problem: *A snowman has a mass of 15kg. It melts at a rate of 0.6% of its mass per minute. (i) What will its mass be after 3 minutes? (ii) After how many minutes will it have a mass of 13.98 kg?*

ii) Well, if we fill in the information in the formula, we'll get this:

13.98 = 15(0.994) x

Anything underlined is the time, because I can't get it to look like a smaller square symbol.

So, there's no mathematical way to figure X out other than trial and error, using simple logic.

So, we know that 15(0.994)3 = 14.73

So, the times number has to be bigger than 3, because 13.98 is smaller than 14.73.

So, my first guess was 9. When I got 14.2091702748,I knew I had to go bigger. I then guessed 12, and when I got 13.9549367311, I had passed it, but not by much. I immediately checked 11, but that was 14.0391717616, so it was then I realised it had to be a decimal number, and a high one at that. So, I checked 11.5, 11.6, until I eventually found that 15(0.994)11.7 = 13.9801540337, which I rounded to 13.98.

So really, it's all trial and error. I'm not the best at explaining, but I still hope I helped **:)**

Irene Stone
09:01 21 Jan
Resolve

There is another way you can solve this problem, however it is something from the Leaving Cert Maths course. So not needed at this stage. Basically you are looking for a function that is going backwards of indices. So.. opposite of multiplication is division isn't it? So what is the opposite of "to the power of "? I can show you if you like or you could try and find out for yourself??? :) (Google search maybe?)
Show less

Irene Stone
09:02 21 Jan

https://www.mathsisfun.com/algebra/logarithms.html

Irene Stone
11:39 22 Jan

[redacted], look at what [redacted] did below....

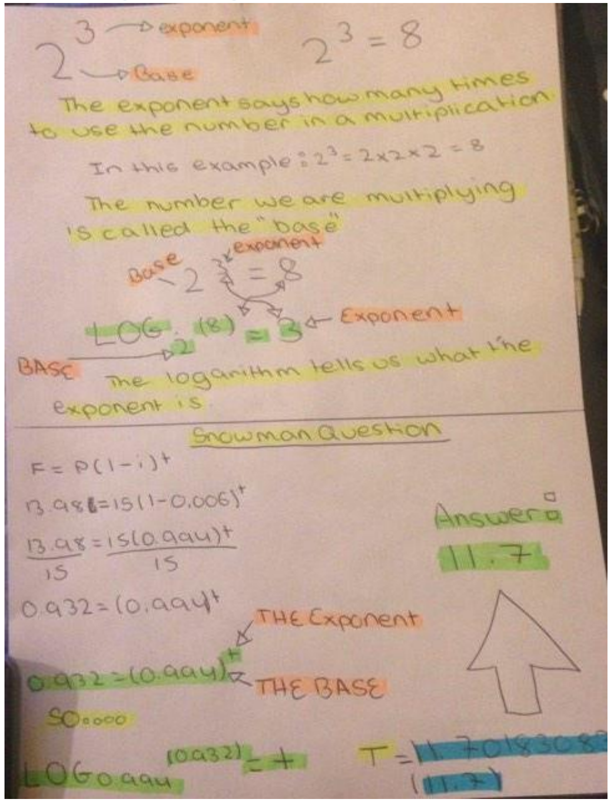
Irene Stone
08:59 21 Jan
Resolve

Well done [redacted]

This is great :)

Student A: Trial and Error method

I only answered (ii) i am not sure if this is right, i looked at the website and tried to do it.
The top part of the page is just an example.
The bottom part is the question.



Irene Stone
11:38 22 Jan
Resolve

[redacted] this is AMAZING well done :)

This is Leaving Cert higher level!!! You obviously are not expected to know this for Junior Cert but no harm.. this is great. Do you see how you got the same answer as [redacted]? Well done :) I'm very impressed.

Student B: Using Logs method

Figure 31: Learning something new – Google Doc

5.8.2 Motivation

It was evident from the interview responses that students liked working on the Google Docs;

> *"It was fun because it was different than being in school"*

They enjoyed working in small groups.

> *"You weren't put under pressure so if you like had to answer the question in front of the class you'd be under pressure that you would say something wrong but when you're doing it with a small group you still get it out but you are not put under the pressure."*

They liked going on at night time and checking what others had written.

> *"It was fun to go on every night and see what people had said and it was good to compare and see what other people had said"*

It is clear that students' attention was captured (Keller, 2010).

One student was conscious of his peers looking at his work. He doesn't feel the need to explain what he is doing in his maths copybook. He explained that only the teacher will be looking at it and he believes the teacher doesn't need explanations.

> *"I was aware unlike in my copy that people were gonna be looking at it and trying to just figure it out themselves but if you're doing it in your copy the only person you need to worry about figuring it out is your maths teacher and they would probably know what you're on about"*

> *"It's just cas in your copy it's just you were as in the google doc its more people so you have to explain it to everyone so they know what you are doing"*

Students recognised the importance and relevance of digital skills for today's generation:

> *"IT is such a major part of our generation so using that and learning really helps us"*

Relevance is a key step in Keller's ARCS model (Keller, 2010).

Some commented that they liked having the support at home.

> *"You gave us some eh like steps to drive us into the right direction"*
> *"I liked the way you could communicate with others so they could help you with the problem"*

Their confidence was increased through the help they received from the teacher and their peers (Keller, 2010). As discussed in the literature review, motivation is required in order for a collaborative constructivist experience to be successful (OECD, 2014; Palmer, 2005). It is clear from these comments that students were clearly motivated.

5.8.3 Negatives

During the interview, the teacher asked the students *"What did you dislike about working on the Google Doc?"* Knowing the answer to this question, allows the researcher to reflect on the process.

Students commented that they really wanted to be online at the same time as others. This points to a direction further study in this area could focus on.

> *"When you were on online you wanted somebody else to be online to help but they weren't on the same time as you so you just have to wait till they're on"*
> *"I felt like there wasn't enough times when people were on at the same time*

There was some technical issues with the technology such as getting used to the tools on Google Doc and also the type of device used to access the Google Doc.

> *"I think sometimes it was difficult to ... there were some things you couldn't do as if you were writing things down with pen and paper you could .. I was finding it very hard to press the divide button cas I couldn't find it on the keyboard so... yea I found that very difficult"*
>
> *"Handwriting entry was hard ... like you'd write something and then think that's not me"*
>
> *"If you didn't have a computer you could use your phone and then you couldn't really do much things on your phone so it was a bit of a problem.*
>
> *"It kind of lagged a bit."*

5.8.4 Do you find problem solving easy?

For the question “Do you find problem solving easy?” there was an increase in the number of students who answered “No” from 21% to 34% (figure 32). It could be inferred that because students are more aware of what problem solving involves that it is less easy. After the intervention, findings showed that students are more likely to read a problem again (figure 14, p50) and also they are using more algebra to solve problems. Some of the questions presented during the intervention were more challenging than would normally have been given. This was to allow for scaffolding. Another reason could be because they were using words more;

> *“I feel like the questions were harder in a lot of ways cas you had to explain it to people who weren't looking at it the same way you were”.*

This is in line with the findings of Jeffes et al (2013); students struggle with providing written explanations.

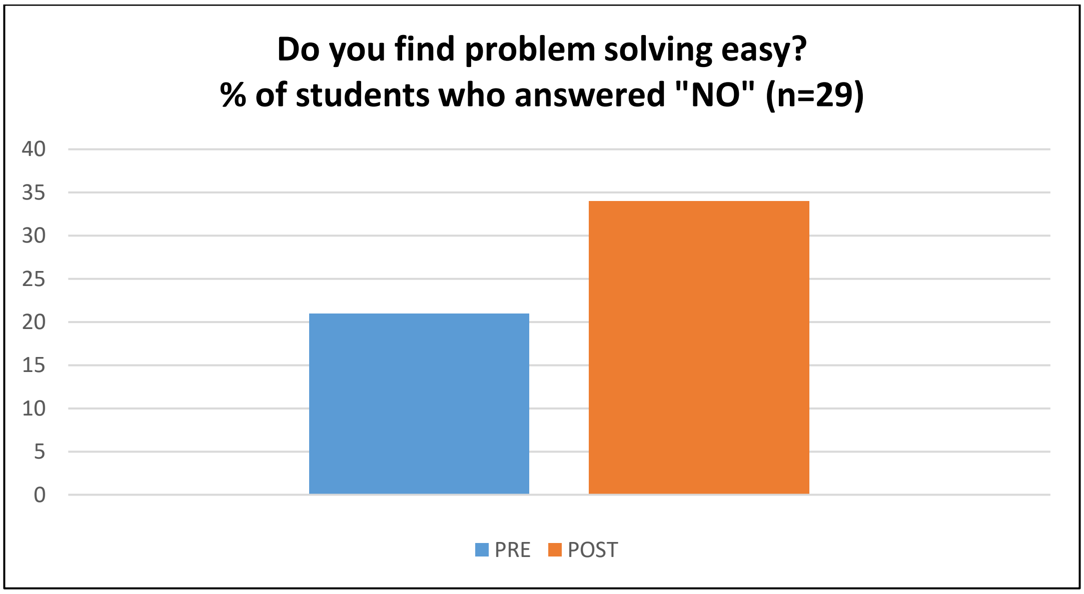


Figure 32: Do you find problem solving easy?

5.8.5 Open-ended survey question

Finally, the responses to the open ended survey question were analysed to help support the overall arguments that were made from the sub-questions. At the end of the survey, students were asked the following *"Thinking again of the last time you worked on solving problems, can you describe what you think it means to "problem solve""*

All of the responses were themed. See Appendix L. After the intervention the number of references to the theme *"Finding an answer or one solution"* almost halved. This shows that students are more aware that problem solving is not just about finding an answer. Students were also more aware after the intervention that problem solving involves using different methods. There was also an increase in the number of references to using words and checking your answer. There was 3 references to "breaking a problem down/involves steps" after the intervention. This suggests a greater willingness to persevere and put a greater effort into solving a problem. Most notably, there was no reference made to working with others before the intervention. After the intervention, there were 5 references.

As discussed in the literature review, using different methods, using words, checking answers, and working with others are all important components of problem solving (Boaler, 2010; Hurme & Järvelä, 2005; Jeffes et al., 2013; Kim & Hannafin, 2011; Muir et al., 2008; SEC, 2015a).

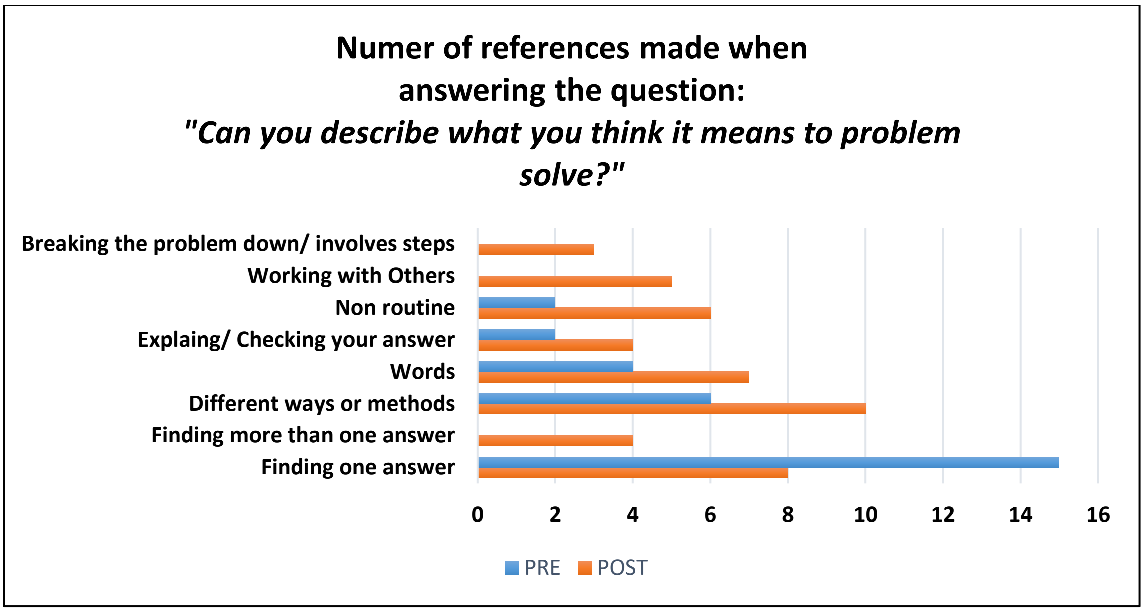


Figure 33: Open-ended survey question

5.9 Summary of findings

By analysing the data collected, it is clear that there was plenty of evidence of problem solving being supported by the online collaborative environment, Google Docs.

- There was evidence of an increase in the number of attempts made at questions in the post assessments. After the intervention, students were clearly checking answers more and were less likely to think that a problem can be solved in less than 5 minutes. More students believed that reading a problem more than once is not a waste of time. The interview responses and evidence of their work showed evidence of reflection and trying again. It is clear therefore that through working on the Google Docs, students were reflecting on what they were doing and/or trying again.

- The survey showed evidence that students were using words more. Observations of work done on the Google Docs and interview responses clearly pointed to use of words being used through this environment. The Google Docs platform allowed for this to happen through the type and comments features. Google Docs supported and encouraged students to use words when solving problems.

- A multi-representational approach to solving problems was evident in the Google Doc artefacts (Appendix M). The interviews included many references to students solving problems in different ways. The features of Google Docs allowed them to do this while the process of working with others encouraged them to try different ways.

- Scaffolding was a key feature of the Google Docs intervention. It was easy for the teacher to guide and support learning through the comments. Students also guided each other through different type fonts and colours and in the comments. The Google Docs environment made it easy to intervene at appropriate points of the learning. Students were also challenged to work at higher levels and expectations were raised.

- Collaboration was embedded throughout the experience as students helped each other to solve problems. They communicated with each other using words, and clearly learned from each other.

In summary, it is clear that all the sub-questions were answered. There was evidence of all the elements of problem solving being supported through the online environment. However, it remains unclear whether these elements *improved* through working on the Google Docs. What this research shows, is *how* the Google Docs environment can support problem-solving skills. It is through working together on shared documents, with support from a teacher, that students can be helped to problem solve. Through answering all the sub-questions, it is apparent that the environment of Google Docs can support reflection, using words, showing different representations/methods for problems, scaffolding and collaboration.

The research set out to answer the question *"Can working collaboratively through an online environment support post-primary mathematics students' problem-solving skills?"* The research comes to a point where the question is answered; working collaboratively through an online environment can support problem-solving skills of post-primary mathematics students.

6 Conclusions

The literature review highlighted the importance of problem-solving skills in today's world (OECD, 2014). This is backed up by the needs identified in the Project Maths syllabus and the new Junior Cycle curriculum; for problem-solving skills to be embedded in the learning of post-primary students (DES, 2013, 2015a, 2015b). In addition, it was highlighted that digital and collaboration skills should also be key in students' learning (DES, 2015a, 2015b). Problem-solving skills are still lacking in Irish classrooms as highlighted in the literature (Bray & Tangney, 2016; Jeffes et al., 2013; SEC, 2015a, 2015b). This project set out to investigate how working collaboratively through an online environment can support post-primary mathematics students' problem-solving skills.

The literature review identified elements of problem solving including;

- Constructivism as a pedagogy, is a conducive environment for problem solving.
- Scaffolding by a teacher can enhance problem-solving skills.
- When problem solving, one should use words to describe, explain, or justify what they're doing.
- Problem solving should be collaborative.
- Students should aim for a multi-representational approach when problem solving.

Triangulation of data demonstrated that these elements of problem solving were clearly evident during the intervention. Students were reflecting and attempting problems, they were using words to describe what they were doing and applied a multi-representational approach to problem solve. The online environment of Google Docs, supported these elements of problem solving, mainly due to the fact that it allowed students work together in groups.

As discussed in the literature review, teachers find it challenging to facilitate problem-solving activities in their classrooms due to pressure of exams and content coverage (Kim & Hannafin, 2011; NCCA, 2012a). Google Docs can allow for students to improve their problem-solving skills from their home environment. Bray & Tangney (2016) highlighted how teachers are not using a skill-based pedagogical approach in their mathematics teaching. The Google Docs environment can also support collaborative and digital skills. This environment created a collaborative space to work in, where students felt compelled to explain what they were doing and try different methods. The teacher was able to scaffold their learning through the comments. Peer to peer scaffolding was observed with students helping each other. While the sub-questions were answered, their suitability to measure the improvement of problem-solving ability is questionable. However, it was not the intention of the intervention to improve problem-solving skills (in particular when considering the short timeframe); rather to investigate how the online environment could help support these skills. The research comes to a point which concludes that working collaboratively through an online environment can support post-primary mathematics students' problem-solving skills.

6.1 Limitations of the study and future work

The sample size was small at n=29 and the intervention short at two weeks. The quantitative data was therefore analysed with a cautionary view. Statistically, the validity of this approach is questionable. The statistical analysis of the survey and assessment responses would have been more valid if paired between pre and post. The anonymity of the participants could still have been protected if they had of been coded to allow for matching of the pre and post data. This would have resulted in a better comparison of the two data sets by carrying out a paired t-test. The research, therefore lacks generalisability due to its small sample size.

While the quantitative comparison of pre and post survey data yielded limited statistical conclusions, what was evident from looking at the pre-test results alone was that the participants already exhibited many problem-solving attributes. It would be interesting to run a similar intervention on a less motivated/engaged group.

It was evident from the assessments that students attempted more problems after the intervention. On reflection, this could have been explored during the interviews; it would have been useful to know *why* the students attempted more problems. Through the data analysis it became clear that students had learned some new content (e.g. Log functions). An area of further study would be to investigate what compelled students to use these methods and to explore what was the catalyst in the online environment that facilitated this.

Another area of further study would be to investigate if an online environment can *improve* problem-solving skills; this would require larger samples of students and a longer intervention period. The rubric to categorise naïve, routine and sophisticated problem solvers, was not used in the post assessment. In a longitudinal study, this could be used to measure if there would be any changes in these categories. While the researcher was observing and commenting on Google Docs every night during the intervention, an actual log of all the activity of students was not recorded as it was an onerous task. Correlating activity times of users with the aforementioned problem solver categories would also be worthy of investigation.

Finally, another interesting finding was students expressing a preference for working synchronously on the Google Doc environment. An area of further study would be to look at comparing synchronous and asynchronous collaborative problem solving through an online environment.

7 References

Baxter, P., & Jack, S. (2008). Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. *The Qualitative Report Volume*, *13*(4), 544–559. Retrieved from http://www.nova.edu/ssss/QR/QR13-4/baxter.pdf

Bergmann, J., & Sams, A. (2012). *Flip your classroom : reach every student in every class every day*. International Society for Technology in Education.

Boaler, J. (1998). Open and Closed Mathematics: Student Experiences and Understandings. *Journal for Research in Mathematics Education*, *29*(1), 41–62.

Boaler, J. (2010). *The Elephant in the Classroom: helping children learn and love maths*. London: Souvenir Press.

Bray, A., & Tangney, B. (2016). Enhancing student engagement through the affordances of mobile technology: a 21st century learning perspective on Realistic Mathematics Education. *Mathematics Education Research Journal*, *28*(1), 173–197.

Carson, J. (2007). A problem with problem solving: Teaching thinking without teaching knowledge. *The Mathematics Educator*, *17*(2), 7–14.

Cosgrove, J., Perkins, R., Shiel, G., Fish, R., & Mcguinness, L. (2012). *Teaching and Learning in Project Maths : Participated in PISA 2012*. Dublin: Educational Research Centre.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative and mixed methods approaches* (2nd ed.). Thousand Oaks, CA: SAGE Publications.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative and mixed methods approaches* (4th ed.). Thousand Oaks, CA: SAGE Publications.

Cronin, C. (2014). Using case study research as a rigorous form of inquiry. *Nurse Researcher*, *21*(5), 19–27.

DES. (2013). Junior Certificate Mathematics Syllabus: Foundation, ordinary & higher level. For examination from 2016. Dublin: Department of Education and Skills. Retrieved from http://www.ncca.ie/en/Curriculum_and_Assessment/Post-Primary_Education/Project_Maths/Syllabuses_and_Assessment/JC_Maths_English_2013.pdf

DES. (2015a). A Framework for Junior Cycle. Dublin: Department of Education and Skills. Retrieved from http://www.juniorcycle.ie/NCCA_JuniorCycle/media/NCCA/Documents/Framework-for-Junior-Cycle-2015-2.pdf

DES. (2015b). Digital Strategy for Schools, 2015 - 2020: Enhancing Teaching, Learning and Assessment. Dublin: Department of Education and Skills. Retrieved from https://www.education.ie/en/Publications/Policy-Reports/Digital-Strategy-for-Schools-2015-2020.pdf

DES. (2016a). General information note: Launch of major international study of Irish Students' Performance in Mathematics and Science in TIMSS 2015. Dublin: Department of Education and Skills. Retrieved from https://www.education.ie/en/Publications/Statistics/International-Statistical-Reports/Launch-of-major-international-study-of-Irish-Students'-Performance-in-Mathematics-and-Science-in-TIMSS-2015.pdf

DES. (2016b). General information note: Launch of major international study of Irish Students' Performance in Science, Mathematics and Reading in PISA 2015. Dublin: Department of Education and Skills. Retrieved from https://www.education.ie/en/Publications/Statistics/International-Statistical-Reports/PISA-2015-Briefing.pdf

DES. (2016c). Whole-School Evaluation Management , Leadership and Learning report. Dublin: Department of Education and Skills. Retrieved from http://www.education.ie/en/Publications/Inspection-Reports-Publications/Whole-School-Evaluation-Reports-List/

Gerstein, J. (2011). The Flipped Classroom Model: A Full Picture. Retrieved April 12, 2017, from https://usergeneratededucation.wordpress.com/2011/06/13/the-flipped-classroom-model-a-full-picture/

Gill, M. G., Ashton, P. T., & Algina, J. (2004). Changing preservice teachers' epistemological beliefs about teaching and learning in mathematics: An intervention study. *Contemporary Educational Psychology*, *29*(2), 164–185.

Gupta, A. (2008). Constructivism and peer collaboration in elementary mathematics education: The connection to epistemology. *Eurasia Journal of Mathematics, Science and Technology Education*, *4*(4), 381–386.

Hakim, C. (2000). *Research design : successful designs for social and economic research* (2nd ed.). London: Routledge.

Hattie, J. (1999). Influences on student learning (Inaugural professorial address, University of Auckland, New Zealand). Auckland. Retrieved from https://cdn.auckland.ac.nz/assets/education/hattie/docs/influences-on-student-learning.pdf

Hurme, T. R., & Järvelä, S. (2005). Students' activity in computer-supported collaborative problem solving in mathematics. *International Journal of Computers for Mathematical Learning*, *10*, 49–73.

Jeffes, J., Jones, E., Wilson, M., Lamont, E., Straw, S., Wheater, R., & Dawson, A. (2013). Research into the impact of Project Maths on student achievement , learning and motivation: Final Report. Slough: NFER. Retrieved from http://www.nfer.ac.uk/publications/NCCB01/NCCB01.pdf

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Towards a Definition of Mixed Methods Research. *Journal of Mixed Methods Research*, *1*(2), 112–133.

Keller, J. M. (1987). Development and use of the ARCS model of motivational design. *Journal of Instructional Development*, *10*(3), 2–10.

Keller, J. M. (2010). *Motivational design for learning and performance: The ARCS model approach.* New York: Springer.

Kim, M. C., & Hannafin, M. J. (2011). Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. *Computers and Education*, *56*(2), 403–417.

Krulik, S., & Rudnick, J. A. (1988). *Problem Solving: A Handbook for Elementary School Teachers*. Boston: Allyn and Bacon.

Laal, M., & Laal, M. (2012). Collaborative learning: What is it? *Procedia - Social and Behavioral Sciences*, *31*, 491–495.

Lazakidou, G., & Retalis, S. (2010). Using computer supported collaborative learning strategies for helping students acquire self-regulated problem-solving skills in mathematics. *Computers & Education*, *54*(1), 3–13.

Liu, S. H. J., & Lan, Y. J. (2016). Social constructivist approach to web-based EFL learning: Collaboration, motivation, and perception on the use of Google Docs. *Educational Technology and Society*, *19*(1), 171–186.

Meudec, C. (2016). Blended Collaborative Cloud Learning : Foundations and Practice. Maynooth: 9th International Conference on Engaging Pedagogy, ICEP, Maynooth, Ireland, 2016.

Muir, T., Beswick, K., & Williamson, J. (2008). “I’m not very good at solving problems”: An exploration of students’ problem solving behaviours. *Journal of Mathematical Behavior*, *27*(3), 228–241.

NCCA. (n.d.). Focus on Learning: Formative feedback. Dublin: NCCA. Retrieved from http://www.juniorcycle.ie/NCCA_JuniorCycle/media/NCCA/Documents/Assessment/Ongoing Asssessment/NCCA-Junior-Cycle-Assessment-Workshop-3.pdf

NCCA. (2005). Review of Mathematics in Post-Primary Education. Dublin: NCCA. Retrieved from http://www.ncca.ie/uploadedfiles/MathsReview/MathsDiscusPaperEng.pdf

NCCA. (2012a). Project maths: reviewing the project in the initial group of 24 schools - report on school visits. Dublin: NCCA. Retrieved from http://www.ncca.ie/en/Curriculum_and_Assessment/Post-Primary_Education/Project_Maths/Information/Reports/Report-on-school-visits-.pdf

NCCA. (2012b). Project maths responding to current debate. Dublin: NCCA. Retrieved from http://www.ncca.ie/en/Publications/Other_Publications/Project-Maths-Responding-to-Current-Debate.pdf

OECD. (2013). *Pisa 2015 Draft Collaborative Problem Solving Framework*. Paris: OECD. Retrieved from https://www.oecd.org/pisa/pisaproducts/Draft PISA 2015 Collaborative Problem Solving Framework .pdf

OECD. (2014). *PISA 2012 results: Creative problem solving: Students’ skills in tackling real-life problems (Volume V)*. PISA, OECD Publishing.

Øvretveit, J. (1998). *Evaluating health interventions : an introduction to evaluation of health treatments, services, policies, and organizational interventions*. Buckingham: Open University Press.

Palmer, D. (2005). A Motivational View of Constructivist-informed Teaching. *International Journal of Science Education*, *27*(15), 1853–1881.

PDST. (n.d.). School Self-Evaluation Tools. Retrieved November 10, 2016, from http://www.pdst.ie/SSE-Tools

Perkins, R., & Shiel, G. (2014). Problem Solving in PISA: The Results of 15-year-olds on the Computer-based Assessment of Problem Solving in PISA 2012. Dublin: Educational Research Centre.

Perkins, R., & Shiel, G. (2016). PISA in Classrooms: Implications for the teaching and learning of mathematics in Ireland. Dublin: Educational Research Centre.

Perkins, R., Shiel, G., Merriman, B., Cosgrove, J., & Moran, G. (2013). Learning for Life: The Achievements of 15-yer-olds in Ireland in Mathematics, Reading Literacy and Science in PISA 2012. Dublin: Educational Research Centre.

Polya, G. (1957). *How to Solve It: A New Aspect of Mathematical Method* (2nd ed.). New York: Doubleday Anchor Books.

Ross, A., & Onwuegbuzie, A. J. (2012). Prevalence of Mixed Methods Research in Mathematics Education. *The Mathematics Educator*, *22*(1), 84–113.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. *Handbook for Research on Mathematics Teaching and Learning*, (1), 334–370. Retrieved from http://gse.berkeley.edu/sites/default/files/users/alan-h.-schoenfeld/Schoenfeld_1992 Learning to Think Mathematically.pdf

SEC. (2015a). Junior Certificate Examination 2015 Mathematics Chief Examiner's report. Athlone: State Examinations Commission. Retrieved from https://www.examinations.ie/misc-doc/EN-EN-25073660.pdf

SEC. (2015b). Leaving Certificate Examination 2015 Mathematics Chief Examiner's Report. Athlone: State Examinations Commission. Retrieved from https://www.examinations.ie/misc-doc/EN-EN-53913274.pdf

Tan Yeen-Ju, H., Mai, N., & Selvaretnam, B. (2015). Enhancing Problem-Solving Skills in an Authentic Blended Learning Environment: A Malaysian Context. *International Journal of Informaton and Education Technology*, *5*(11), 841–846.

Tanner, H., & Jones, S. (2000). *Becoming a Successful Teacher of Mathematics* (1st ed.). London: Routledge.

Tucker, B. (2012). The Flipped Classroom. Retrieved April 12, 2017, from http://educationnext.org/the-flipped-classroom/

Vygotsky, L. S. (1978). *Mind in society : the development of higher psychological processes*. Cambridge: Harvard University Press.

Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Child Psychiatry*, *17*, 89–100.

Yin, R. K. (2003). *Case Study Research - Design and Methods* (3rd ed.). London: SAGE Publications.

Appendix A: Phased implementation of project maths syllabus

Project Maths was introduced to an initial group of 24 school (pilot schools) in 2008 on a phased basis; Strands 1 and 2 (Statistics and Probability) introduced in 2008, followed by Strands 3 and 4 (Number and Algebra) in 2009, and Strand 5(Functions) in 2010. The syllabus was subsequently rolled out to all other schools on a phased basis from 2010 (Perkins et al., 2013, p. 41).

Table 2.2. Timeline for Project Maths

	Cohort	Years of study at Junior Cycle	Years of study at Senior Cycle	Syllabus strands
Initial 23 schools	1	2008 – 2011	2008 – 2010	Strand 1: Statistics and Probability Strand 2: Geometry and Trigonometry
	2	2009 – 2012	2009 – 2011	Strand 1: Statistics and Probability Strand 2: Geometry and Trigonometry Strand 3: Number Strand 4: Algebra
	3	2010 - 2013	2010 – 2012	Strand 1: Statistics and Probability Strand 2: Geometry and Trigonometry Strand 3: Number Strand 4: Algebra Strand 5: Functions
All schools	1	2010 – 2013	2010 – 2012	Strand 1: Statistics and Probability Strand 2: Geometry and Trigonometry
	2	2011 – 2014	2011 – 2013	Strand 1: Statistics and Probability Strand 2: Geometry and Trigonometry Strand 3: Number Strand 4: Algebra
	3	2012 – 2015	2012 – 2014	Strand 1: Statistics and Probability Strand 2: Geometry and Trigonometry Strand 3: Number Strand 4: Algebra Strand 5: Functions

Note: Students taking the Leaving Certificate in 2015 and beyond will study all the material in strand 1 (statistics and probability).

Appendix B: Pre and post assessments

Pre-Assessment

Attempt as many questions as you can! *You will not be graded on this…*

1) If I add a fifth of a number to a quarter of the same number I get 9. What's the number?

2) Lady Mary was getting ready for the ball when her pearls broke. Half of the pearls fell onto the floor; a fourth rolled under a chair; a sixth fell into her lap; and three pearls remained on the strand. How many were there originally on the strand?

3) When a certain number is multiplied by 5 and the answer is added to 45 the result is the same as multiplying the number by 20 and subtracting 15. What is the number?

4) Harry got a loan from his Mam of €5000. He pays her back every month in instalments of €200.
Annmarie takes out a loan of €7000 from her Dad. She pays him back €300 every month.
Who will have their loans paid back the quickest?
At the start, Annmarie owes more money than Harry. When will Harry owe more than Annmarie?

5) A garden with an area of 99 m^2 has width x m and its length is 2m longer than its width. Write its area in term of x. Solve the equation to find the length and width of the garden.

6) Omitted due to error

7) Some children were playing with some rabbits in a yard. I tried to count them and found that there were 30 legs and 11 heads. How many children and how many rabbits were in the yard?

8) How many tiles are in the 20^{th} pattern?
What type of pattern is this?
Can you come up with a "formula" to describe the pattern? (I.e. generalise the pattern)

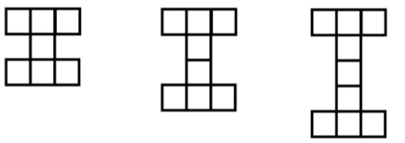
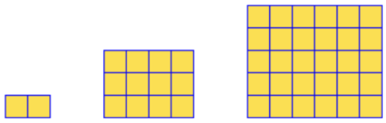


Figure 1 Figure 2 Figure 3

9) How many tiles are in the 20^{th} pattern?
What type of pattern is this?
Can you come up with a "formula" to describe the pattern? (I.e. generalise the pattern)



Picture 1 **Picture 2** **Picture 3**

10)

The Kelvin scale is one way of measuring temperature.
To convert a temperature from degrees Fahrenheit (F) to kelvin (K), you:

add 459·67 to F, then multiply your answer by 5 and divide by 9.

(a) Convert 212 degrees Fahrenheit (F) to kelvin (K).

(b) Write an algebraic formula to express K in terms of F.

$K =$

(c) Hence, or otherwise, convert 400 kelvin (K) to degrees Fahrenheit (F).

Post-Assessment

Attempt as many questions as you can! *You will not be graded on this…*

1) A third of a number subtracted away from a half of the same number is 5. What's the number?

2) Sarah divides up a pizza between herself and her friends. She eats 1/3 of the pizza herself. All her friends get 1/2 of what she ate. Assuming all the pizza is gone how many people ate the pizza.

3) When a certain number is multiplied by 3 and the answer is added to 12 the result is the same as multiplying the number by 5 and subtracting 4. What is the number?

4) The temperature of liquid A is heated to 80°C and then cools at a rate of 5°C per minute. Liquid B is heated to 110°C and then cools at a rate of 8°C per minute.
Which liquid reaches 50°C first?
Will they ever both be the same temperature?

5) One number is 2 greater than another number. When these two numbers are multiplied by each other the result is 15. Represent this problem as an equation and solve the equation.

6) Omitted due to error

7) There are a number of rabbits and budgies in a cage. Altogether there are 29 heads and 98 legs. How many of each animal was in the cage?

8) How many tiles are in the 20th pattern?
What type of pattern is this?
Can you come up with a "formula" to describe the pattern? (I.e. generalise the pattern)

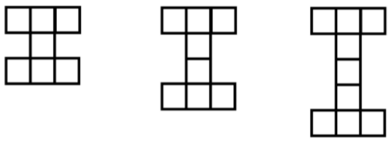
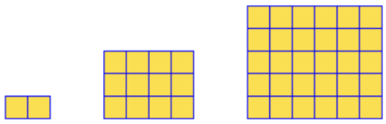


Figure 1 Figure 2 Figure 3

9) How many tiles are in the 20th pattern?
What type of pattern is this?
Can you come up with a "formula" to describe the pattern? (I.e. generalise the pattern)



Picture 1 Picture 2 Picture 3

10)

The Kelvin scale is one way of measuring temperature.
To convert a temperature from degrees Fahrenheit (F) to kelvin (K), you:

add 459·67 to F, then multiply your answer by 5 and divide by 9.

(a) Convert 212 degrees Fahrenheit (F) to kelvin (K).

(b) Write an algebraic formula to express K in terms of F.

$K =$

(c) Hence, or otherwise, convert 400 kelvin (K) to degrees Fahrenheit (F).

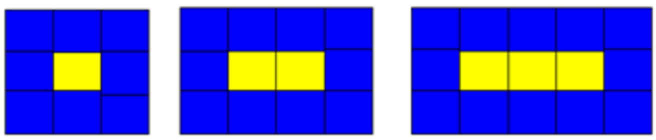
Appendix C: Google Doc problems

1) Paddy thinks of a number, multiplies it be 3, adds 10 and gets 4. What's the number??

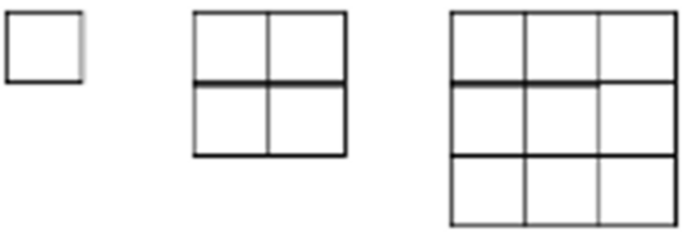
2) Farmer Joe has 20m of fencing. What is the maximum rectangular area he can make with the fencing?

3) One side of a rectangle is 4m bigger than the other side. The area of the rectangle is 60metres squared. What is the perimeter of the rectangle?

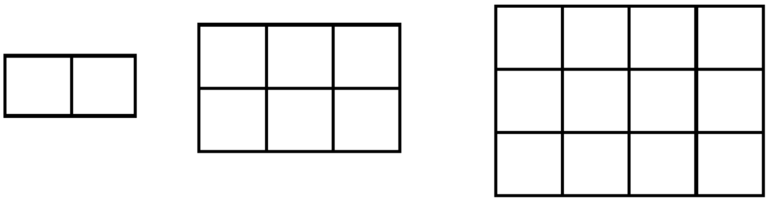
4) How many blue tiles are needed for 5 yellow tiles?
How many blue tiles are needed for 100 yellow tiles?
How many yellow tiles will there be if there are 200 blue tiles?



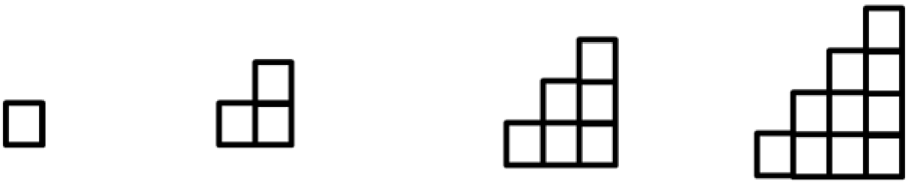
5) Draw the next two patterns of growing squares:
How many tiles would be in the 20th pattern**?**



6) Growing Rectangles – How many tiles are in the 20th pattern?



7) How many tiles are in the 20th staircase?



8) John has 18 ten-cent coins in his wallet 

 Owen has 22 five-cent coins in his wallet

Each day, they decide to take one coin from their wallets and put it into a money box, until one of them has no more coins left in their wallet.
When does Owen have more money than John in his wallet?

Appendix D: Paper surveys

Student Questionnaire on Problem Solving

The reason for this survey is to gather your thoughts on Solving Problems.

Each question is optional. Feel free to omit a response to any question; however the researcher would be grateful if all questions are responded to.

Please do not name third parties in any open text field of the questionnaire. Any such replies will be anonymised.

1. Do you like problem solving?	Yes		No		Don't know
2. Do you find problem solving easy?	Yes		No		Don't know
3. When solving a problem I prefer to work with someone else…	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
4. When solving a problem I prefer to work on my own…	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
5. If I can't solve a problem one way I will try and solve it another way…	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
6. If I can't do a problem I give up straight away…	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree

Each question is optional. Feel free to omit a response to any question; however the researcher would be grateful if all questions are responded to.

For the following questions 7-10 think of the last few times you were solving problems. When solving a problem…					
7. …I do the work in my head and write the answer down. I don't "show my work".	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree
8. …I show every step.	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree
9. …I describe how I solve the problem using words.	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree
10. …I keep trying different methods or ways to get the answer	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree

Each question is optional. Feel free to omit a response to any question; however the researcher would be grateful if all questions are responded to.

11. There is only one way to solve a maths problem	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree
12. Students who have understood the maths taught to them will be able to solve a problem in less than 5 minutes	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree
13. If I am given a problem a bit different from an example in a book, I feel confident I could figure it out myself.	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree
14. When I get the answer to a problem, I look back and check if my answer makes sense.	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree
15. I have trouble getting started on a problem that is new to me.	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree
16. After I have solved a problem, I go back and see if I could have got the answer a different way.	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree
17. Reading a problem more than once is a waste of time.	◯ Strongly Disagree	◯ Disagree	◯ Neither Agree or Disagree	◯ Agree	◯ Strongly Agree

Please do not name third parties in any open text field of the questionnaire. Any such replies will be anonymised.

Thinking again of the last time you worked on solving problems, can you describe what you think it means to “problem solve”.

Appendix E: Interview questions

1) *What did you like about working on the Google Doc?*

2) *What did you dislike about working on the Google Doc?*

3) *When solving problems on the Google Doc, can you describe how you may have used different methods to solve a problem?*

4) *Did anyone…*
   a. …help you understand a problem on the Google Doc?
   b. …help you to solve a problem on the Google Doc?
   c. …did you help anyone?

5) *When working on the Google Doc, did you find you had to explain what you were doing using words?*
   a. …did others explain using words?

Appendix F: Suggested sequence of topics – PMDT

Suggested sequence of topics to be taught in 2nd year as recommended by the Project Maths Development Team (PMDT):

Suggested sequence of topics

Section number	Syllabus section	Lesson Number	Title of lesson Idea	Page	
Section 1	3.4	2.1	Applied measure 1	9	
Section 2	4.1 4.2 4.3 4.4	2.2	Linear and quadratic relationships: multi - representational approach	10	
Section 3	3.3	2.3	Applied arithmetic -financial maths	11	
	3.4	2.4	Applied measure 2 - area and volume	12	
	3.2	2.5	Investigating rules for indices	13	
Section 4	4.6	2.6	Revision of 1st year Algebra	14	
	4.6	2.7	Factors	15	
	4.6	2.8	Adding algebraic fractions	16	
	4.7	2.9	Linear equations, linear inequalities and simultaneous linear equations	16	
	4.7	2.10	Solve quadratic equations	17	
			Introduction to Pythagoras'		

The PMDT develop resources to support teachers including teacher handbooks which suggest the sequence of topics to teach. This extract above is taken from page 6 of the "2nd year handbook" and can be accessed http://www.projectmaths.ie/wp-content/uploads/2015/01/2nd-Year-Handbook-July-2016.pdf

Appendix G: Ethics forms

Letter to Board of Management

November 2016

Dear Secretary of Board of Management,

As part of my Masters in Technology and Learning (MSc) within Trinity College Dublin, the University of Dublin, I am conducting research in the area of problem solving through an online learning environment under the supervision of Assistant Professor Nina Bresnihan. My research study, which is part of my dissertation project, is titled **"Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills."** The online learning environment will be through Google Docs where students will collaborate with each other as they attempt to solve mathematical problems. Working collaboratively is a key skill that students are expected to demonstrate in the new Junior Cycle programme under the name "Working with Others". Problem solving skills are an integral part of mathematical learning as recognised by the National Council for Curriculum and Assessment. The Mathematics syllabus has problem solving skills included in each strand of the maths course as skills that students should learn.

The study will be conducted over 2 weeks. Students will be required to complete paper questionnaires prior to and after the intervention. During the intervention, they will be put into groups (3 or 4 students) and will work collaboratively using Google Docs to solve problems. Students will not have to register to use Google Docs as they will be using their existing school domain Google accounts. This school Google account allows participants to use Google Docs. They will also be using Geogebra software to graph functions. I will be a member of each group so will be able to monitor all communication amongst group members. They will be interviewed after the intervention by a designated teacher at the school. I will also gather data by observing students during the intervention. Students will sit a written assessment before and after the intervention to assess if they attempt more problems and if they use more methods to try solving these problems. I also wish to highlight the section "Information we collect" in the accompanying document "Google for Education"; this summarises the information Google collects from users.

The study will not impinge on the Junior Certificate Mathematics curriculum. Any work that students are required to do online will replace homework that will normally be set for them. It is hoped that students will improve their collaborative and problems solving skills so this intervention can only be advantageous for them. Problem solving questions will be based on the mathematics syllabus. Should I feel, that some students (or all) are not learning or improving their skills I will be available for them after school or during lunchtime should they need extra support. I will also be available to assist them online throughout the learning experience and will be there to guide and support them online and in class.

I am aware that this is a very busy time of year for you and the school and I would greatly appreciate your assistance with this project. I foresee no risks associated with individuals' and schools' participating in this study. The information gathered will be treated as confidential. No information about the school or the participants will be identified in the research. A copy of the results can be made available to you after the study is completed.

Please note that the school or the pupils involved are under no obligation to participate in this study. If at any time a participant wishes to withdraw from the study they may do so. Should a student decide to withdraw from the study they will be given the same problems (as given in the online study) which they can attempt to solve using pen and paper as homework. These problems are based on the mathematics syllabus. I will not collect any data relating to them (through observation or otherwise).

Please find attached the following:

- Cover letter for parents/guardians
- Information Sheet for parents/guardians
- Information Sheet for students
- A "G Suite for Education" privacy notice
- Consent form for parents/guardians
- Assent form for students
- Consent form for Board of Management

If you have further questions regarding this research please feel free to contact my supervisor or me. Finally I would like to thank you for taking the time to consider my research. Without your generous participation, conducting such research would not be possible.

Kind Regards,

____

Students Email: stoneir@tcd.ie Supervisor email: nina.bresnihan@scss.tcd.ie

Students Phone: 0863193358 Supervisor number: 01 896 2704

Letter to Parents/ Guardians

November 2016

Dear Parent/Guardian,

As part of my Masters in Technology and Learning (MSc) within Trinity College Dublin, the University of Dublin, I am conducting research in the area of problem solving through an online learning environment under the supervision of Nina Bresnihan. My research study, which is part of my dissertation project, is titled **"Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills."**

I would be very grateful if you would consider allowing your son/daughter to participate in this study. Please find attached

- An information sheet relating to this study for you
- An information sheet for your son/daughter which should be read to your son/daughter
- A "G Suite for Education" privacy notice
- A consent form for you to fill in should you agree to participate
- An assent form for your son/daughter to fill in should they agree to participate

Your son/daughter is under no obligation to participate in this study and may withdraw from the study at any time. Should you have any questions or require any clarifications about the study please do not hesitate to contact me.

Finally I would like to thank you for taking the time to consider supporting this study. Without your generous participation, conducting such research would not be possible.

Regards,

____

Irene Stone

Mathematics Teacher

Student Contact details: stoneir@tcd.ie

Supervisor Contact details: nina.bresnihan@scss.tcd.ie

Information Sheet for Parents/ Guardians

Title: "Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills."

Study: This project is being conducted as part of a required project for my Masters in Technology and Learning within Trinity College Dublin, the University of Dublin. The study is titled **"Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills."**

The online learning environment will be through Google Docs where students will collaborate with each other as they attempt to solve mathematical problems. Working collaboratively is a key skill that students are expected to demonstrate in the new Junior Cycle programme under the name "Working with Others". Problem solving skills are an integral part of mathematical learning as recognised by the National Council for Curriculum and Assessment. The Mathematics syllabus has problem solving skills included in each strand of the maths course as skills that students should learn.

The study will not impinge on the Junior Certificate Mathematics curriculum. Any work that students are required to do online will replace homework that will normally be set for them. It is hoped that students will improve their collaborative and problems solving skills so this intervention can only be advantageous for them. Problem solving questions will be based on the mathematics syllabus.

Participation information:

The study will be conducted over 2 weeks. A student agreeing to partake in this study will be required to complete paper questionnaires prior to and after the intervention. During the intervention, they will be put into groups and will work collaboratively using Google Docs to solve problems. Students will not have to register to use Google Docs as they will be using their existing school domain Google accounts. This school Google account allows participants to use Google Docs. They will also be using Geogebra software to graph functions. Geogebra is dynamic software that is free to download. This software can be used to make graphs. It is not necessary that your son/daughter uses Geogebra but it may help them solve the problems by visualising some of them as a graph (https://www.geogebra.org/). I will be a member of each group so will be able to monitor all communication amongst group members. They will be interviewed after the intervention by a designated teacher at the school. I will also gather data by observing students during the intervention. Students will sit a summative assessment before and after the intervention to assess if they attempt more problems and if they use more methods to try solve these problems. I also wish to highlight the section "Information we collect" in the accompanying document "Google for Education"; this summarises the information Google collects from users.

Should I feel, that some students are not learning or improving their skills, I will be available for them after school or during lunchtime should they need extra support. I will also be available to assist them online throughout the learning experience and will be there to guide and support them online and in class. Should your son/daughter not have access to a device to participate in the online activities, I can arrange for them to use a computer in school during lunchtime or after school. Please contact me should this be a concern for you.

I foresee no risks associated with individuals' and schools' participating in this study. The information gathered will be treated as confidential. Information regarding your son/daughter will not be identifiable.

A student is under no obligation to participate in this study and may withdraw from the study at any time. Should your son/daughter decide to withdraw from the study they will not have to participate in the online Google Doc work. While they will still participate in the class lessons using Google Docs and Geogebra, I will not collect any data relating to them (through observation or otherwise). They will be given the same problems (as given in the online study) which they can attempt to solve using pen and paper as homework. These problems are based on the mathematics syllabus. Should you have any questions or require any clarifications about the study please do not hesitate me.

Student Contact details: stoneir@tcd.ie

Supervisor Contact details: nina.bresnihan@scss.tcd.i

Information sheet for students

Title: "Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills."

Study: This project is being conducted as part of a required project for my Masters in Technology and Learning within Trinity College Dublin, the University of Dublin. The study is titled **"Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills."**

The online learning environment will be through Google Docs where you will be working in a group as you attempt to solve mathematical problems. Collaboration is a key skill that you are expected to demonstrate in the new Junior Cycle programme under the name "Working with Others". Problem solving skills are an integral part of mathematical learning. The Mathematics syllabus has problem solving skills included in each strand of the maths course as skills that you should learn.

- The study will not impinge on your Junior Certificate Mathematics curriculum. Any work that you are required to do online will replace homework that will normally be set for you.
- The study will be conducted over 2 weeks.
- If you agree to partake in this study, you will be required to complete paper questionnaires prior to and after the intervention.
- During the intervention, you will be put into groups and will work with others using Google Docs to solve problems.
- You do not need to register to use Google Docs. You will use your existing school domain google accounts to access the Google Doc. Any information you share on the Google Doc should only be related to the Maths problem you are attempting to solve.
- You will also be using Geogebra software to graph functions.
- I will be a member of each group so will be able to monitor all communication amongst group members.
- You will be interviewed after the intervention by a designated teacher at the school.
- I will also gather data by observing students interactions that take place on the google doc. While I will be able to identify each group member in the Google Doc, I will make sure that the data I collect for the purpose of my research will not be identifiable.
- You will sit a test on problem solving prior to and after the intervention.

Should I feel, that you are not learning or improving your skills, I will be available after school or during lunchtime should you need extra support. I will also be available to assist you online throughout the learning experience and will be there to guide and support you online and in class. If you do not have access to a device to participate in the online activities, I can arrange for you to use a computer in school during lunchtime or after school.

I foresee no risks associated with you participating in this study. The information gathered will be treated as confidential. Information regarding you will not be identifiable.

You are under no obligation to participate in this study and may withdraw from the study at any time. Should you decide to withdraw from the study, you will not have to participate in the online Google Doc work. While you will still participate in the class lessons using Google Docs and Geogebra, I will not collect any data relating to you (through observation or otherwise). You will be given the same problems (as given in the online study) which you can attempt to solve using pen and paper as homework. These problems are based on the mathematics syllabus. Should you have any questions or require any clarifications about the study please do not hesitate to contact me.

Student Contact details: stoneir@tcd.ie

Supervisor Contact details: nina.bresnihan@scss.tcd.ie

(This document can be accessed https://gsuite.google.com/terms/education_privacy.html)

G Suite for Education Privacy Notice

This Privacy Notice is meant to help G Suite for Education users and parents understand what data we collect, why we collect it, and what we do with it. This Notice summarizes the most relevant portions of the Google Privacy Policy, and includes information about our privacy practices that are specific to Apps for Education. We hope you will take the time to read this Notice and the Google Privacy Policy, which both apply to Apps for Education accounts.

Information we collect

A G Suite for Education account is a Google Account created and managed by a school for use by students and educators. When creating this account, the school may provide Google with certain personal information about its students and educators, including, for example, a user's name, email address, and password. Google may also collect personal information directly from users of G Suite for Education accounts, such as telephone number or a profile photo added to the Apps for Education account.

Google also collects information based on the use of our services. This includes:

- device information, such as the hardware model, operating system version, unique device identifiers, and mobile network information including phone number of the user;
- log information, including details of how a user used our service, device event information, and the user's Internet protocol (IP) address;
- location information, as determined by various technologies including IP address, GPS, and other sensors;
- unique application numbers, such as application version number; and
- cookies or similar technologies which are used to collect and store information about a browser or device, such as preferred language and other settings.

How we use information we collect

1. **In G Suite for Education Core Services**
2. The G Suite for Education Core Services ("Core Services") are Gmail, Calendar, Classroom, Contacts, Drive, Docs, Forms, Groups, Sheets, Sites, Slides, Talk/Hangouts and Vault. These services are provided to a school under its Apps for Education agreement and, as applicable, Data Processing Amendment. (Users and parents can ask their school if it has accepted the Data Processing Amendment.) The Apps for Education agreement as amended applies to the Apps for Education Core Services only.
3. Google does not serve ads in the Core Services or use personal information collected in the Core Services for advertising purposes.
4. **In Google services generally**
5. The Google Privacy Policy describes fully how Google services generally use information, including for Apps for Education users. To summarize, we use the information we collect from all of our services to provide, maintain, protect and

improve them, to develop new ones, and to protect Google and our users. We also use this information to offer users tailored content, such as more relevant search results. We may combine personal information from one service with information, including personal information, from other Google services.
6. For Apps for Education users in primary and secondary (K-12) schools, Google does not use any user personal information (or any information associated with an Apps for Education Account) to target ads, whether in Core Services or other Google services accessed while using an Apps for Education account.

Information users share

A school may allow students to access Google services such as Google Docs and Sites, which include features where users can share information with others or publicly. When users share information publicly, it may be indexable by search engines, including Google. Our services provide users with various options for sharing and removing content.

Information we share

Information we collect may be shared outside of Google in limited circumstances. We do not share personal information with companies, organizations and individuals outside of Google unless one of the following circumstances applies:

- **With user consent.** We will share personal information with companies, organizations or individuals outside of Google when we have user consent or parents' consent (as applicable).
- **With G Suite for Education administrators.** G Suite for Education administrators have access to information stored in the Google Accounts of users in that school or domain.
- **For external processing.** We provide personal information to our affiliates or other trusted businesses or persons to process it for us, based on our instructions and in compliance with our Privacy Policy and any other appropriate confidentiality and security measures.
- **For legal reasons.** We will share personal information with companies, organizations or individuals outside of Google if we have a good-faith belief that access, use, preservation or disclosure of the information is reasonably necessary to:

1. meet any applicable law, regulation, legal process or enforceable governmental request.
2. enforce applicable Terms of Service, including investigation of potential violations.
3. detect, prevent, or otherwise address fraud, security or technical issues.
4. protect against harm to the rights, property or safety of Google, our users or the public as required or permitted by law.

We may share non-personal information publicly and with our partners – like publishers or connected sites. For example, we may share information publicly to show trends about the general use of our services.

Transparency and choice

We provide a variety of user controls that enable Apps for Education users to make meaningful choices about how information is used in Google services. Depending on the settings enabled by the school, users can use the various controls described in the Privacy Policy, such as Google activity controls, to manage their privacy and information. We provide additional information for parents, students, and administrators on the Apps for Education Privacy Center.

Parental review and deletion of information

The parents of Apps for Education users in Primary/Secondary (K-12) schools can access their child's personal information or request that it be deleted through the school administrator. School administrators can provide for parental access and deletion of personal information consistent with the functionality of our services. If a parent wishes to stop any further collection or use of the child's information, the parent can request that the administrator use the service controls available to them to limit the child's access to features or services, or delete the child's account entirely. Guidance for administrators on how to use service controls to accomplish this is available in the G Suite Help Center.

Interpretation of conflicting terms

This Notice is generally consistent with the Google Privacy Policy and the Apps for Education agreement. Where there are terms that differ, as with the limitations on advertising in Apps for Education, the G Suite for Education agreement (as amended) takes precedence, followed by this Privacy Notice and then the Google Privacy Policy.

Contact us

If you have questions about management of Apps for Education accounts or use of personal information by a school, please contact the Apps for Education account administrator. If you have questions about our practices, please visit the G Suite for Education Privacy Center. Also see our Privacy Troubleshooter for more questions about privacy and Google's products and services. Apps for Education administrators can contact Google about the information in this Notice by submitting the contact form while signed in to their administrator account.

Google

1600 Amphitheatre Parkway, Mountain View, CA 94043 USA

Phone: +1 650-253-0000

(This document can be accessed https://gsuite.google.com/terms/education_privacy.html)

Consent Form for Parent/Guardian

Title of Project: "Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills."

DECLARATION:

- I am 18 year or over and competent to provide consent.
- I have read, or had read to me, an information form providing information about this research (as detailed in the information sheet) and this consent form.
- I understand that my son/daughter's participation is fully anonymous and that no personal details about him/her will be recorded.
- I understand that it is a staff member of St. Mark's Community School conducting this study but that no information in this study will be used to identify my son/daughter.
- I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I understand the description of the research that is being provided to me.
- I agree to my son/daughter's data being presented as part of the project work for the MSc in Technology and Learning (TCD) in a way that does not reveal his/her identity.
- I freely and voluntarily agree to my son/daughter being part of this research study, though without prejudice to his/her legal and ethical rights.
- I consent to my son/daughter being observed, by the researcher (the maths teacher), through the online Google Doc, while completing the tasks associated with this project.
- I understand that my son/daughter will use their school google account to access the Google Doc and all school rules apply while communicating with their group members and teacher via this environment.
- I have read the "Privacy and Security Information" relating to the Google For Education platform my son/daughter is using for the purpose of this research (https://www.google.com/edu/trust/index.html#how-do-you-know-were-keeping-our-word)
- I have read the "Information we collect" in the accompanying document "Google for Education"; this summarises the information Google collects from users (https://gsuite.google.com/terms/education_privacy.html)
- I understand that any content that my son/daughter via the Google Doc will only be related to the maths problem(s) he/she is trying to solve and that any communication between the group members/ teacher and my son/daughter only relates to the maths problem (s).
- I understand that in the unlikely event that illicit activities become known over the course of this research, these will be reported to appropriate authorities.
- I consent to my son/daughter being interviewed by a designated teacher in the school after the intervention. I understand this interview will be recorded (audio only) and once transcribed, the audio recording will be deleted.
- I understand that my son/daughter may refuse to answer any question (in interview or questionnaires) and that he/she may withdraw at any time without penalty.
- I understand that his/her data will be stored securely and deleted on completion of the study (by 31st August 2017).
- I understand that the study involves viewing a computer screen and that if my son/ daughter or anyone in his/her family has a history of epilepsy then he/she is proceeding at his/her own risk.
- I have received a copy of this agreement.

I ________________________consent to my son/daughter ____________________ taking part in this research project.

Signature of Parent/Guardian: ____________________________ Date: ___________

Signature of project leader (TCD): ___________________________ Date: ___________

Statement of investigator's responsibility:

I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent. I undertake to act in accordance with the information supplied.

RESEARCHER CONTACT DETAILS: **stoneir@tcd.ie**

Assent Form for Student

Title of Project: "Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills."

DECLARATION:

- I am under 18 years old and I am not competent to provide consent. Permission has been sought from my parent/guardian to participate in this study.
- I have read, or had read to me, an information form providing information about this research (as detailed above) and this assent form.
- I understand that my participation is fully anonymous and that no personal details about me will be recorded.
- I understand that it is a staff member of St. Mark's Community School running this study but that no information in this study will be used to identify me.
- I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I understand the description of the research that is being provided to me.
- I agree to my data being presented as part of the project work for the MSc in Technology and Learning in a way that does not reveal my identity.
- I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
- I assent to being observed, by the researcher (my maths teacher), through the online Google Doc, while completing the tasks associated with this project.
- I understand that I will use my school google account to access the Google Doc and all school rules apply while communicating with my group members and teacher via this environment.
- I have read the "Privacy and Security Information" relating to the Google For Education platform we are using for the purpose of this research. (https://www.google.com/edu/trust/index.html#how-do-you-know-were-keeping-our-word)
- I have read the "Information we collect" in the accompanying document "Google for Education"; this summarises the information Google collects from users (https://gsuite.google.com/terms/education_privacy.html)
- I understand that any content that I share via the Google Doc will only be related to the maths problem(s) I am trying to solve and that any communication between my group members/ teacher and I only relates to the maths problem (s).
- I understand that in the unlikely event that illicit activities become known over the course of this research, these will be reported to appropriate authorities.
- I assent to being interviewed by a designated teacher in the school after the intervention. I understand this interview will be recorded (audio only) and once transcribed, the audio recording will be deleted.
- I understand that I may refuse to answer any question (in interview or questionnaires) and that I may withdraw at any time without penalty.
- I understand that my data will be stored securely and deleted on completion of the study (by 31st August 2017)
- I understand that the study involves viewing a computer screen and that if I or anyone in my family has a history of epilepsy then I am proceeding at my own risk.
- I have received a copy of this agreement.

I ________________________________assent to taking part in this research project.
Signature of Participant: _____________________________ Date:___________
Signature of project leader (TCD): ____________________________ Date: _____________
Statement of investigator's responsibility:
I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed assent. I undertake to act in accordance with the information supplied. RESEARCHER CONTACT DETAILS: stoneir@tcd.ie

Consent Form for Board of Management

Title of Project: "Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills."

DECLARATION:

- I am 18 year or over and competent to provide consent.
- I have read, or had read to me, an information form providing information about this research (as detailed in the information sheet) and this consent form.
- I understand that participation of students is fully anonymous and that no personal details about them will be recorded.
- I understand that it is a staff member of St. Mark's Community School conducting this study but that no information in this study will be used to identify any students.
- I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I understand the description of the research that is being provided to me.
- I agree to students' data being presented as part of the project work for the MSc in Technology and Learning (TCD) in a way that does not reveal their identity.
- I freely and voluntarily agree to students from St. Mark's Community School being part of this research study, though without prejudice to their legal and ethical rights.
- I consent to the students being observed, by the researcher (the mathematics teacher), through the online Google Doc, while completing the tasks associated with this project.
- I understand that students will use their school google accounts to access the Google Doc and all school rules apply while they are communicating with their group members and teacher via this environment.
- I have read the "Privacy and Security Information" relating to the Google For Education platform that is being used for the purpose of this research. (https://www.google.com/edu/trust/index.html#how-do-you-know-were-keeping-our-word)
- I have read the "Information we collect" in the accompanying document "Google for Education"; this summarises the information Google collects from users. (https://gsuite.google.com/terms/education_privacy.html)
- I understand that any content that is shared via the Google Doc will only be related to the maths problem(s), the students are trying to solve and that any communication between group members/ teacher and only relates to the maths problem (s).
- I understand that in the unlikely event that illicit activities become known over the course of this research, these will be reported to appropriate authorities.
- I consent to students being interviewed by a designated teacher in the school after the intervention. I understand these interviews will be recorded (audio only) and once transcribed, the audio recordings will be deleted.
- I understand that students may refuse to answer any question (in interview or questionnaires) and that they may withdraw at any time without penalty.
- I understand that students' data will be stored securely and deleted on completion of the study (by 31st August 2017).
- I understand that the study involves viewing a computer screen and that if a student or anyone in their family has a history of epilepsy then he/she is proceeding at his/her own risk.
- I have received a copy of this agreement.
- I have received copies of the following: Letter to parents, Information sheet for parents, Information Sheet for students, Consent form for parents, and Consent form for students.

I _________________________, on behalf of the Board of Management of St. Mark's Community School give consent for the research to be carried out.

Signature: ____________________________ Date: ____________

Signature of project leader (TCD): ___________________________ Date: ____________

Statement of investigator's responsibility:

I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent. I undertake to act in accordance with the information supplied.

RESEARCHER CONTACT DETAILS: **stoneir@tcd.ie**

Appendix H: Ethical approval

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Search All Trinity

TCD Research Ethics WebApp

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Navigation

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Home › Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills.

Investigating if working collaboratively through an online environment can improve post primary mathematics students' problem solving skills.

Status | View | Assign Supervisor

Current Status	Submission date	Last Status Update	Academic Supervisor / Lead Researcher	Application Number
Approved	Tuesday, October 25, 2016 - 08:40	Friday, December 2, 2016 - 14:57	bresnine	20161004

No workflow transitions are possible at this time.

Status:
Approved

Timeline of state changes for this application

Friday, December 2, 2016 - 14:57
State change:
from *Commented by Reviewers; Pending REC Meeting*
to ***Approved***

Tuesday, November 29, 2016 - 10:32
State change:
from *Assigned to Reviewers; Pending Comments*
to ***Commented by Reviewers; Pending REC Meeting***

Thursday, November 17, 2016 - 09:58
State change:
from *Submitted to REC; Awaiting Reviewer Assignment*
to ***Assigned to Reviewers; Pending Comments***

Thursday, November 17, 2016 - 09:58
State change:
from *Submitted to Supervisor; Pending Review*
to ***Submitted to REC; Awaiting Reviewer Assignment***

Wednesday, November 16, 2016 - 22:04
State change:
from *REC Amendments Required*
to ***Submitted to Supervisor; Pending Review***

Wednesday, November 16, 2016 - 17:33
State change:
from *Commented by Reviewers; Pending REC Meeting*
to ***REC Amendments Required***

Monday, November 14, 2016 - 09:24
State change:
from *Assigned to Reviewers; Pending Comments*
to ***Commented by Reviewers; Pending REC Meeting***

Appendix I: T-Test analysis of survey responses

			Pre			Post		
Q	**Survey Question**	**Mean**	**Variance**	**Std. Dev.**	**Mean**	**Variance**	**Std. Dev.**	**p value**
3	When solving a problem I prefer to work with someone else…	3.689655	1.078818	1.038662	3.862069	1.194581	1.092969	0.540527
4	When solving a problem I prefer to work on my own…	2.758621	0.975369	0.987608	2.689655	1.007389	1.003688	0.792939
5	If I can’t solve a problem one way I will try and solve it another way…	3.758621	1.046798	1.023131	3.965517	0.67734	0.823007	0.39989
6	If I can’t do a problem I give up straight away…	1.827586	1.076355	1.037475	1.931034	0.70936	0.842235	0.678415
7	…I do the work in my head and write the answer down. I don’t “show my work”.	2.448276	0.899015	0.948164	2.448276	1.041872	1.020721	1
8	…I show every step.	3.275862	1.135468	1.065583	3.413793	0.965517	0.982607	0.610353
9	…I describe how I solve the problem using words.	3	1.142857	1.069045	3.551724	0.970443	0.985111	0.045687
10	…I keep trying different methods or ways to get the answer	3.413793	1.32266	1.15007	3.551724	1.1133	1.055131	0.635989
11	There is only one way to solve a maths problem	1.655172	0.448276	0.669534	1.551724	0.470443	0.685889	0.563433
12	Students who have understood the maths taught to them will be able to solve a problem in less than 5 minutes	2.793103	0.884236	0.940338	2.310345	0.578818	0.760801	0.036109
13	If I am given a problem a bit different from an example in a book, I feel confident I could figure it out myself.	3.310345	1.221675	1.105294	3.448276	0.6133	0.783135	0.585902
14	When I get the answer to a problem, I look back and check if my answer makes sense.	3.827586	1.076355	1.037475	4.172414	0.576355	0.75918	0.154728
15	I have trouble getting started on a problem that is new to me.	3.482759	0.758621	0.870988	3.517241	0.758621	0.870988	0.88071
16	After I have solved a problem, I go back and see if I could have got the answer a different way.	2.931034	1.280788	1.131719	3.103448	1.310345	1.144703	0.566385
17	Reading a problem more than once is a waste of time.	1.827586	1.147783	1.071346	1.37931	0.243842	0.493804	0.047504

Appendix J: Coding the interview responses

An excerpt of an interview and how it was coded:

we were in groups and if we had different answers *we could explain them, like we could communicate.*

we could write out different ways to solve the answer.

if someone did balancing, the other person showed a different way of solving … on a graph or on a table

hard to get used to .. like all the buttons and everything else

we used graphs, we used tables and we also tried to explain how we did it.

say if somebody didn't understand how you got the answer, we would have to explain how we did it and why we did it.

yes because then i understand myself more how i did it.

formulas.

i think i learned how to like make formulas out of tables.

like the group members explained me and communicated well.

as a group say if someone did this, like people could say yeah ***that's right or that's not right****, ye can do it this way. it's just like consulting between everyone else and it's easier than doing with a teacher*

Scaffolding

Working with Others

Negatives

Different ways/methods

Reflect/ Try Again

Motivation

Learning something new

Communicate with words

Appendix K: Themes in interviews – percentage occurrences

Note: Not all interview transcripts are shown here, only examples from each theme. The word counts in the right hand columns represent the actual word counts. Also, some comments were themed more than once; for example; the quote "*using words helped to describe what I was doing and how other people can understood the problem better"* was themed as "communicate using words", "working with others" and "reflecting". Therefore the percentages do not add up to 100%.

Category	**Description**	**Phrases (Examples)**	**Word count**	**% (Total word count = 3212)**
Communicate using words	Where students mention using words to explain a problem to someone else or where someone else used words to explain to them.	*I used words to describe what I would do* *using words helped to describe what I was doing and how other people can understood the problem better* *communicate with others* *I tried to explain in words* *explaining it in words* *I'd say in words then do the math version and then do an example* *I would write down what I was doing in words* *easy to like communicate with everyone cas you can just like text them* *looked at the other people's message* *the other person could type back* *I find it easier to explain in words.*	408	13%
Scaffolding	Where students mention being helped by the teacher or other. Where they were given hints or initial steps to allow them to start or continue with a problem.	*It was slightly confusing what to do on the 4th problem but then like xxx gave me a brief understanding of the problem so I managed to solve the problem on my own* *As when you show someone else and then they kinda get it and then they can develop on the way they done it.* *for harder problems to be able to get formulas for different harder problems* *the teacher was there to help you as well* *Viewing each person's perspective like what they said and you can add on… add stuff to it ... to make it better* *I just asked someone else in my group would they help me ... they made it easy for me and I understood it then* *like we kind of tried it both ways and then we both understood* *I think X started a problem and I finished it*	231	7%
Working with others	Where students mention working with others to solve a problem.	*I just liked the way you didn't have to do it on your own* *I liked it when we were in groups... so we were viewing each person's perspective like what they said and you can add on... add stuff to it .. to make it better* *There was this one time I put up that I didn't understand what the question meant and everyone in the group helped me to understand it and I was able to solve it* *Viewing each other's perspective, whenever I saw ... whatever I didn't get I asked the question and then they'd help me see (?) to it* *em.. Yea so like we were doing a problem and they did it a different way and then they couldn't understand my way so I just explained to them, like we kind of tried it both ways and then we both understood*	1256	39%

		I think I was doing a formula and somebody else was doing a table but they didn't know how to like find the point of intersection and I just tried to help them *Everyone just kind of did different things and then you just like clicked them together how it all worked.*		
Different ways/ methods	Where students mention using different methods to solve a problem.	*Yea it was different cas you got to see different ways of doing stuff. you might do it one way and then somebody else does it another way and you might think that's a bit easier than doing it my way ok i might try that next time* *I was stuck on a question and one of my friends on the google doc they described how you did the solution using boxes and stuff and it helped me to understand the question and do the question using different tools like the boxes, the graphs and stuff.* *Viewing each other's perspective* *I think I was doing a formula and somebody else was doing a table but they didn't know how to like find the point of intersection and I just tried to help them* *I would write down what I was doing in words then do like tables or diagrams and then describe it again just to make it easier to solve* *Everyone just kind of did different things and then you just like clicked them together how it all worked.* *so like some people would do like the stairs or something, like boxes going up and then other people would do like a graph showing different numbers and you could link them together*	590	18%
Reflect and Try Again	Where students mention reflecting on work they have done and/or trying to solve something again.	*Say if somebody didn't understand how you got the answer, we would have to explain how we did it and why we did it….* *When there were certain questions that I didn't understand I just asked people in my group and then they helped me* *em.. Yea so like we were doing a problem and they did it a different way and then they couldn't understand my way so I just explained to them ... like we kind of tried it both ways and then we both understood* *I would write down what I was doing in words then do like tables or diagrams and then describe it again just to make it easier to solve* *If 2 people were on at the same time you could kinda like type in what you found hard and the other person could type back and then you could like look at them doing it ...so find out how they're doing it as well as you doing it if you're stuck* *On the google doc you can put a diagram and then underneath it you don't write anything and then other people in your group were trying out the question how you were doing it so it's kind of easier doing it in your group cas you have to explain it to other people*	752	23%
Motivation	Where students mention being motivated by the experience and/or why they may have liked it.	*It was fun because it was different than being in school* *…and also it was more fun cas we did it like on computers and I feel like we are all used to computers so it's more like fun and easy then in our copies in class.* *It was fun to go on every night and see what people had said and it was good to compare and see what other people had said* *I was aware unlike in my copy that people were gonna be looking at it and trying to just figure it out themselves but if you're doing it in your copy the only person you need to worry about figuring it out is your maths teacher and they would probably know what you're on about* *I think like IT is such a major part of our generation so using that and learning really helps us and like even like when you're at home like usually when you walk out of the maths class you work by yourself but I think it was nice being able to talk to people and even having like you at home and it just felt more like we were learning more in-depth from the class.* *I liked it.* *yea I liked it* *Because you gave us some eh like steps to drive us into the right direction*	667	21%

		It's just cas in your copy it's just you were as in the google doc its more people so you have to explain it to everyone so they know what you are doing *Yep it was very different you don't really do it in any other classes* *The diagrams... you could draw your own diagrams onto the computer... I thought that was really cool* *I think X started a problem and I finished it* *…and as well if 2 people were on at the same time you could kinda like type in what you found hard and the other person could type back and then you could like look at them doing it ..so find out how they're doing it as well as you doing it if you're stuck* *Cas on the google doc you can put a diagram and then underneath it you don't write anything and then other people in your group were trying out the question how you were doing it so it's kind of easier doing it in your group cas you have to explain it to other people*		
Negaties	Where students mention anything negative about the experience.	*Hard to get used to ... like all the buttons and everything else* *I felt like there wasn't enough times when people were on at the same time* *2 of the people in my group were out sick so there wasn't much interaction going on and when there was work going on it was more just working off each other instead of finding other ways of doing it.* *when you're at home not everyone was on at the same time so you had to keep checking on it to see if anyone answered you if had a comment.* *some people just copied your answers and they didn't put work into it so that kind of annoyed some people in the group* *I think sometimes it was difficult to ... there were some things you couldn't do as if you were writing things down with pen and paper you could .. I was finding it very hard to press the divide button cas i couldn't find it on the keyboard so.. yea I found that very difficult* *Handwriting entry was hard ... like you'd write something and then think that's not me (?)* *Maybe when you were on online you wanted somebody else to be online to help but they weren't on the same time as you so you just have to wait till they're on* *If you didn't have a computer you could use your phone and then you couldn't really do much things on your phone so it was a bit of a problem.* *It kind of lagged a bit.* *Online with everyone like you're on different times ...*	271	8%
Learning something new	Where students mention where they may have learned something new through working on the Google Doc.	*I think I learned how to like make formulas out of tables* *There was a question I had a problem with coming up with a formula, then ... eh... I saw that somebody solved it so I asked them how they do it so then I … eh... actually understood it and I knew how to do the formula then* *There was one question where a person in the group couldn't find a formula and then when I found it he was like that makes sense so I think I helped him that way, it was the part of a problem where he couldn't figure out a formula.* *There was a time when one of my friends couldn't come up with a formula for a… the... it was the ... growing squares I think... it was creating a formula and I just helped explain emm what it is and how you did it* *It helped me to do the formulas and getting...getting... for harder problems to be able to get formulas for different harder problems* *I was stuck on like how to make a problem... make the formula for it and I just asked someone else in my group would they help me ... they made it easy for me and I understood it then* *I think I was doing a formula and somebody else was doing a table but they didn't know how to like find the point of intersection and I just tried to help them*	258	8%

Appendix L: Open-ended survey question - responses

"Thinking again of the last time you worked on solving problems, can you describe what you think it means to "problem solve"…"

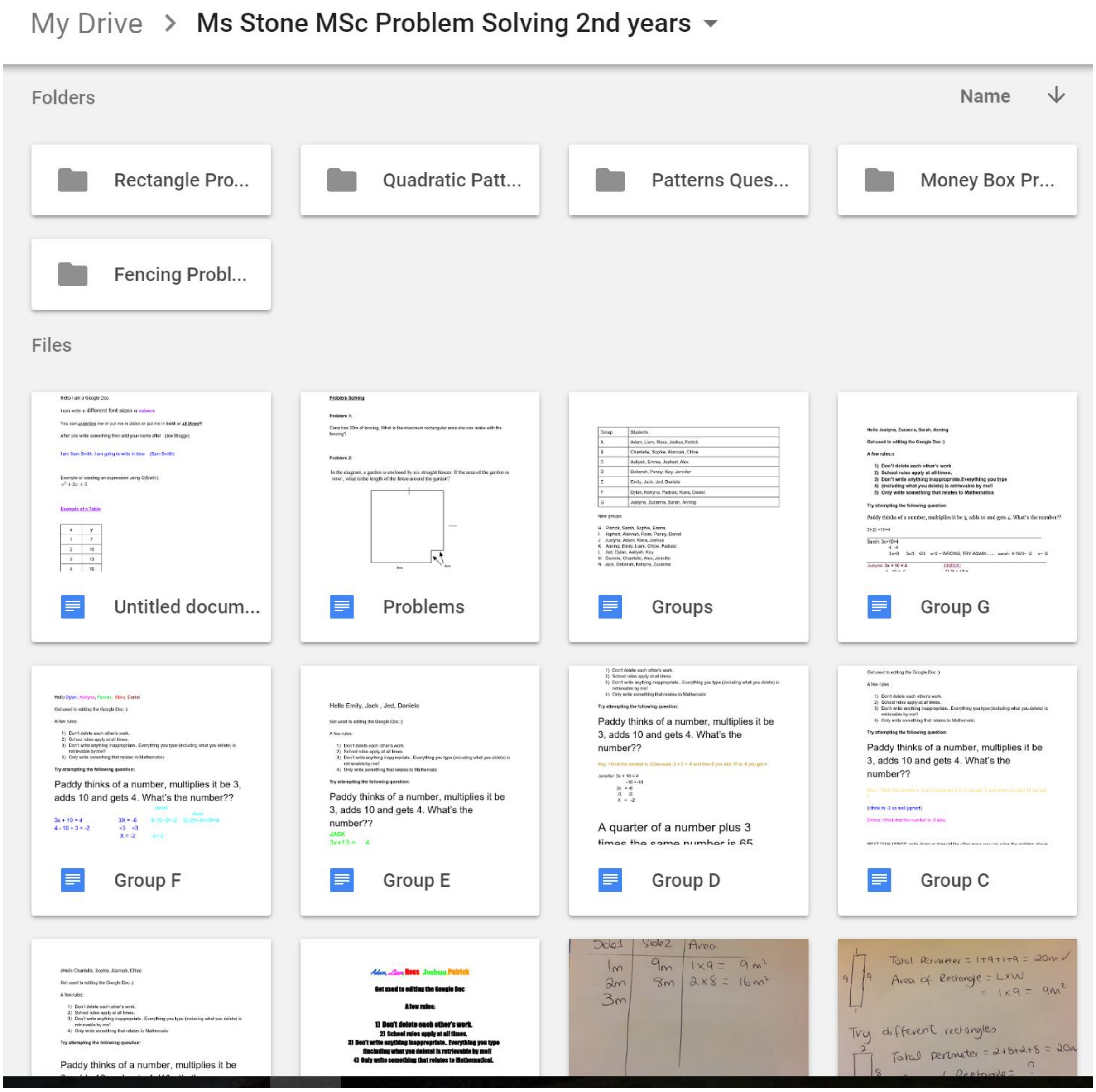
Pre Survey (24 responses)	Post Survey (26 responses)
I think it means to find an answer to a problem which is given to you in words.	**To find the answer to the problem. To try and figure out what the answer could be. It can be in both words and equation. There are different types of problem solving questions.**
It means to solve a question in as many ways as possible.	**To problem solve is to solve a problem. It means find a solution to a problem.**
To work out the answer to a problem and finding the possible ways to figure out a problem.	**I think problem solving means to answer a question without the question being direct.**
If you get a question but not answer, problem solving is finding the answer.	**Problem solving is a quicker way and how to explain an answer. Solve problems.**
I think it means you are trying to work out the answer.	**I think problem solving is trying to solve an equation or anything in life with or without maths. It is working out problems in life.**
If you get a problem but do not get an answer you can get the answer by problem solving.	**When you have a problem and you try work it out or fix it. It doesn't have to do with maths it can just be a problem that you have to resolve or fix.**
To use logic and your knowledge of maths to solve a problem.	**To problem solve is to resolve a problem and find a solution to the question.**
To problem solve is to solve problems, it can be in any subject.	**To find a solution to a problem given to you by either words or mathematical terms.**
I think it means to solve a problem with a method and explanation how.	**Mathematical sentence in words that you need to solve.**
To solve a problem is to work out an answer using the information given.	**I think it is not about finding the answer but how it is found and if it can be found many different ways like with graphs, algebra or a table.**
Solve a question such as x(3)=6, x=2 or something more difficult such as $\frac{x}{5}+\frac{2x}{3}=\frac{11}{13x}$	**I think problem solving is when you find the answer to a problem using many different methods. It can be solved using tables, graphs, expressions, equations, logic, quick thinking and overall common sense. And this is just to name a few, naturally, because there are many methods, there are lots of interesting ways to find an answer, and people might have different answers. It's basically a really interesting part of Maths that I enjoy.**
Problem solving means to figure out problems and get new ways to solve them.	**To "problem solve" means to understand and figure out what question is given to you. You can "problem solve" in different ways, by yourself, in groups etc. To "problem solve" is also like breaking down a problem.**
Problem solving means to answer a maths question that was asked mostly with words.	**After the 2 week course I still hate problem solving. I always find it way too difficult to complete. However I never give up. I still don't know what it means to problem solve and don't think I will use it in the future but maybe I will who knows? Even though I hate to problem solve but I enjoyed working with others and communicating with people I don't know too much.**
Problem solve means to find the problem and try to find a solution. There could be lots of different ways to do it.	**Problem solving is to work out an answer from words rather than numbers. There are multiple ways to interpret problem solving questions as it isn't written out all nicely for you like 2+5. Different people see a problem solving question a different way as problem solving questions generally use vague language and not much information is given unless you read between the lines.**
To problem solve means to find a solution to an unanswered question.	**To find out different ways to answer a word problem with solutions. Also finding different methods to solve a question with a group or alone.**
It means to be able to find an answer or solution to a question.	**Solving different problems and finding the answer to it using different methods of Maths.**
Reading a problem and trying to find a solution.	**It means to understand or figure out a problem. In a sense it means to discover or find out about something.**
	Problem solving is using the information provided to you to find a suitable way, understanding a question and answering it.
	I think it means to solve a problem using maths.
	To problem solve is to find answers, and to also find a way to always get the answers for other question like it.

I think to problem solve you are working out ways to fix things in the world. You are trying to calculate different things to solve the world. *I think it means to find a solution to the question given to use by using different types of methods and by showing all of your work.* *Problem solve to find a solution to that problem.* *To problem solve is solving problems with words.* *Find out the answer.* *To problem solve means to find an answer to a problem.* *A word problem is given to you and you try to solve it. It's very difficult to solve in my opinion. I honestly find it very difficult so I really don't know what it means.*	**I think to problem solve means to solve a problem in many different ways. Also, I think to problems solve means that you find different ways and answers to solve a problem.** **Problem solve means to break down a maths problem, and solve it by yourself, in pairs, or more than two people. In problem solving it is important to try and solve it in different ways and to be able to explain how and why you did some of the steps in solving the problem.** **I think it means to try many different methods, using your maths skills, to figure out a problem. I think you have to write down everything your doing so it's more clear. I also think problem solving is something takes time and you shouldn't rush.** **Problem solving is when you're given a problem, you should try work it out, show your work, check everything to make sure it's ok and then create a formula in case you have to find it for any day.** **When you find the answer to a problem.** **"Problem solve" means to work out something. If you are given something and you don't know the answer and you need to find the answer that is problem solving.**

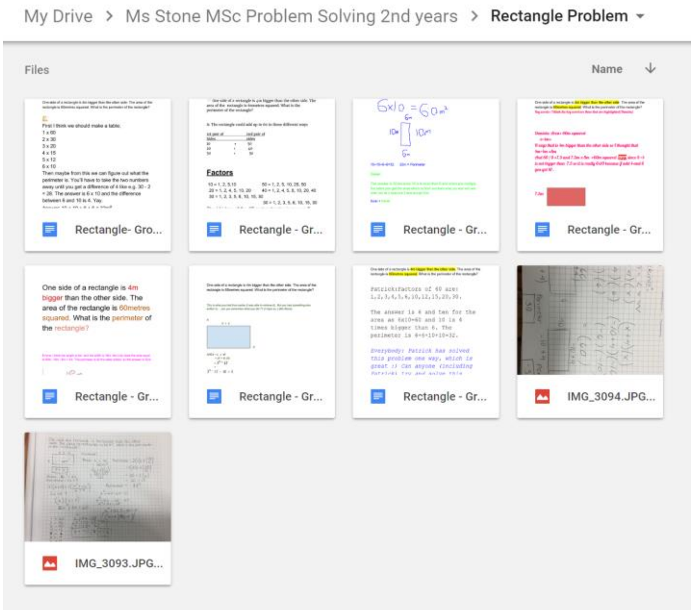
Theme	**Number of references**	
	Pre Survey	**Post Survey**
Finding an answer or one solution	15	8
Finding more than one answer or not about finding one answer only	0	4
Different ways/ methods	6	10
Words	4	7
Explaining what you're doing/ checking your answer	2	4
Non routine	2	6
Working with others	0	5
Breaking the problem down/ Problem solving involves different steps	0	3

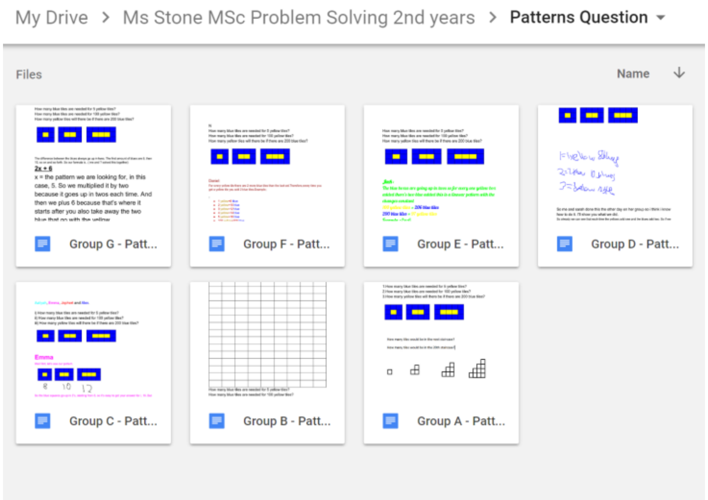
Appendix M: The Google Docs artefacts

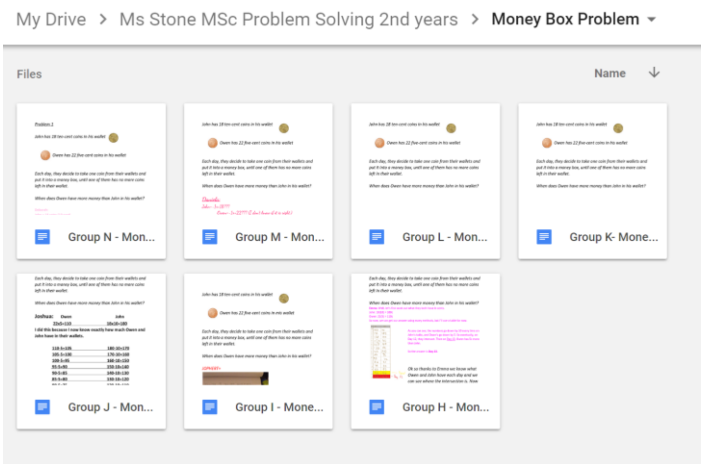
It is not possible to share the Google Docs links as the identities of the users would be revealed. This would compromise the ethics of the process. There were 35 Google Docs that students worked on altogether. These Google Docs files were sorted into folders; the names of the folders corresponded to the name of the problem; e.g. "Fencing problem". These folders can be seen below in the screenshot image of the Google Drive folder "Ms Stone MSc Problem Solving". The "test" documents are also shown below; where students were working in their groups; group A, group B etc as they became familiar with using the technology.



The images on the next page show what is inside 3 of the folders:


My Drive > Ms Stone MSc Problem Solving 2nd years > Rectangle Problem
Files
Name
Rectangle- Gro...
Rectangle - Gr...
Rectangle - Gr...
Rectangle - Gr...
Rectangle - Gr...
Rectangle - Gr...
Rectangle - Gr...
IMG_3094.JPG...
IMG_3093.JPG...


My Drive > Ms Stone MSc Problem Solving 2nd years > Patterns Question
Files
Name
Group G - Patt...
Group F - Patt...
Group E - Patt...
Group D - Patt...
Group C - Patt...
Group B - Patt...
Group A - Patt...


My Drive > Ms Stone MSc Problem Solving 2nd years > Money Box Problem
Files
Name
Group N - Mon...
Group M - Mon...
Group L - Mon...
Group K- Mone...
Group J - Mon...
Group I - Mone...
Group H - Mon...

In order to view the actual Google Docs work, the Google Docs had to be “published to web”. This created URL links. Publishing the Google Docs to web does not allow for comments to be seen. The only way the comments can be seen is by sharing the documents. By doing this, the identity of the participants would be revealed. This would compromise the ethics of the process. This is an unfortunate consequence of the process as it is the comments that show the scaffolding process. To address this, it was decided to take screenshots of some of the comments; these are shown on the next page.

A sample of the published URL links are listed below. In each link, the names of students were changed to capital letters, e.g. A, B, C, D or by a “?” mark. This was to protect the anonymity of the students.

Rectangle Problem

Group B:
https://docs.google.com/document/d/1Q8YVwTS7Q1U4irsn96X_dHWF9kjyIgfPM2jEM_Y3a5w/pub

Group D:
https://docs.google.com/document/d/1IowzglUBdcjx5io1XYs0vgs1hxqklKjwsHoFPOtTMX8/pub

Group G:
https://docs.google.com/document/d/1Z_mpbV7fkDbqCUUOXxwQzsOdikLI7KnP-dUpnrseak8/pub

Farmer Joe Fencing Problem

Group G:
https://docs.google.com/document/d/1SwD2TnyJxRLMXmIvA6uwFKzGKsFmNxXKPSZ3z1zlfo0/pub

Group E:

https://docs.google.com/document/d/1ZmSifEhv7PbFOmTM3jB0InVsWQ6CJE8MjjTMElALik8/pub

Patterns Problem

Group G: https://docs.google.com/document/d/12ysBqSyy273ByUcjz0SU-KcMIrFMPQ6jzAz3zxfHkLw/pub

Money Box Problem

Group H:
https://docs.google.com/document/d/1WceeDNjyfrV3y5_PFKz6FBi8ppHUwjssVfp4QQdnsA8/pub

Comments on Google Docs

Some examples of comments on Google Doc files.

Irene Stone 18:14 8 Dec
Is this [redacted]? Can you write in a different colour and then put your name beside your comment?
Did you read through what all the others have done?

[redacted] 20:36 8 Dec
Yeah sorry I'll change it now.

yeah I was reading threw them all but i don't understand perimeter and area a lot, then what we were doing in class confused me

Irene Stone 20:46 8 Dec
Perimeter is when you add up all the sides, imagine you were walking around the edge of the field.. how far would you walk.
Then area is how much space is in the field (i.e imagine it's covered in grass). so to get area you multiply the length by the width.
Well done on what you are doing here :)

[redacted] 20:47 8 Dec
Ohhhh okay I kind off get it now I'm getting the hang of it thanks miss

---

Irene Stone 19:53 6 Dec
This is amazing work girls. I'm very impressed well done!!!
Can you see what type of pattern these numbers are? (i.e. the Area numbers).

This is a big challenge: would you be able to GRAPH the area numbers against the length? (Put the length on the X axis)

[redacted] 20:00 6 Dec
I think what you did is right because the length of the outside of the rectangles add up to 20m

Irene Stone 21:09 6 Dec
yes.. correct but what would the AREA be?

[redacted] 18:18 7 Dec
i didn't thought that way! Cool:)

Reply...

Irene Stone 08:47 16 Dec
well done [redacted]

Is there a quicker way to get the answer?

Could you try algebra?

Irene Stone 14:54 13 Dec
great work girls. See if the 3 of you can come up with a "formula" for both of these patterns

---

[redacted] 15:05 13 Dec
i get the formula :)

[redacted] 15:16 13 Dec
yay!!!!

[redacted] 15:19 13 Dec
woohoo

---

formula:

$$\frac{x(x+1)}{2}$$

[redacted] can you explain how you got the formula?

Q3. The 100th Staircase:

$$\frac{100(100+1)}{2} = \frac{100\times101}{2} = \frac{10,100}{2} = 5,050$$

Q1. This is a quadratic pattern because the 2nd changes are constant. They are all going up in 1. It's not a linear pattern because the 1st changes are not constant.

[redacted] this is amazing! How did you figure this out??

Irene Stone 19:46 12 Dec
[redacted], this is very impressive. How did you work out that this is the "formula"?

[redacted] 14:55 13 Dec
Its hard to explain but I have the rough work on how I figured it out in my copy. I will take a picture of it and put it up here if that helps.

Irene Stone 16:35 13 Dec
Yes [redacted] please do