# Teaching Algebra Conceptually: The Process of Bringing Research to Practitioners

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Using a case study, the complex challenge of making mathematics education research accessible to secondary mathematics teachers was addressed with two questions. How can we design a method that will meet the challenge of making research usable for mathematics teachers? And what would this method be? To address this challenge we describe a process and product that emerged from using the stages of design-thinking. We invite fellow researchers to join us in the collective mission of bridging the gap between mathematics research and practice, furthermore, we seek to stimulate conversations about what counts as a research output.

## Introduction

Linking research and practice is fraught with challenges and has become a high profile topic in the education research community. For example, the theme of the American Educational Research Association (AERA)'s annual meeting is, "*Non Satis Scire* To Know is Not Enough" (2012). In essays commissioned prior to AERA's 2012 annual meeting, researchers highlight the gap between research and practice and suggest that we need to think about this problem in different ways. Carol Lee suggests that "there is significant evidence that the relationship of research to practice is mine-filled, inconsistent, and incomplete" (2012, p. 4) and we must expand our efforts "to understand complex cultural systems embedded in multi-tiered ecologies" (p. 7). In another essay, Cynthia Hudley and Barbara Wells express a need for "better translation of research to practice to research in an ongoing loop structured by the knowledge and experience of researchers and practitioners" (2012, p. 5).

In New Zealand's mathematics education community, there is considerable effort being made to link research and practice for mathematics teachers. Efforts include the publication of documents, internet accessible websites, and collaborative projects to promote research-informed practice (e.g., Education Counts, 2012; NZMaths, 2012; Teaching and Learning Research Initiative [TLRI], 2012a), however, there remains a gap between communicating these findings to teachers and teachers changing their practice to incorporate these effective teaching strategies. (Nuthall, 2004). In this paper we describe a process for bridging this gap and the results of our efforts. First we describe the research that we wanted to make accessible for mathematics teachers. Then we outline how we designed a method to make this research accessible. Lastly, we describe the significance and implications of the method we designed.

## The Research: Teaching Algebra Conceptually (TAC)

In 2010 and 2011, a research team consisting of five mathematics teachers from two Dunedin secondary schools and three researchers from the University of Otago studied the impact of teaching approaches used to help students acquire the algebraic knowledge and strategies. Preliminary findings have been reported by Linsell et al. (2011) and a brief interview with a teacher researcher, Anna Cox about her involvement in the project can be

In J. Dindyal, L. P. Cheng & S. F. Ng (Eds.), Mathematics education: Expanding horizons (Proceedings of the 35th annual conference of the Mathematics Education Research Group of Australasia). Singapore: MERGA.

found on the TLRI (2012b) website. The project produced a refined diagnostic assessment tool and a collection of teaching approaches that mathematics teachers in secondary schools can use to support their students' learning of algebra. Another project goal was to bring the research finding to other secondary mathematics teachers across New Zealand and this goal provides the focus of this paper.

The TAC research was an investigation of mathematics teaching practice; it was intended to feed back into practice and to inform the teaching of algebra. Considering previous attempts to bridge the gap between research and practice and the notion that "to know is not enough" (AERA, 2012), the team faced a complex challenge; how to develop an effective way to communicate our research findings to practitioners and improve teachers' practice in light of these findings.

## Designing a Solution to the Challenge

### *Part 1: Considering Effective Communication with Practitioners*

To find a solution to the first part of the challenge, "effectively communicate our research findings to practitioners", the teachers involved in the project were consulted. They reported finding the more theoretically-oriented research articles (i.e., Sfard, 1991) challenging to read because of the dense academic language and lack of explicit links to their practice, whereas they expressed a preference for the more practitioner-oriented papers (i.e., Barnes & Hamon, 2010) because of the more accessible language and vivid classroom examples described in those texts. The teachers also revealed that they had very little time to read any research literature at all because their days were filled with teaching duties. The team realised that any resource we created would have to be 'practice-oriented' and integrate seamlessly into teachers daily activities. The team suggested an on-line resource and the teachers on the team emphasised that it should be practical in its nature and linked to websites they visit to inform their planning and assessment practices (i.e. TKI, 2012b; NZMaths, 2012). The decision to create an on-line resource led us to consider design-thinking as process to create a useful product for bridging the gap between research and practice.

### *Part 2: Applying the Design-Thinking Process*

Fostering teachers to change their practice to incorporate research-informed teaching strategies is a complex challenge (Hudley & Wells, 2012; Lee, 2012; Nuthall, 2004), and the research team wanted to use a process that promoted expansive learning (Roth & Lee, 2007). The team had access to staff at the University of Otago with expertise in design-thinking; therefore, a partnership was formed between the two authors of this paper to bring knowledge of the research project together with the design-thinking process. The design-thinking process is a problem-solving protocol used by designers to solve complex challenges (Dorst, 2011). These challenges often do not have one right answer, but rather a collection of better and worse possibilities (Owen, 2007). In order to find better solutions, design-thinking uses a process of divergent and convergent thinking (Ambrose & Harris, 2010) and this structured approach often leads to both creative and functional solutions. The design-thinking process used in the TAC project is summarised in Figure 1.

*Identify the challenge.* The first stage of the design-thinking process required us to identify the overall vision and ultimate goal for the on-line resource. Through different exercises, we realized that the ultimate goal of the resource stretched beyond changing the

practice of teachers and extended to improving the mathematical understandings and achievement of students. By explicitly stating that our goal was student understanding and achievement, it became possible to see that our framework should not only include the "what" or content, and the "how" to teach algebra conceptually, but also "why" this endeavour is important. We decided to emphasise the value that the research findings can add to a teachers' practice.

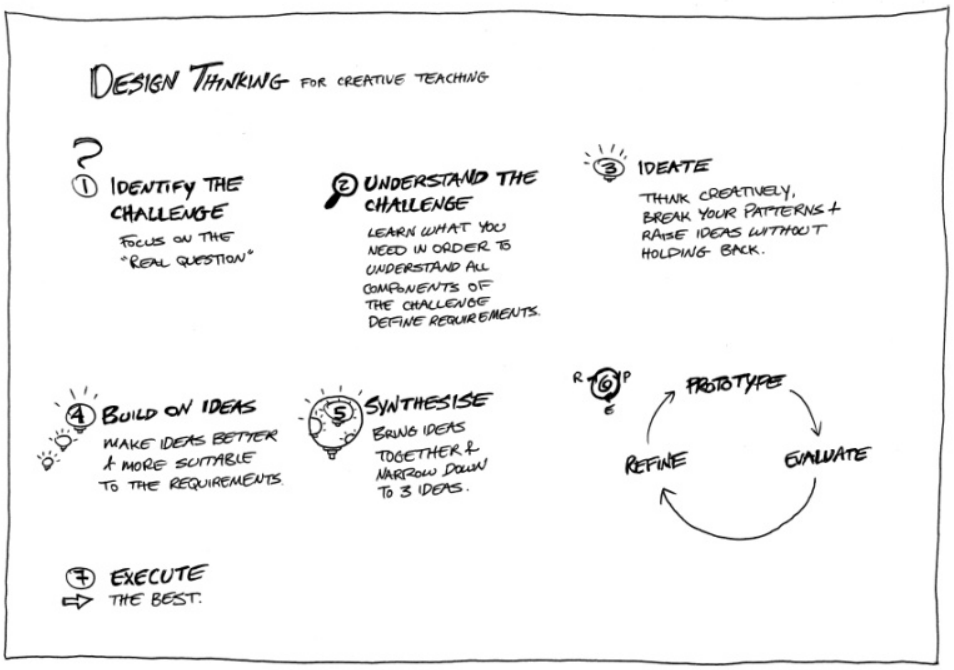


*Figure 1.* An early draft of the design-thinking process for teachers (Cohen, 2011).

*Understand the challenge.* The second stage of the process involved understanding the different aspects of the challenge and defining the parameters of the on-line resource. Among the different aspects considered were the audience for the on-line resource, the context in which the resource would be used, and what the related literature suggested as viable approaches. To generate the parameters of the resource, a thinking exercise was used to generate lists of what must/should/could be included in the solution. The "musts" are the absolute requirements, without them the solution would not work. The "shoulds" are the parameters that would make the solution better; the solution would work without them. The "coulds" are possibilities that come to mind as the "musts" and the "coulds" are generated. "Coulds" are considered optional extras; again the solution would work without them. An early version of the parameters produced in the second phase of design thinking is shown in Figure 2.

Looking at the literature, we wondered if theories about research dissemination could be used to inform the development of the on-line resource. *Research dissemination* refers to the process by which findings from research studies are moved from their site of origin, such as a research project, to be put into action by practitioners, in this case, secondary mathematics teachers who then incorporate novel ideas or strategies into their practice with the goal of enhancing the achievement of their students (Hutchinson & Huberman, 1994). A variety of knowledge-for-action models of research dissemination were consulted and we considered

how our choices would foreground different aspects involved in changing a teachers' practice of teaching mathematics (Ottoson, 2009). Research dissemination is a difficult process to theorise when we consider who might use the resource and for what purpose, how might the resource be interpreted by different users, and that information can flow in two directions (Nutley, Jung, & Walter, 2008).

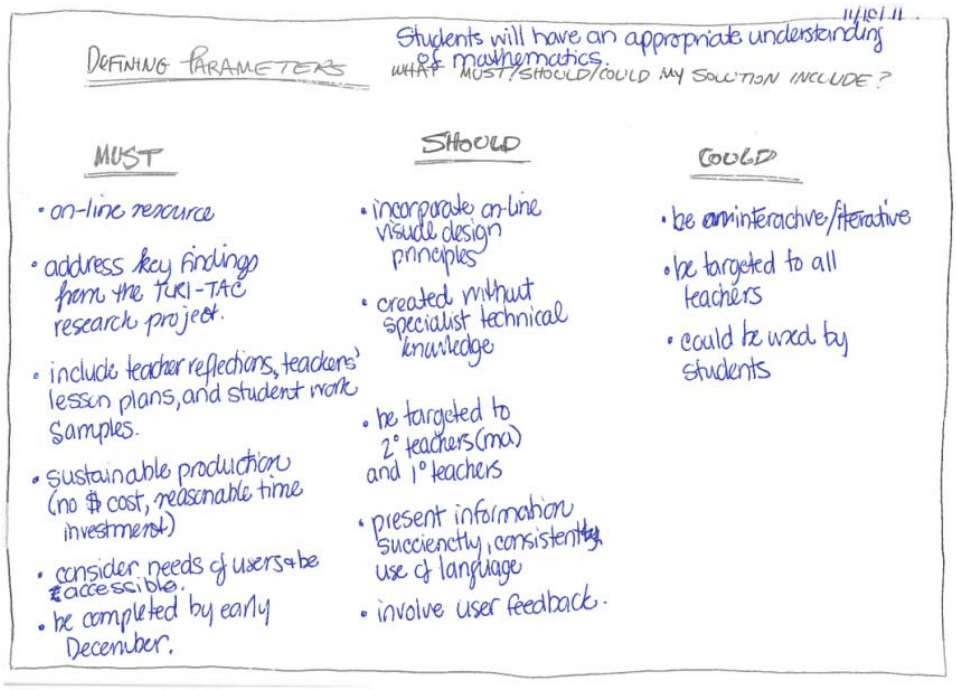


*Figure 2.* An early version of the parameters of the TAC output.

*Ideate and Build on Ideas.* After deepening our understanding of the research dissemination literature and developing the parameters for the resource, we moved to the third and fourth steps of the process: creating ideas for solutions and building on them in order to develop better solutions. Rather than choosing a possible solution and building upon it, we used creative thinking techniques and cycles of divergent exercises for idea generation and convergent exercises for idea refinement. An example of several ideas produced by this process is shown in Figure 3.

By this stage of the design thinking process, the initial picture we had in our minds for the resource faded away. Instead of a collection of static pages, the idea of a two-way interaction between all stakeholders began to take a central role in our possible solutions. The notion of a two-way interaction was reinforced by learning theories developed to support research-informed practice (Nutley, et al., 2008; Roth & Lee, 2007). The parameters for a solution were defined in a new light. Firstly, the resource had to be inviting and accessible to teachers who teach algebra in diverse settings to students in New Zealand. Secondly, the resource had to provide teachers with practical examples of how to teach algebra conceptually and engage them with the research findings at practical and intellectual levels. Thirdly, the resource had to allow for interaction and collaboration so that teachers could offer feedback from their experiences and suggest variations or new examples. The platform that seemed to best meet these parameters was a blog because it combines "static" and collaborative content with interactions mediated by commenting and discussion functions (Wordpress.com, 2012).

*Synthesise.* With the idea of creating a blog, we were able to move to the synthesis stage of the design-thinking process. Engaging with a number of synthesis exercises allowed us to generate a structure for the blog. The result of one such activity is shown in Figure 4.

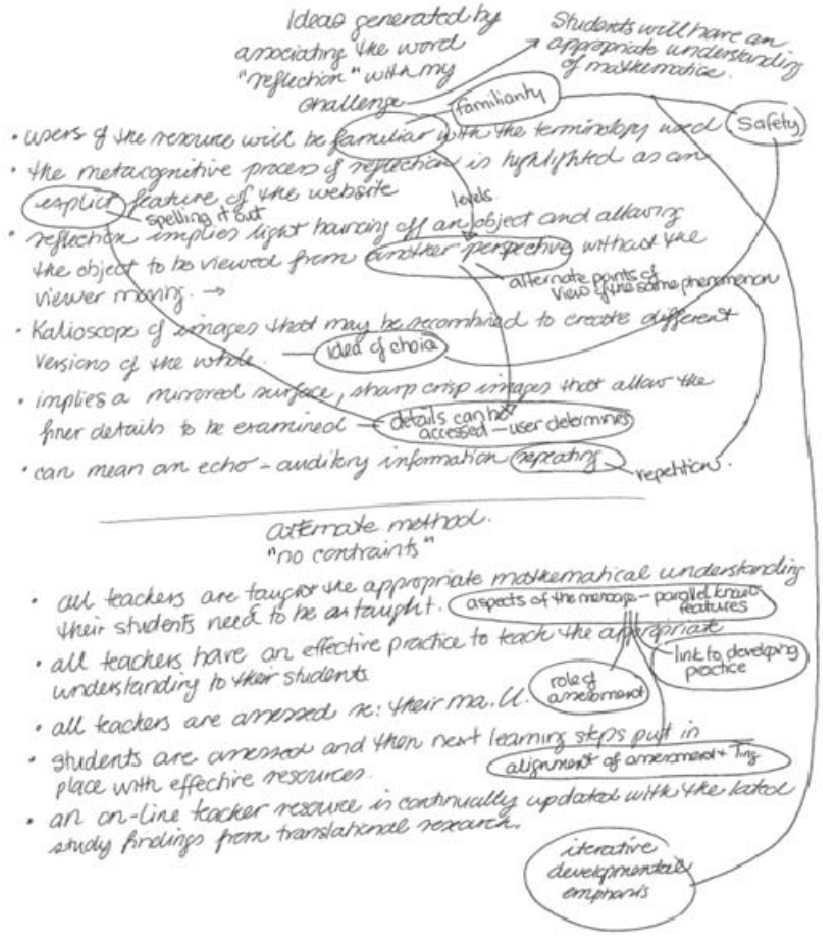


*Figure 3.* Ideas generated by two divergent thinking tools (shown as bullet points) and a subsequent convergent thinking tool (shown as interlinked circled words and phrases).

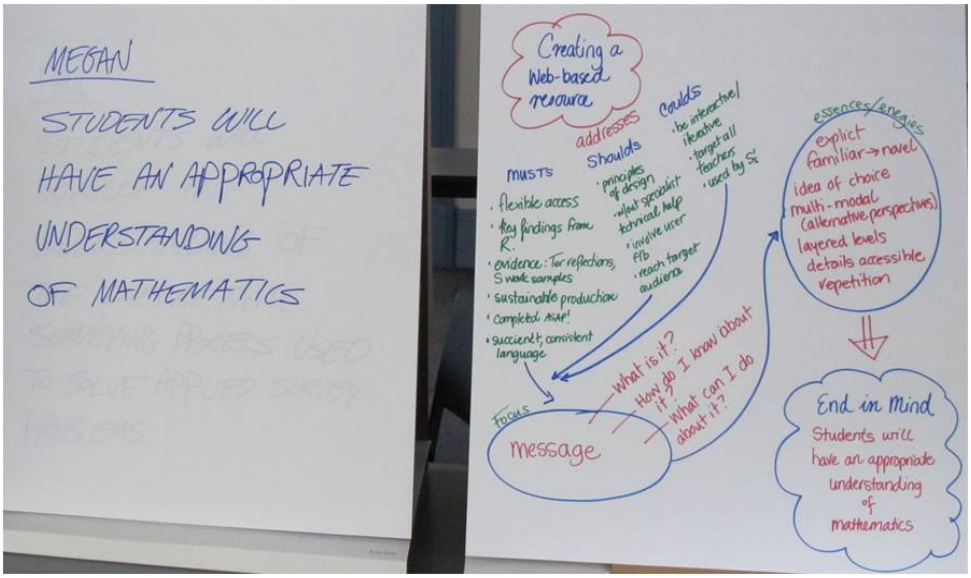


*Figure 4.* The structure of the blog emerging from the result of a synthesis activity.

*Prototype, Evaluate, Refine*. The interactive website is now in the prototype and pilot stage of construction. The structure of the interactive website is stable and the final details are being added before "going live" in June 2012. A single question phrased from a teachers' perspective greets users on the blog's homepage and asks, "How can we create engaging classroom lessons that help our students learn algebra?" (Linsell et al., 2012, Home: Teaching Algebra Conceptually). The phrasing was deliberate so the blog would be targeted at secondary mathematics teachers rather than researchers. The blog also contains images of research teachers and their students showing them working on classroom activities to emphasise the key findings of the TAC project in practical ways. The site itself is divided into different sections which are framed around four elements: "presenting challenges our students face as they learn algebra, showing how we've identified those challenges, offering some practical ways to help students learn algebra, and encouraging teachers to share challenges and suggest practical ways to help students learn algebra" (Linsell et al., 2012, Home: Teaching Algebra Conceptually).

The first section is structured to hook teachers' interest by identifying the key algebraic concepts students struggle to learn. The challenges students face when they learn algebra were identified by teachers involved in the TAC project and written in the words they said to or heard from their students. The second section is structured to engage teachers intellectually with the findings. It introduces the algebra framework, stresses the importance of diagnostic assessment, and offers classroom-tested assessment tools and techniques as downloadable materials. The third section is structured around practice; teachers participating in the TAC project provided practical activities to engage teachers with the findings. The practical activities include images, video clips, links, and downloadable materials for use with students in secondary mathematics classrooms. The fourth section emphasises the interactive nature of the blog and is designed to invite discussion, suggestions, critique and further contributions by those who use it. Comment functions have been embedded at the bottom of each webpage. The home page suggests a pathway so that first time users can experience the complete structure of the blog (see Figure 5).

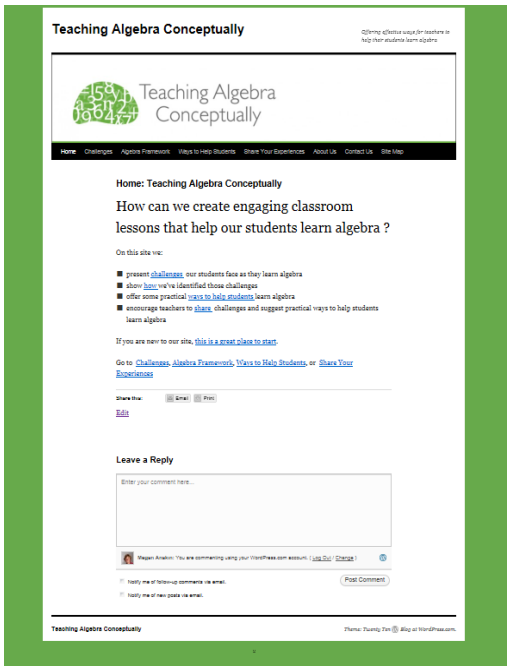


*Figure 5.* Teaching Algebra Conceptually home page (Linsell et al., 2012)

## Significance and Implications

In this paper, we used the TAC project as a case study to demonstrate how the complex challenge of making mathematics education research accessible to secondary mathematics teachers was addressed. We described a process and product that emerged from using the stages of design-thinking specifically targeted at fostering secondary mathematics teachers in New Zealand to use recent research about teaching algebra conceptually. The design thinking process helped us understand the challenge we faced, be clear about the parameters for a solution, and finally, to produce a set of possible solutions, from which we could choose the most suitable one. The method has resulted in an on-line resource in the form of a collaborative and interactive blog. The blog communicates the research findings, contains examples suggesting how to link the findings to practice, and provides opportunities for teachers to add comments and share their own relevant teaching experiences.

We feel that the design of a practitioner-oriented research-informed blog is an important contribution to the mathematics education community. We hope that the interactive options that are built into the blog, such as the commenting system and discussion board, will be used by teachers to continually demonstrate the link between the research findings and current practice. By choosing a blog as a dissemination medium we seek to complement traditional dissemination avenues available to us, which tend to be removed from the lived richness of the research project and experiences of mathematics teachers in secondary schools across New Zealand.

A significant question raised during the production of the TAC blog is the value that the research community may assign to this form of output, since a blog is typically considered a social rather than a scholarly medium. We seek to stimulate conversations about what counts as a research output as we explore alternate modes of interaction and collaboration between researchers, practitioners and learners. We hope that the process we described in this paper will encourage our fellow mathematics education researchers to join us in searching for creative ways to bridge the gap between research and practitioners.

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## References

Ambrose, G., & Harris, P. (2010). *Design Th!nking*. Lausanne, Switzerland.

American Educational Research Association. (2012, March 23). *Annual meeting 2012 details*. Retrieved from http://www.aera.net

Barnes, R., & Hamon, S. (2010). Proof & prealgebra. *Mathematics Teacher*, *103*(8), 597-602.

Cohen, A. (2011). Increasing Creativity in Teaching. In K. Shephard, T. Harland, & A. Cohen (Eds.), Proceedings *of the Spotlight on Teaching and Learning Colloquium*, (p. 16). Dunedin, New Zealand: HEDC, University of Otago.

Dorst, K. (2011) The core of 'design thinking' and its application. *Design Studies*, doi:10.1016/j.destud.2011.07.006

Education Counts. (2012). *BES (iterative best evidence synthesis) programme*. Retrieved from http://www.educationcounts.govt.nz

Hudley, C., & Wells, B. (2012). *The case for translational reserach in education*. Retrieved from http://www.aera.net/Portals/38/docs/Annual_Meeting/CynthiaHudley_AERA%20essay%20June%201_11.pdf

Hutchinson, J. R., & Huberman, M. (1994). Knowledge Dissemination and Use in Science and Mathematics Education: A Literature Review. *Journal of Science Education and Technology*, *3*(1), 27-47.

Lee, C. (2012). *Implications of cultural, complex ecological systems for what we think we know and how such knowledge can enhance teaching and learning.* Retrieved from http://www.aera.net/Portals/38/docs/Annual_Meeting/Lee_Essay_rmc.pdf

Linsell, C., Tozer, L., Anakin, M., Cox, A., Jones, R., McAuslan, E., Smith, D., Turner, G. (2011). *Teaching algebra conceptually: Preliminary findings.* Paper presented at the New Zealand Association for Research in Education.

Linsell, C., Tozer, L., Anakin, M., Cox, A., Jones, R., McAuslan, E., Smith, D., Turner, G. (2012, March 23). *Teaching algebra conceptually.* Retrieved from http://teachingalgebraconceptually.wordpress.com

Nutley, S., Jung, T., & Walter, I. (2008). The many forms of research-informed practice: a framework for mapping diversity. *Cambridge Journal of Education*, 38(1), 53-71.

Nuthall, G. (2004). Relating classroom learning to student learning: A critical analysis of why research has failed to bridge the theory-practice gap. *Harvard Educational Review, 74*(3), 273-306.

NZMaths (2012). *Annual research and evaluation reports and compendium papers.* Retrieved from http://www.nzmaths.co.nz

Ottoson, J. M. (2009). Knowledge-for-action theories in evaluation: Knowledge utilization, diffusion, implementation, transfer, and translation. *New Directions for Evaluation, 124*, 7-20.

Owen, C. (2007). Design Thinking: Notes on its Nature and Use. *Design Research Quarterly, 2*(1), 16-27.

Roth, W.-M., & Lee, Y.-J. (2007). "Vygotsky's neglected legacy": Cultural-historical activity theory. *Review of Educational Research, 77*(2), 186-232.

Sfard, A. (1991). On the dual nature of mathematical conceptions: Reflections on processes and objects as two sides of the same coin. *Educational Studies in Mathematics, 22*, 1-36.

Teaching and Learning Research Initiative. (2012a). *Home.* Retrieved from http://www.tlri.org.nz/

Teaching and Learning Research Initiative. (2012b). *TLRI research involvement gets teachers thinking.* Retrieved from http://www.tlri.org.nz/about-tlri/news-archive/tlri-research-involvement-gets-teachers-thinking

Te Kete Ipurangi. (2012b). *The New Zealand Curriculum on-line*. Retrieved from http://nzcurriculum.tki.org.nz

Wordpress.com. (2012). *Get a Free Blog Here*. Retrieved from http://wordpress.com/