Introducing the Multi-faceted Teaching Experiment

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A mathematics classroom is comprised of many mathematicians with varying understanding of mathematics knowledge, including the teacher, students and sometimes researchers. To align with this conceptualisation of knowledge and understanding, the multi-faceted teaching experiment will be introduced as an approach to study all classroom participants' interactions with the shared knowledge of mathematics. Drawing on the experiences of a large curriculum project, it is claimed that, unlike a multi-tiered teaching experiment, the multi-faceted teaching experiment provides a research framework that allows for the study of mathematicians' building of knowledge in a classroom without privileging the experience of any one participant.

Introduction

This paper proposes a variant of design research (Cobb, Jackson, & Dunlap, 2016), which we refer to as the multi-faceted teaching experiment (MFTE). The proposition is based upon the authors' participation in the *Accelerating the Mathematics Learning of Low Socio-Economic Status Junior Secondary Students* (*XLR8)* project (Cooper, Nutchey & Grant, 2013). To support this proposition the paper firstly summarises a variety of literature which has informed the authors' understanding of design research. The aims of the XLR8 project are briefly introduced, leading into an overview of an epistemology that has influenced the project's implementation. The key activities of the project's implementation are summarised, which sets the scene for presenting a series of vignettes illustrating the nature of the project participants' interactions as they develop mathematical knowledge and understanding. The project's methodology is re-considered and the MFTE is proposed and discussed.

Design Research

A recent issue of ZDM Mathematics Education was dedicated to design research with a focus on learning processes. In the opening article, Prediger, Gravemeijer and Confrey (2015) provided a survey of literature in this field. They noted the variants of design research and their associated names, but reiterated the five common features of what Cobb et al (2003 p.9) referred to as a design experiment: 1. interventionist; 2. theory generative; 3. prospective and reflective; 4. iterative; and 5. ecologically valid and practice-oriented. Cobb et al. emphasised that design experiments "are conducted to develop theories, not merely to empirically 'tune what works'". This differentiates design research from action research, which has been described as less formal and "leading to the development and improvement of practice" and being "concerned with practical knowledge informing the moral disposition to act wisely, truly and justly" (Groundwater-Smith & Irwin, 2011 p.57). In their survey, Prediger et al. (2015) distinguished design research that focusses upon curriculum products and design principles from design research that focusses upon learning processes and local theories.

In mathematics, the term teaching experiment is often used to describe a class of design research whose primary purpose is to provide opportunities for "researchers to experience, firsthand, students' mathematical learning and reasoning" (Steffe & Thompson, 2000 p.267). In some cases, researchers act as teachers in one-one teaching experiments, whereas the multi-tiered teaching experiment (Lesh & Kelly, 2000) permits research of the students, teachers and researchers each as independent although related investigators in the mathematics classroom. Often, a multi-tiered teaching experiment is conducted in a classroom that uses mathematical modelling: the students investigate mathematical concepts and construct models; the teacher investigates students' behaviours as they construct and refine their mathematical models; and the researcher investigates and explains the teacher's and the students' collective behaviours. The teaching experiment is a type of hierarchical design research that can focus upon learning processes or curriculum innovations.

Aims and Theoretical Underpinnings of the XLR8 Project

The XLR8 project has aimed to develop theory and practice in relation to the acceleration of under-performing but high potential junior secondary students. Typically, students entered the program with mid-primary level (nominally Year 4) ability but had the potential, with the aid of a targeted intervention, to operate at an age-appropriate level. The underlying impetus for the project was to enable such students to access mathematics courses in their latter-years of secondary school, to further their study and to open up career prospects, and thereby improve their life chances. To achieve these aims and long-term outcomes the project is based upon three interrelated pillars: the structured sequencing of mathematical content which is believed to be imperative for acceleration; the use of a pedagogy grounded in the reality of students; and the provision of sustained support for the professional growth of teachers. The first pillar is important because knowledge is central to the MFTE.

The pillar of structured sequencing is based upon Piaget's (1977) reflective abstraction as an explanation for the way in which learners assimilate and accommodate experiences and so shape their conceptual schema. Building upon this and the three-world proposition of Popper (1978), Nutchey (2011) has proposed an alternative theoretical framework for considering and resolving the difference between the shared, improvable but often relatively static knowledge of a discipline, in particular mathematics, from the idiosyncratic and continually developing and refining understanding of the individual. In summary, this framework distinguishes: the World 1 actions of the individual (including actions upon physical objects and, in the case of mathematics, the manipulation of more abstract symbols); the World 3 knowledge that is shared and improved upon by the members of a community; and the World 2 understanding of the World 3 knowledge held by each member of the community and which has developed as a result of each member's unique experience and which mediates and shapes the member's World 1 actions. The three-world conceptualization of knowledge and understanding models the interactions among all participants in a learning environment, including how their interactions with one another shape their individual understanding of the shared knowledge. Applying this epistemology, the aim of classroom teaching and learning is for individuals to converge toward mutually compatible understandings of the shared knowledge. Metaphorically, this can be described as individuals sitting in a circle viewing a central object. Depending on their relative position to the object they will have a unique perspective. However, by discussing what they can see with one another, or by moving about the circle to a different location, they may construct a more complete and compatible understanding of the object. This three-world conceptual framework will form the basis for considering the XLR8 research activities and the proposition of the MFTE.

Project Implementation

The XLR8 project was conceptualised as a form of design research. Aligned to the three pillars, the intervention was in three parts: a suite of curriculum materials that carefully sequenced mathematical concepts across a two-year period in a way that was anticipated to support acceleration; use of a pedagogical framework to inform classroom activity that has previously shown to promote engagement; and professional learning activities to enable participating teachers to implement the intervention in the classroom. In many regards, this organization of the project was a form of multi-tiered teaching experiment: the researchers proposed an intervention and were to study its use (and make subsequent refinements); the teachers were to be engaged in understanding how their practices were influencing and being influenced by the students' actions; and the students were to participate in classroom learning activities designed to develop their structural understanding of mathematics.

The following short vignettes describe interactions among participants that have occurred across the three years of the project as the intervention has been trialled and refined. The first three vignettes describe the interactions that occurred earlier in the project and which are typical of those in a multi-tiered teaching experiment.

Researcher and Teacher. The researchers and the teachers met regularly in professional development sessions and in post-lesson reflective discussions. During these times the teachers were supported in their own development of pedagogical and mathematical knowledge which influenced their future selection of appropriate activities and resources.

Teacher and Student. The teacher provided activities in the classroom. The students responded in ways that displayed their (mis)conceptions. Based upon the students' response the teacher modified the activities. The success of these modifications in scaffolding students' development was moderated by the teacher's own pedagogical and mathematical knowledge.

Student and Student. Various classroom activities required students to work together and discuss their mathematical activity. These student discussions served to shape their understanding, either towards mutual compatibility or misconception. Sometimes, when the students were unable to resolve conceptual conflicts they referred to the teacher for aid.

Upon reflection, it has become apparent that over the course of the project the interactions between the participants in regard to the subject matter expanded to include the following.

Researcher and Researcher. During the first year of the project, the first and second authors regularly observed teacher and student participants. At the end of the year, it was apparent that a significant rewrite of the curriculum was required to better sequence and connect the content, since it seemed that the curriculum was addressing topics in a disjointed fashion. Throughout the project the first two authors discussed the intervention, but the curriculum rewrite resulted in more intense discussions as they refined their individual understanding of the knowledge (i.e., concepts, their connections and sequencing).

Researcher-as-Teacher and Student. In the latter iterations of the design research the role of the researcher shifted from classroom observer to interactive classroom participant. The researchers, especially the second author, interacted with students in a co-teaching capacity in whole-class, small group and individual situations. The nature of the researcher-as-teacher's interactions focused on eliciting and clarifying students' understanding of mathematics.

Researcher-as-Teacher and Teacher. The researcher-as-teacher's interactions with students lead into their conversation with the teacher, in which they discussed the students' developing understanding of the mathematical knowledge and how classroom pedagogy might be adapted to best suit the students' development of mutually compatible understanding. These conversations were less theory-oriented, however they provided a basis for the researcher to then reflect upon and build theory at a later date.

Teacher and Teacher. Throughout the project, teacher participants have had regular opportunities to engage in discussions with one another. Primarily these have focused on practical classroom issues, however as the teachers' individual understanding of the structure of mathematical knowledge has developed there have been more theoretical discussions.

Discussion, Proposition and Conclusion

Initially, the project's implementation of design research could be described as a multi-tiered teaching experiment. The researchers, based upon their experience and knowledge of the classroom environments typical of the target participants, designed an intervention to address the perceived problem. This was trialed in the classroom and the researchers observed the intervention's implementation and noted what worked well and what could be improved. During this initial time the researchers' focus was drawn to the more practical aspects of the intervention, in particular the resources and pedagogy used in the classroom. However, as time progressed the teachers became more confident in the pedagogy and the resources became more refined, enabling attention to shift towards detailed consideration of students' cognition, how they were developing or refining their understanding of the mathematical knowledge and how this was being supported by the teacher.

The researchers' shift in attention resulted in increased involvement in classroom activities, to the point of becoming active participants within classroom interactions and refinement of mathematical understanding. This authentic engagement also served to shape the researchers' own understanding of the mathematical knowledge that was being learnt by the students; it exposed views of the knowledge that the researchers were unaware of or connections between mathematical ideas that were previously unknown by the researchers. The interpretation and description of the way in which the students, teachers and researchers interacted in the classroom milieu have been influenced by the three-world conceptualization of knowledge, understanding and action. It is the claim of this paper that the multi-tiered teaching experiment, with its hierarchical nature, is an inadequate methodology to accurately describe the XLR8 project and that an alternative researcher methodology is required.

The MFTE is proposed as an alternative way to view classroom interactions. Instead of focussing upon the processes of learning, the proposed MFTE uses the three-world conceptualization to place mathematical knowledge – the richly connected set of mathematical ideas – at the centre of the methodology. The methodology is proposed as a way to authentically study how mathematical knowledge is experienced by every participant in the classroom milieu, including the researcher, as they develop individual understandings, how these understandings relate to action, and how learning can be influenced by interactions between individuals with respect to the shared knowledge.

The embedding of the researcher as an active participant in the research classroom using the proposed MFTE has the following benefits: researchers gained rich experience of student development of understanding through authentic engagement in their learning (i.e., not vicarious, but true first-hand experience); increased rapport between researcher and teacher, which contributed to richer on-the-spot professional learning support; and, informed the refinement of the intervention based upon genuine data related to students' learning. Methodologically, the proposition also allows for the same framework to study an intervention at both curriculum innovation and local learning theory levels.

The three-world conceptualization of knowledge and understanding places knowledge at the epicentre of learning, and has been adopted as the basis for proposing the MFTE. In the MFTE, each participant is treated as a mathematician who is developing their understanding of the shared mathematical knowledge, albeit at different levels of sophistication. It is claimed that this variation of design research is closely aligned to the way in which all participants in the XLR8 project interacted in the classroom and during professional learning.

References

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in education research. *Educational Researcher*, 32(1), 9–13.

Cobb, P., Jackson, K., & Dunlap, C. (2016). Design research: An analysis and critique. In L. D. English & D. Kirshner (Eds.), *Handbook of International Research in Mathematics Education (3rd ed.)* (pp. 481-503). New York, NY: Routledge.

Cooper, T., Nutchey, D., & Grant, E. (2013). *Accelerating the mathematics learning of low socio-economic status junior secondary students: An early report.* Paper presented at the 36th Annual Conference of the Mathematics Education Research Group of Australasia, Melbourne, Australia.

Groundwater-Smith, S., & Irwin, J. (2011). Action research in education and social work. In L. Markausite, P. Freebody & J. Irwin (Eds.), *Methodological Choice and Design* (pp. 57-68). Dordrecht: Springer.

Lesh, R., & Kelly, A. (2000). Multitiered Teaching Experiments. In A. Kelly & R. Lesh (Eds.), *Research Design in Mathematics and Science Education* (pp. 197-230). Hillsdale, NJ: Erlbaum.

Nutchey, D. (2011). *Towards a model for the description and analysis of mathematical knowledge and understanding* PhD. QUT, Brisbane, Australia.

Piaget, J. (1977). *The development of thought: Equilibration of cognitive structures*. New York: Viking.

Prediger, S., Gravemeijer, K., & Confrey, J. (2015). *Design research with a focus on learning processes: an overview on achievements and challenges.* ZDM Mathematics Education, 47(6), 877-891.

Steffe, L., & Thompson, P. (2000). Teaching experiment methodology: Underlying principles and essential elements. In R. Lesh & A. Kelly (Eds.), *Research Design in Mathematics and Science education* (pp. 267-307). Hillsdale, NJ: Erlbaum.

Acknowledgements

The research reported in this paper is supported by an Australian Research Council Linkage Grant (LP 120200591) awarded to Cooper, English, and Nutchey. Opinions expressed in this paper are those of the authors and not of the Council.