



australasian journal of **TECHNOLOGY EDUCATION**

Editor: Professor Wendy Fox-Turnbull, University of Waikato, New Zealand

Editorial board:

Prof Stephanie Atkinson, Sunderland University, England, United Kingdom

Prof Marc de Vries, Delft University of Technology, Netherlands

Prof Jacques Ginestié, Aix-Marseille Université, France

Prof Mishack Gumbo, University of South Africa, South Africa

Prof Jonas Hallström, Linköping University, Sweden

Assoc Prof Kurt Seemann, Swinburne University of Technology Australia, Australia

Prof David Spendlove, University of Manchester, England, United Kingdom

Prof Scott Warner, Millersville University, United States

Assoc Prof P John Williams, University of Waikato, New Zealand

The Australasian Journal of Technology Education is a peer refereed journal and provides a forum for scholarly discussion on topics relating to technology education. Submissions are welcomed relating to the primary, secondary and higher education sectors, initial teacher education and continuous professional development, and general research about technology education. Contributions to the ongoing research debate are encouraged from any country. The expectation is that the Journal will publish articles at the leading edge of development of the subject area.

The Journal seeks to publish

- reports of research,
- articles based on action research by practitioners,
- literature reviews, and
- book reviews.

Publisher: The Technology, Environmental, Mathematics and Science (TEMS) Education Research Centre, which is part of the Division of Education, The University of Waikato, publishes the journal.

Contact details: The Editor, AJTE, wendy.fox-turnbull@waikato.ac.nz

Cover Design: Roger Joyce

This journal provides immediate open access to its content on the principle that making research freely available to the public supports a greater global exchange of knowledge.

ISSN: 2382-2007



Coding and mathematics: How did coding and collaboration facilitate thinking?

Nigel Calder and Kate Rhodes
The University of Waikato
New Zealand

Abstract

This paper reports on teachers' perceptions of their students' learning as part of a project examining the learning that took place when the students used *ScratchMaths* in their classroom programme. The project used design-based methodology, which incorporated video-recorded classroom excerpts, teacher interviews and teacher analysis and review of their practice. The teachers identified the students' problem solving, use of unplugged activities and collaborating using explicit mathematical and coding language as ways to facilitate thinking. They also recognised that their own practice evolved into a more facilitatory role, while their understanding of coding processes grew through learning beside, and through, their students.

Introduction

In 2020, the new Digital Technologies aspect of Technology in the New Zealand Curriculum (DTC) became a mandatory part of the New Zealand Curriculum (NZC) for NZ primary-school aged children (Ministry of Education, 2017). The technology education curriculum was altered to include coding as a part of computational thinking with the overall aim to develop core programming concepts. The technology learning area of NZC has three strands, technological practice, technological knowledge and the nature of technology, which underpin students' technology learning (Ministry of Education, 2007). The two new technological areas that became mandatory were computational thinking for digital technologies and designing and developing digital outcomes (Ministry of Education, 2017).

Computational thinking encompasses a broad range of skills and application of processes. For instance, problem composition and solving, the development of logical sequencing, abstract reasoning, and creating and debugging coding to solve practical problems. By using and synthesising a blend of these skills and processes, students have the opportunity to develop analytical and problem-solving practices (Zang & Biswas, 2019). As well as digital coding, computational thinking involves unplugged activities, using authentic contexts to develop precise, step-by-step instructions for non-digital activity, and the debugging of errors that emerged as the instructions are enacted (Ministry of Education, 2017).

However, research indicates that NZ teachers and schools will find adopting and implementing DTC challenging. This is because it encompasses proficiencies such as coding that are outside the expertise and experience of many NZ primary teachers' current understanding of digital technologies (Crow et al., 2019; ERO, 2019). Crow et al. (2019) indicated a gap in the availability of resources that are specifically situated in curriculum contexts, which would practically assist engagement with coding. They also advocated that teachers and schools develop unique implementations, suitable for their school context.

This project aims to support teacher learning in DTC through using, evaluating and modifying the University College London's (UCL) *ScratchMaths* project resources to enhance teachers' coding and computational thinking-based pedagogies and the associated student learning. It also aims to address the limited resources available for teaching coding in NZ. The intention was that the project will impact positively on learners' computational and mathematical thinking. The *ScratchMaths* project produced and evaluated resources that develop coding and computational thinking for primary-aged children for the UK curriculum and the UK school context, both of which are different to NZ. Hence, another aim is to evaluate and modify these UK resources so that they will be suitable and effective for the NZ context. This paper reports on a small two-year research project that examined teacher practice with coding through the use, evaluation and adaption of UCL's *ScratchMaths* resources, and the associated student learning. This paper reports on one aspect of the research, teachers' perceptions of student learning in the project.

Some NZ research has evaluated similar curriculum implementation at high-school level (M. Johnson et al., 2017) and international research has examined some aspects of DTC (Falkner et al., 2014; L. Johnson et al. 2014). However, none of this research specifically examined the affordances and implementation of DTC in the NZ primary-school context. There has been very little research on the use and influence of coding in NZ primary schools. Hence, the implementation of the DTC would benefit from being analysed by a collaborative partnership of teachers and researchers, as teachers consider how, when and where it will best be integrated into existing classroom practice.

Scratch is a free-to-use graphical programming environment that provides opportunities for creative problem-solving. It is a media-rich digital environment that utilises a building block command structure to manipulate graphic, audio and video aspects (Peppler & Kafai, 2006). Studies have shown its potential for developing computational and mathematical thinking in an integrated way, particularly in geometry and algebraic thinking (Calder, 2010, 2018). *ScratchMaths* aims to integrate computing and mathematical thinking effectively. Mathematics is used as a context and gives purpose for developing computational thinking, while the process of coding, particularly with *ScratchMaths*, is identified as being influential on the development of mathematical thinking (Benton et al., 2018) and the understanding of mathematical ideas such as algorithms and the 360-degree turn (Benton et al., 2017). However, the *ScratchMaths* resources, while well tested and effective resources, are structured, with small incremental steps to be undertaken by students individually, whereas in NZ learning is seen as a more collaborative, creative process (Ministry of Education, 2007). The project examined how the *ScratchMaths* resources might evolve to be more conducive for learning in the NZ context. For instance, the development of collaborative student-led projects in *Scratch* (e.g., Calder, 2018), which might also emerge with *ScratchMaths*, would be conducive to collaborative problem solving.

Collaborative problem solving

In the consideration of collaborative problem solving, collaborative learning is first discussed, together with its potential to improve learning and understanding. Ways that collaboration supports learning when digital technologies are used and the influence of both in facilitating problem solving are next briefly identified. The connection between collaborative problem solving, the use of digital technologies, thinking and student engagement is then considered. Collaborative learning occurs when

two or more students are engaged in an activity, interacting with each other and learning together (Dillenbourg, 1999). This perspective of learning in mathematics repositions learning more as participation in a social practice than as an acquisitional process (e.g., Cobb & Bowers, 1999; Sfard, 1998). Educational collaboration associated with problem solving has been connected to academic success. For example, Mercer and Sams (2006) showed how students collaborating while engaged in an online task indicated enhanced learning outcomes in mathematics. Other studies have illustrated how the collaborative use of digital technologies can support students in developing more flexible approaches to problem solving (Mercier & Higgins, 2013).

Mercer and Littleton's (2007) definition of collaborative learning goes beyond the sharing of ideas and task coordination to "reciprocity, mutuality and the continual (re)negotiation of meaning" (p. 23). Collaborative learning in line with this definition involves the utilisation of individual understandings and expertise, with the collaborative interaction influencing the thinking of at least one participant in the interaction, even if there is only a minor adaption, coupled with a repositioning of the learners' perspective and understanding. When students work collaboratively on a task there is frequently a coordinated approach to the sense making and the approach taken when engaging with the task. The joint coordination of a task enables students to communicate and negotiate in order to support decision-making (Zurita & Nussbaum, 2004), and, as such, they are involved in "a coordinated joint commitment to a shared goal" (Mercer & Littleton, 2007, p.23).

In general, digital technologies can enable opportunities to explore and organise data or mathematical phenomena in ways that might facilitate mathematical thinking, and to see patterns and trends more quickly in mathematical situations that might otherwise be too complex to do so. With coding, this offers potential to learn through the iterative process of engagement with the coding process and reflection on the output that the coding generates. The coder can try something and instantaneously identify the effects of the new coding, enabling them to generalise coding attributes and refine their approach. With a visual environment such as *Scratch*, where the coding and output screen sit side by side, these relationships are even more easily identified (Calder, 2018).

Computational thinking can be considered a collection of problem-solving skills that relate to principles of computer science (Curzon et al., 2009). At times, computer science involves creating applications to solve real-life problems using computational thinking, an analytical, computing approach for problem solving, modelling situations and designing systems (Wing, 2006). Abstraction, allied with logical thinking, innovation and creativity, is considered central to the constitution of computational thinking (Wing, 2006). These elements also resonate with mathematical thinking and problem solving in mathematics. *ScratchMaths* appeared to be an engaging and relatively easy to use space for problem solving.

Research has indicated that students become more engaged when using digital technologies, with enhanced mathematical learning also evident (e.g., Attard & Curry, 2012; Bray & Tangney, 2015; Pierce & Ball, 2009). In educational settings, engagement is recognised as more than the student being interested or participating positively, but as a complex, eclectic relationship between the student and classroom work (Fredricks et al., 2004). They perceived it as being multi-faceted and operating at cognitive, affective and behavioural levels. With regard to using mobile technologies in the process of learning mathematics, Attard (2018) concluded that they do improve student engagement at operative, cognitive and affective levels.

Additionally, studies have indicated that *Scratch* was an effective medium for encouraging communication and collaboration (e.g., Calder, 2010, 2018). This paper considers teachers' observations and perspectives of the students' problem solving, collaboration and engagement as they undertook coding tasks using *ScratchMaths*.

Research methodology and design

Using a design-based research methodology, with the teachers as co-researchers, the project examined teachers and their students' use of the *ScratchMaths* resources. This methodology, designed by and for educators, endeavours to enhance the impact and implementation of educational research into improved classroom practice (e.g., Anderson & Shattuck, 2012). It can illuminate the challenges of implementation, the processes involved and the associated pedagogical and administrative elements (Anderson & Shattuck, 2012). Design research necessarily comprises multiple cycles, which involve a number of different design and research activities. Nieveen and Folmer (2013) divide these activities into three distinct phases: the preliminary research phase, the prototyping or development phase, and the summative evaluation phase. These three phases, involving the teachers and including videoing of their classes, were implemented through iterations of use, reflection and modification of the resources and the associated pedagogy.

The project involved two teachers in one primary school in the first year, who were teaching collaboratively in an Innovative Learning Environment (ILE) with 52 students and two teachers co-teaching in a shared learning setting. ILE is the term given to “pods” of classes with shared open spaces and several teachers, with the intention to better facilitate flexibility with learning, student-centred pedagogies, integrated use of digital technologies and the development of 21st century skills. In the second year, the project included six teachers in four schools, including the two teachers from year one, and three new schools. This second year encompassed teachers and classes covering the junior, middle and senior levels (ages 6–12) of the primary school system. Design-based research principles and findings reflect the context and associated conditions in which they take place (Anderson & Shattuck, 2012), so providing space in the second year for new participants, in new conditions, to emerge from the first-year design iterations and dissemination recognised the importance of varying contexts and new participants to emerge through the design process. Most of the data presented in this paper were related to the two teachers involved in both years.

As well as the purposive sample spanning the range of primary-school levels, there is also variance in the nature and organisation of the schools. Included in the participant schools are single classroom situations, innovative learning environments (double and larger) and a range of student and teacher-centred learning environments. The teachers also have varying levels of teaching experience and expertise with digital technology. All the schools include a range of ethnicities. This range of contexts enhances the research, while the schools all being part of the same broader community also enhances the collaborative nature of the research, as some of these schools already work together collegially. The research design was also aligned with teacher and researcher co-inquiry whereby the university researchers and practising teachers work as co-researchers and co-learners (Hennessy, 2014). Allied to this was an emphasis on collaborative knowledge building. The research design was based on a transformational partnership arrangement that aims to generate new professional knowledge for both academic researchers and teachers (Groundwater-Smith et al., 2013).

The *ScratchMaths* resources identified by the teachers to use initially were from module one, a series of activities that included moving, turning and stamping a sprite, and creating circular rose patterns. The *ScratchMaths* resources and existing projects were used as starting points for the lessons, with the “unplugged” activities also incorporated into the sessions. Some of these class sessions and individual groups working on the tasks were video recorded. There were two iterations of the review and design process with videoing of classes each time, followed by co-researcher meetings to examine the classroom practice. One element of these meetings was the analysis of classroom video recordings. Discussions in the meetings were recorded, as were the teacher interviews. Analysis of the qualitative data from the interviews and observations will be through thematic analysis, with the research team identifying the initial themes, and the nodes for the nVivo analysis drawn from these themes. The data

from the interviews and observations went through six phases of thematic analysis adapted from Braun and Clarke (2006) (see Table 1).

Table 1. Phases of Thematic Analysis

Phase	Name	Description
1.	Familiarise with data	Transcribe, re-read the data, note down initial idea.
2.	Generate initial code	Code interesting features of the data (research team).
3.	Search for themes	Collate code into potential themes, gather all data relevant to each potential theme. Designate nodes for nVivo analysis. (research team).
4.	Review themes	Check if the themes work, in relation to the coded extracts and the entire data set, generate a thematic 'map' of the analysis.
5.	Define and name theme	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generate clear definitions and names for each theme (research team).
6.	Produce the report	Selection of vivid, compelling extract examples, analysis of selected extracts, relating back to the research question and literature, producing a report of the analysis (research team).

Adapted from Braun & Clarke (2006)

The research question related to this paper was: In what ways might the use of coding embedded within a mathematics curriculum context influence teacher practice and children's learning? This paper reports on one element of the research, teachers' perceptions of student learning.

This research question was addressed through iterations of teachers, and teachers and their students, engaging with the *ScratchMaths* and modified resources, followed by teacher reflection and re-modification of the materials by the research team. Episodes from the video-recorded observational data were analysed by the teacher researchers and the resources developed through this and their in-class experiences. Several new materials and pedagogical approaches were developed through this process. In particular, a collaborative problem-solving approach emerged as being effective and several of the resources were adapted to include NZ Māori motifs rather than purely mathematical ones.

The research project gained approval from the participating university's Division of Education ethics committee. This approval included having all participants being invited to participate, giving informed consent (and participant assent for the student participants), confidentiality (e.g., transcriber confidentiality agreements), anonymity (e.g., use of pseudonyms), mitigation of the potential influence of power differentials, and participants' right to withdraw. Validity was enhanced through the design of the project matching the purpose of the research questions, using a range of methods to generate the e data, the design of the analysis plan, the range of contexts and participants (given the place of context in design-based research), the frequency of design iterations, the collaborative teacher/researcher research team, and ongoing peer-review of the formative findings through the research team and their colleagues.

Results and Discussion

The paper reports on teachers' perceptions of how using *ScratchMaths* facilitated the learning process in four key areas: problem solving, collaboration, using unplugged activities and the teachers' pedagogical approach to teaching computational thinking. These themes emerged from the thematic analysis of the data. The teachers consistently commented on how using *ScratchMaths* fostered a problem-solving approach as students found solutions to unfamiliar problems in mathematical contexts through a variety of approaches. For example:

Annie: The children were problem solving, risk taking and learning from failure.

Marama: It's massive (problem solving). For some activities there are no instructions for how to get them from there to there, they just had to work it out.

The students use of *ScratchMaths* within the problem-solving process at times led to enhanced engagement. The process of debugging code was a particular aspect that some students became immersed in. This is a part of computational thinking that involves reviewing the code through trialling, and when it didn't produce the desired output, collaboratively problem-solving for possible solutions. It might also involve the output unexpectedly stopping or going into continuous loops. This is consistent with Mercier and Higgins' (2013) suggestion that the collaborative use of digital technologies can support students in developing more flexible approaches to problem solving. While the aspect of debugging was highlighted by the teachers at times, usually students were self-motivated with this process through wanting the script to be consistent with their expectations of the output. Marama commented on the student engagement consequential of the debugging process:

There would not be many things that would have them that focused on what they're doing so intensely. They would be doing debugging the whole time.

The teachers identified that the students not only appeared more cognitively engaged but that the process facilitated enjoyment and a sense of fun.

Marama: They're having a laugh as well you know ... it's not all serious ... even though it's heavy-duty problem solving. They're having fun, they're smiling and enjoying working with each other too.

Marama: Well, it's not quiet in our classroom, but it's not off task noise, it is completely on task noise. It's talking about what they are doing and it's excited talk.

Some of the problem solving involved mathematical thinking. The teachers also indicated that the mathematical thinking related to both concepts and processes arose more naturally within the *ScratchMaths* activities. For instance:

Annie: I think because maybe the opportunities with this program and what it's actually focused on with the angles and the measurement side and the negative numbers ... that's probably been more cemented than what it could have been if we had been teaching it in isolation.

While the teachers made the mathematical thinking explicit to the students by referring directly to the mathematics and using mathematical language, some of the mathematics thinking emerged through attempting to solve and accomplish the tasks, and the collaboration on the coding aspects. In this way, some of the thinking and learning was more incidental as the need arose, and outside the usual curriculum level for that age group.

Annie: It was just-in-time learning around the maths concepts. The use of angles was very in-depth. They used negative numbers, degree turns and always mathematical language.

For instance, negative numbers are not part of the curriculum for this particular age group. In a later discussion they identified some of the other mathematical thinking that occurred: relationships, exploring variations, precision with language, methodical thinking, and strategies for problem solving. Their spatial awareness, understanding of angles and positioning sense through the use of coordinates, were all engaged to varying degrees. There was also evidence of relational thinking as students made links between their input, the actions that occurred on screen and the effect of specific variations of size in coding procedures. They discussed how the students came to conclusions and gave explanations of what they had done.

The students interacted with each other in a relatively natural, seamless manner as they explored potential solutions and then collaborated to make their codes more efficient. As they worked to design the scripts and subsequently make the codes more economical, they shared ideas and potential solutions using language that included coding terminology, or was related to the mathematical or coding processes that they were discussing. The teachers noted this in the interviews. For instance, Annie indicated how the collaboration fostered their shared understanding of language, and hence from her perspective, their mathematical and computational thinking:

Annie: It supported students' learning through communicating with friends, problem solving, increasing their mathematical knowledge and mathematical and coding language, bringing that all into the norm of how we can talk about coding.

Annie: So then we can look at different ways of how children create a script to get to an end product and look at just simplifying the script.

Marama identified instances when students found efficient ways to code that were valued by other students, enhancing their mana (respect) within the class. Sometimes this was the students who were not usually perceived as being more capable in mathematics, so it readjusted those perceptions.

Marama: There are kids that are capable but then someone quietly just comes up with this really simple code to do something that someone else has taken a long time to do and they think they're good, so it's kind of just levelled everyone out.

This also indicated how using *ScratchMaths* facilitated collaboration. Collaborative learning can be perceived as going beyond the sharing of ideas and task coordination to the ongoing negotiation of perspectives and meanings (Mercer & Littleton, 2007). Collaborative learning in line with this definition was identified:

Annie: So it gives a context for social interaction to happen where they're learning to code and learning maths.

Marama: They're definitely getting extended in their maths but also that social side of it, working together collaboratively like that and not ... someone not (always) taking a lead role, they're all in different roles all the time, sometimes they're teachers, sometimes they're learners.

While the ongoing negotiation and evolving perspectives are indicated here, this also indicates that the students' roles were flexible and contingent on their personal, and the group's, understandings. Observational data also suggested that there was contestation of ideas during the collaborative work. This contestation indicates reciprocity and negotiation of meaning (Mercer & Littleton, 2007). This also involved the students in a coordinated approach to a common goal (Mercer & Littleton, 2007). Not only did the students interact through the ongoing dialogue as they problem solved to find solutions, students at times became leaders of learning.

Marama: One of the girls solved this thing that really no one else was managing to do, and she managed to crack it. Well the whole class was whoosh over there, so that's fantastic that she's having to explain it and off they go all excited.

The unplugged activities were valuable in terms of developing instructions or codes that designated actions, including movements. Some of these were repetitions, such as a series of dance moves and some were a single task. The children wrote code that another student would enact. Once they began to trial their script it often became clearer where the debugging was needed. A teacher from the second year of the project commented:

Katarina: When we introduced the repeat, I tried to do something unplugged with it, so we did the dance. They created the five-step dance on the grid and then they had to repeat it, and they had to work out how many times they needed to repeat it for one person to complete the grid or for two people etc. And so it's quite good for making sure that the instructions were accurate, so that everybody got the right steps at the same time to do it and to get there [the end of the grid] And then, if it didn't work ask why it didn't work, and then that introduced the debugging.

Another teacher indicated that the unplugged activities consolidated the moves needed and hence assisted with the coding process.

Annie: We wouldn't have thought to use the unplugged if it wasn't in the resource, but what we have found is that using the unplugged really helps to consolidate and cement in the children's minds how to create an object or whatever it is they've been asked to create. It's like the first step and then they can go and create that object on a device.

She also indicated the value of the unplugged activities as students oscillated between the coding in the app and a physical activity. This helped them with developing the code and with debugging it. She identified that the unplugged activity moved their thinking.

Annie: Also, in the teaching [of coding] when children are struggling, it's good to go back to that process so they physically do it using the unplugged ... I think what I'd do more is using unplugged more ... actually that's how I would adapt it [the *ScratchMaths* resources through the design-based process].

The fourth aspect reported here is the teachers' pedagogical approach, which varied from their usual approach when teaching mathematics.

Marama: I don't know that I need to know everything. Most of the time it's the kids that are the ones that solve things. They are learning off each other a lot more, they're going to each other a lot more, they're talking a lot more.

Annie: The classroom approach is to explore, but the mathematics and coding objectives are explicit. At times [we] start with *ScratchMaths* for say, angles. There is a purposeful context for the learning.

Marama: The teachers' role is facilitating learning—actively scaffolding processes and content.

The teachers were consistent in their belief that positive student learning had occurred and also regarding students' collaboration and engagement when problem solving. They articulated their personal learning regarding coding processes, while acknowledging that their role in the classroom had evolved.

Conclusion

Although findings are presented as four separate aspects, they were mutually-influential elements that the teachers perceived had contributed to student engagement and learning. The work with *ScratchMaths* simultaneously influenced teacher practice, moving them towards a more facilitatory approach and greater understanding of coding processes. The students' thinking and learning in coding were tied to their solving of both mathematical and coding problems, while the explicit language of both contributed to the communication of processes, concepts and solutions. These processes facilitated thinking. As well, students at times became leaders of the learning.

There was also conceptual understanding and thinking related to the Geometry and Measurement strand of the NZ curriculum, in particular, angles and spatial perception. However, the process the participants undertook more directly facilitated thinking through the creative problem-solving process it evoked and the development of logic and reasoning as they negotiated understanding and responded to various forms of feedback.

While the findings were limited by the size of the project and the particular context in which they were enacted, they nevertheless give insights into the ways learning in coding, including unplugged activities, might be enhanced through the *ScratchMaths* resources. The research is ongoing, with more schools and a broader range of classes and teachers now involved, but further research into a broader range of contexts and some assessment and analysis of students' computational thinking is anticipated and will give clearer, more comprehensive insights.

Affiliations

Nigel Calder
Associate Professor
The University of Waikato, New Zealand
nigel.calder@waikato.ac.nz

Kate Rhodes
Teaching Fellow
The University of Waikato, New Zealand
kate.rhodes@waikato.ac.nz

References

- Anderson, T. & Shattuck, J. (2012). Design-based research: A decade of progress in education research? *Educational Researcher*, 41(1), 16–25.
<https://doi.org/10.3102/0013189X11428813>
- Attard, C. (2018). Mobile technologies in the primary mathematics classroom: Engaging or not? In N. Calder, K. Larkin & N. Sinclair (Eds.). *Using mobile technologies in the teaching and learning of mathematics*. Springer. <https://doi.org/10.1007/978-3-319-90179-4>
- Attard, C., & Curry, C. (2012, July). *Exploring the use of iPads to engage young students with mathematics*. Paper presented at Mathematics education: Expanding horizons, (Proceedings of the 35th annual conference of the Mathematics Education Research Group of Australasia) Singapore.
- Benton, L., Hoyles, C., Kalas, I., & Noss, R. (2017). Bridging Primary Programming and Mathematics: Some Findings of Design Research in England. *Digital Experiences in Mathematics Education* (3), 115-138. <https://doi.org/10.1007/s40751-017-0028-x>

- Benton, L., Kalas, I., Saunders, P., Hoyles, C., & Noss, R. (2018). Beyond jam sandwiches and cups of tea: An exploration of primary pupils' algorithm-evaluation strategies. *Journal of Computer Assisted Learning*, 34, 590–601. <https://doi.org/10.1111/jcal.12266>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), 77-101.
- Calder, N.S. (2010). Using Scratch: An integrated problem-solving approach to mathematical thinking. *Australian Primary Mathematics Classroom*, 15(4), 9–14.
- Calder, N. S. (2018). Using Scratch to facilitate mathematical thinking. *Waikato Journal of Education*, 23(2), 43–58. <https://doi.org/10.15663/wje.v23i2.615>
- Bray, A., & Tangney, B. (2015). 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. <https://doi.org/10.1007/s13394-015-0158-7>
- Cobb, P., & Bowers, J. S. (1999). Cognitive and situated learning perspectives in theory and practice. *Educational Researcher*, 28(2), 4–15. <https://doi.org/10.3102/0013189X028002004>
- Crow, T., Luxton-Reilly, A., Wünsche B.C., & Denny, P. (2019). *Resources and support for the implementation of digital technologies in New Zealand schools*. ACM International Conference Proceeding Series. <https://doi.org/10.1145/3286960.3286969>
- Curzon, P., Black, J., Meagher, L. R., & McOwan, P. (2009). *cs4fn.org: Enthusing students about computer science*. In C. Hermann, T. Lauer, T. Ottmann, & M. Welte. (Eds). Proceedings of Informatics Education Europe IV, 73–80.
- Dillenbourg, P. (1999) *Collaborative learning: Cognitive and computational approaches*. *Advances in learning and instruction series*. Elsevier Science.
- Education Review Office. (2019) *It's early days for the new digital technologies curriculum content*.
- Falkner, K., Vivian, R., & Falkner, N. (2014). ACE '14. Proceedings of the Sixteenth Australasian Computing Education Conference 148(48), 3–12. Retrieved from <https://dl.acm.org/citation.cfm?id=2667491>
- Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, 74(1), 59–110. <https://doi.org/10.3102/00346543074001059>
- Groundwater-Smith, S., Mitchell, J., Mockler, N., Ponte, P., & Ronnerman, K. (2013). *Facilitating practitioner research*. Routledge. <https://doi.org/10.4324/9780203803172>
- Hennessy, S. (2014). *Bridging between research and practice: Supporting professional development through collaborative studies of classroom teaching with technology*. Sense. <https://doi.org/10.1007/978-94-6209-434-5>
- Johnson, L., Krueger, K., Adams Becker, S., & Cummins, M. (2014). *Horizon Report: 2014 K–12 Edition*. Horizon Report.
- Johnson, M., Maguire, J., & Wood, A. (2017). *Digital technologies in schools 2016–17*. Research New Zealand. Retrieved March 15th from www.researchnz.com
- Mercer, N., & Littleton, K. (2007) *Dialogue and the development of children's thinking: A sociocultural approach*. Routledge. <https://doi.org/10.4324/9780203946657>
- Mercer, N., & Sams., C. (2006). Teaching children how to use language to solve mathematics problems. *Language and Education*, 20(6), 507–528. <https://doi.org/10.2167/le678.0>
- Mercier, E., & Higgins, S. (2013) Collaborative learning with multi-touch technology: Developing adaptive expertise. *Learning and Instruction*, 25, 13–23. <https://doi.org/10.1016/j.learninstruc.2012.10.004>
- Ministry of Education (2007). *The New Zealand Curriculum*. Learning Media Ltd.
- Ministry of Education. (2017). *Technology in the New Zealand Curriculum 2017*. Retrieved from <https://nzcurriculum.tki.org.nz/The-New-Zealand-Curriculum/Technology/Learning-area-structure>
- Nieveen, N., & Folmer, E. (2013). Formative evaluation in educational design research. Educational design research. In T. Plomp & N. Nieveen (Eds.), *Educational design research* (pp. 152–169). Springer.
- Pierce, R., & Ball, L. (2009). Perceptions that may affect teachers' intention to use technology in secondary mathematics classes. *Educational Studies in Mathematics*, 71(3), 299–317.

- <https://doi.org/10.1007/s10649-008-9177-6>
- Peppler, A.P. & Kafai Y.B. (2006). *Creative codings: Personal, epistemological, and cultural connections to digital art production*. Proceedings of the 2006 International Conference of the Learning Sciences, Bloomington, IN.
- Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher*, 27(2), 4–13. <https://doi.org/10.3102/0013189X027002004>
- Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33–35. <https://doi.org/10.1145/1118178.1118215>
- Zang, N., & Biswas, G. (2019). Defining and assessing students' computational thinking in a learning by modeling environment. In S.-C. Kong & H. Abelson (Eds.), *Computational thinking education*. Springer. https://doi.org/10.1007/978-981-13-6528-7_12
- Zurita, G. & Nussbaum, M. (2004). Computer supported collaborative learning using wirelessly interconnected handheld computers. *Computers & Education*, 42, 289–314. <https://doi.org/10.1016/j.compedu.2003.08.005>