THE ROLE OF TEACHING DECISIONS IN CURRICULUM ALIGNMENT

Mike Thomas, Caroline Yoon

The University of Auckland

The classroom implementation of open-ended mathematics tasks, such as Model-Eliciting Activities (MEAs), can be challenging for teachers. This case study research considers a teacher, Adam, implementing a lesson intended to be an MEA on graphical antiderivative. We describe the lack of alignment of the written, intended and enacted curricula that occurred. An analysis of Adam's conflicting resources, orientations and goals, and how these influenced his pedagogical decision making, enables a description of the reasons for this misalignment. One possible implication for teacher professional development arising from the case study is presented.

INTRODUCTION AND LITERATURE

Although curriculum designers often provide teacher guides on how to implement certain tasks, research shows, and even assumes that "fidelity between written plans in a teacher's guide and classroom action is impossible" (Stein, Remillard, & Smith, 2007, p. 344). Teachers draw on their experiences, goals, knowledge and beliefs to interpret written curricula to form their own implementation plans, which are further transformed upon entering the classroom setting by the actions and thinking from students and the teacher. As a result, the curriculum experienced by the students in a classroom can differ considerably from what the teacher had intended to implement, and what the curriculum designers hoped would be implemented.

This misalignment between written, intended and enacted curricula is often greater for open-ended, non-routine tasks, than for conventional tasks such as procedural exercises (Stein et al., 2007). Open-ended tasks are more dependent on the responses from students and teachers, who may not be used to implementing them. We found great divergence in the ways teachers implemented a particular open-ended task, called a Model-Eliciting Activity (MEA) (Lesh, Hoover, Hole, Kelly, & Post, 2000), involving antidifferentiation in a tramping (hiking) context. In this paper, we report on one case study of a teacher, Adam, who planned to implement the Tramping MEA within a 50 minute lesson, but spent the whole lesson setting up the task, and ran out of time to launch the modelling problem itself. We investigate the research question: What caused the misalignment between Adam's enactment of the Tramping MEA as it was implemented, and his prior intended implementation of the MEA?

The literature suggests that the alignment of written, intended and enacted curricula is influenced by a number of factors, including: teachers' theories of teaching and learning (Biggs, 1996); deep levels of teacher pedagogical and content knowledge (Jaworski, 2012); and the need to deal with a wide range of incumbent educational

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priorities (Skott, 2001). We analyse how Adam's conflicting goals, orientations and resources (Schoenfeld, 2011) influenced the eventual misalignment between his enacted curriculum and the written and intended curricula regarding the MEA.

THEORETICAL FRAMEWORK

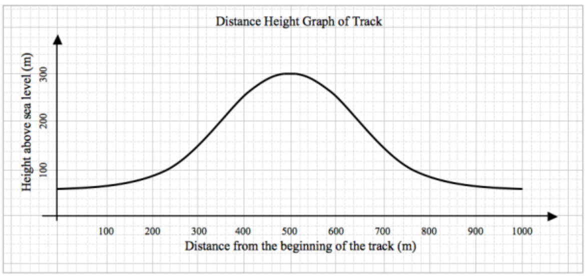
Stein, Remillard and Smith (2007) distinguish between the three broad meanings of curriculum. The *written curriculum* comprises the curriculum materials that are given to teachers, and which may include textbooks, curriculum documents, and specific mathematical tasks. The *intended (or planned) curriculum* is the teacher's interpretation of how they plan to implement the curriculum materials, and the *enacted curriculum* is what is actually implemented in the classroom. A number of factors can affect transitions between these three curricula, which may look quite different, despite being based on the same materials. These include: teacher beliefs, knowledge, orientations, and professional identity; students' capacities and willingness to engage; time, school and classroom culture, and characteristics of the curriculum (Stein, Remillard & Smith, 2007, p. 322). Many of these factors can be incorporated into Schoenfeld's (2011) theoretical framework for decision-making, which is based on *Resources, Orientations*, and *Goals* (ROGs). In this framework a teacher's orientations, which include beliefs, dispositions, attitudes and so forth, determine the goals established in any given situation. The teacher draws on and orchestrates available resources, such as mathematical knowledge for teaching (Ball, Hill & Bass, 2005) and physical artefacts to attain goals. In each lesson a teacher will have a number of competing goals in broad areas such as classroom management, student engagement and student learning outcomes. The manner in which she balances these competing goals and their dynamic relationships, and the extent to which pragmatism is allowed to intervene, will be determined by the relative strength of her orientations.

In this paper, we use Schoenfeld's ROG framework to analyse the misalignment between one teacher's enacted curriculum (the implementation of a particular MEA), his planned curriculum and the written curriculum.

THE TASK: THE TRAMPING MODEL-ELICITING ACTIVITY

The task in this study was a Model-Eliciting Activity, or MEA (Lesh, Hoover, Hole, Kelly & Post, 2000), set in the context of tramping (the term for hiking in New Zealand). MEAs are a class of tasks designed to provide students with authentic experiences of modelling a mathematically rich context. Any given MEA consists of three components: (1) A newspaper article, picture, or video for contextualising the problem, (2) A set of brief warm-up questions, and (3) The modelling problem itself. Correspondingly, the Tramping MEA begins with a newspaper article that describes shortcomings of difficulty ratings for tramping tracks (hiking trails) in New Zealand. After reading the newspaper article, students work on warm-up questions to familiarise themselves with the tramping context and mathematical tools that are necessary to start (but not necessarily successfully finish) the problem. For example, in the Tramping

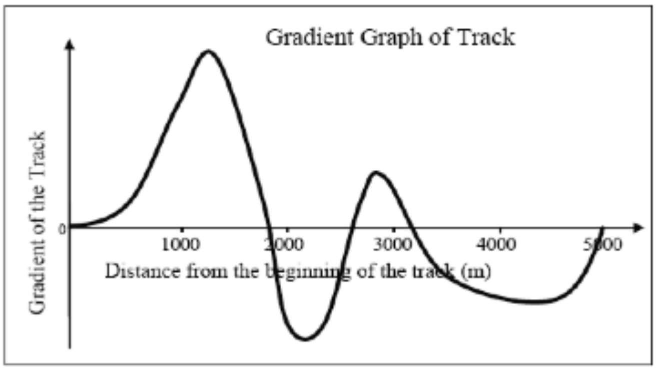
MEA, the warm-up questions ask students to plot the gradient graph (i.e., derivative) of a distance-height graph of a simple tramping track so that students can understand what a gradient graph and distance-height graph are (see Figure 1). However, it does not give them any tips on how to construct a distance-height graph from a given gradient graph, which is the focus of the actual modelling problem.



- How high is the highest part of the track?
- Find the gradient of the track at (a) 400m (b) 600m.
- What does the track look like when the gradient is zero?
- Where is the track steepest uphill? How can you tell?
- Plot the gradients of the track on the axes below and join them with a smooth curve.
- The graph you have drawn is a "gradient graph" of the tramping track. How is it related to the "distance-height graph of the track?

Figure 1: Excerpts from the set of warm-up questions in the Tramping MEA.

The heart of the MEA is the modelling problem itself, which is designed according to six principles (Lesh et al., 2000) to encourage students to express, test and revise their initial mathematical interpretations via multiple modelling cycles. The modelling problem component of the Tramping MEA (Figure 2) asks students to create a method for visualising the terrain of tramping tracks from a graph of the track's gradients—a task that is mathematically equivalent to finding the antiderivative of a function presented graphically. Students are also asked to generalise their method, and to communicate their method in writing.



The O'Neills need your help!

Design a method that the O'Neills can use to sketch a distance height graph of the original track (like the one given in the warm up question). You can assume that the track begins at sea level.

Write a letter to the O'Neills explaining your method, and use your method to describe what the tramping track will be like on the day. In particular, you must clearly show any summits and valleys in the track, uphill and downhill portions of the track, and the parts of the track where the slopes are steepest and easiest.

Most importantly, your method needs to work not only for this tramping track, but also for any other tramping track the O'Neills might consider.

Figure 2: The problem statement for the Tramping Problem MEA.

The modelling problem component of an MEA is intended to be challenging, and students are typically given at least 30 minutes to work on it in groups of three. In contrast, the newspaper article and warm-up components of the MEA are meant to take less than 15 minutes. The warm-up component ensures that students can *start* the modelling problem, but it does not guarantee immediate success; instead, students are likely to begin the modelling problem with primitive mathematical interpretations, and only develop more insightful mathematical models through expressing, testing and revising their ideas within their groups.

METHOD

As part of an international project, seven secondary school teachers implemented the same set of curriculum materials, consisting of four graphical antiderivative tasks, in their classrooms in New Zealand, Israel and Italy. Prior to this study, the tasks had only been implemented in semi-clinical environments using volunteers who worked in pairs, outside of class time, and in the presence of a researcher who was not their teacher. A goal of the international project was to see how teachers could transform and implement these tasks in authentic secondary school classroom environments.

The three New Zealand teachers in the project were instructed to adapt the materials as they saw fit to suit their particular classroom environment. For example, they were encouraged to change the context of the first task (the Tramping MEA) if they wished, and use videos or apps they thought might be useful. They were specifically told to reduce the warm-up questions to fit into 15 minutes (about one-third) of the whole lesson time, and were given concrete suggestions to achieve this, such as reducing the number of calculations students needed to perform, having students gesture rather than plot the gradients, or providing the gradient graph for students. The teachers were also reminded that at least 30 minutes of the lesson time should be allocated to having students working in groups on the modelling problem.

We report on Adam's implementation of the first task, the Tramping MEA. Adam was in his second year of secondary school teaching, and the class was a high ability year 12 (age 16-17) mathematics class in a low socioeconomic school in Auckland, New Zealand, with predominantly Maori and Pacific Island students. The topic of graphical antiderivatives was not part of the New Zealand curriculum (NCEA), although the topic of graphical derivatives was. After each lesson, Adam participated in audiotaped debriefing interviews, in which he described explained his teaching decisions in the lesson and planned for subsequent lessons. These four interviews were transcribed and coded according to Schoenfeld's ROG framework, and used to create descriptions of Adam's overall espoused ROG, and his specific ROGs for each lesson. Adam personally checked and corroborated the coding. The videos of the lessons were transcribed and annotated with photos and descriptions of the teacher's and students' actions, gestures, boardwork and written work.

RESULTS

In accordance with MEA epistemology (Lesh et al., 2000), the primary goal of the Tramping MEA is to have students express, test and revise their initially primitive interpretations of graphical antiderivatives, and develop more powerful ones through modelling cycles over the course of 30 minutes as they worked on the modelling problem. An ancillary goal is to ensure all students can start the modelling problem, by engaging them in a brief 15-minute warm-up beforehand. This means that the entire MEA can fit into one 50-minute lesson. Although Adam also intended to implement the entire Tramping MEA during his 50-minute lesson, he only managed to enact the warm-up questions and ran out of time to enact the modelling problem.

A description of the enacted curriculum

Table 1 describes a timeline of events in Adam's 50-minute lesson. Adam spends the first 4 minutes 50 seconds of his lesson in setting up the context for the MEA. He introduces two contexts—a tramping one, using pictures of mountains accompanied by music, and a rollercoaster one, describing going up and down a rollercoaster and the speed at different points. Next, Adam spends 9 minutes 10 seconds reading out loud the warm-up questions and reviewing the notion of a tangent and its relationship to the gradient at a point on a curve. He then has students work on the first set of warm-up questions in small groups for 15 minutes 37 seconds.

Time	Description
Start—4min 50s	Adam introduces tramping and roller coaster contexts (whole class)
—15min 0s	Adam reviews tangents of gradients (whole class)
—30min 37s	Students work on warm-up questions (group work)
—39min 52s	Adam discusses solutions to first warm-up questions (whole class)
—43min 33s	Students plot warm-up gradient graph (group work)
—50min 0s	Adam discusses gradient graph and features (whole class)
End	Adam tells students to do tramping modelling problem for homework

Table 1: A timeline description of Adam's implementation of the Tramping MEA.

At 30 minutes 37 seconds into the lesson, Adam leads a whole class discussion of possible solutions to the warm-up questions, asking for answers and writing them on the board. During this time, he invites a student to the board to demonstrate his answer to the question, "where is the track steepest uphill", which takes less than 2 minutes. After 9 minutes of teacher led discussion, Adam tells students to plot the gradient graph in the warm-up and proceeds to walk around the classroom observing and helping students. Once again, at 43 minutes and 33 seconds, he invites a student to draw his gradient graph on the whiteboard. The student does so in less than 2 minutes, and although the solution is reasonable Adam says, "Let me just polish this", and redraws the end points of the student's graph to show them trailing off towards the *x*-axis at the sides, then discusses the concept of asymptotes.

With less than 4 minutes of the lesson remaining, Adam decides to erase the graph he has drawn so far and says "I think I should draw it better." He redraws the graph so that the vertical correspondence of the points with the graph above aligns better with inflection points matching maximums and minimums, and so forth. This is followed by a detailed explanation of the relationship between critical points on each of the graphs, using the terms gradient, increase, maximum, point of inflection, steepest, positive, negative, zero, more negative and less negative. When the bell rings, signalling the end of the lesson, Adam realises that he hasn't yet implemented the modelling problem (Figure 2) so tells students to complete it at home.

ANALYSIS

Adam's failure to implement the modelling problem component of the MEA within the 50-minute lesson can be explained by his adherence to eight, sometimes conflicting, goals, which are summarised in Table 2.

G(A)	**To prepare students for success on future tasks**
G(B)	**To engage in student-centred learning as much as possible**
G(C)	**To complete the entire MEA (warm-up and modelling problem) within the lesson time**
G(D)	**To align the MEA with the national curriculum assessment (NCEA)**
O_1(D)	Belief that although NCEA should drive his teaching, the MEA helps develop understanding so he's happy to make an exception.
O_2(D)	Belief that the NCEA curriculum is the more important, "real curriculum".
O_3(D)	Concern about time spent doing something that is external to the curriculum.
R_1(D)	Knowledge that the content of the MEA lies outside the NCEA curriculum
G(E)	**To cover all the content in a structured and ordered manner**
O_1(E)	Fear of leaving anything out.
O_2(E)	Belief that he has to cover everything he is given.
G(F)	**To make sure the content is in a context meaningful for the students**
O_1(F)	Belief that the context must be meaningful for student understanding
O_2(F)	Belief that a second context will be needed in addition to tramping
R_1(F)	Knowledge that his students are familiar with roller-coasters
G(G)	**To make sure students understand all the content correctly**
O_1(G)	Belief that students need a firm foundation before working on a problem
O_2(G)	Belief that understanding develops over time
R_1(G)	Knowledge that it takes time to develop an understanding of new ideas
G(H)	**To use the MEA to revise previous content on graphical derivative**
O_1(H)	Belief that the modelling problem is too difficult for his students.
O_2(H)	Belief that the warm-up can cover concepts that students didn't "get" previously
R_1(H)	Prior knowledge from students' tests that many couldn't create gradient graphs.

Table 2: The eight goals (A-H) and their corresponding resources and orientations.

Goals A and B arise from Adam's four debriefing interviews, and are described in further detail together with their associated orientations and resources in Thomas and Yoon (2013). Goal C was evident from Adam's lesson plan, in which he stated his intent to complete the entire MEA (warm-up and modelling problem) within the 50-minute lesson. The remaining five goals (D, E, F, G and H) and their associated orientations and resources emerged from Adam's first debriefing interview. Figure 3 shows the core conflict between Adam's desire to implement the entire MEA (goal C) and his desire to prepare students for upcoming tasks (goal A). Goal A was supported from two core directions by a complex, connected network of seven goals. In the first instance, goals B, E and F supported Adam's desire to ensure students understood all the content (goal G) as they contribute to enhanced understanding through student-centred participation, a structured approach to learning provided by the teacher and a meaningful context. The second influence on his decision making came from Adam's desire to align the MEA with the NCEA curriculum (goal D), which also strongly supports his goal to prepare his students well for future tasks. Both of these directional influences on goal A were supported by goal H, to use the MEA for revision purposes, and the cluster of goals caused him to proceed slowly through the warm-up so students would be prepared for the modelling problem itself. This left his other goal, C, to complete the warm-up and modelling problem within the allotted lesson time alone, unsupported and eventually unachieved.

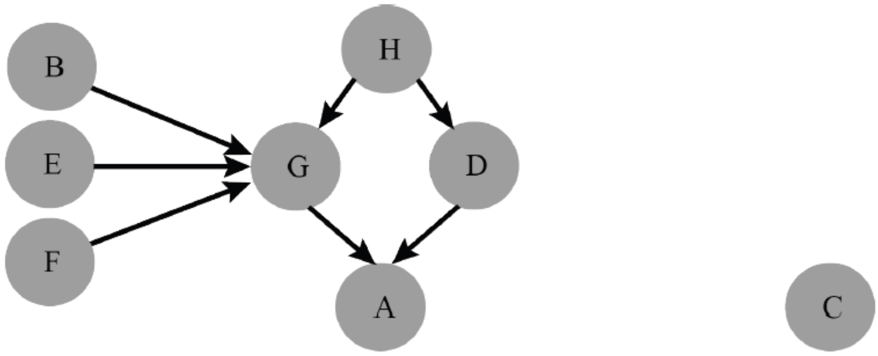


Figure 3: Connections between seven of the goals and the isolation of goal C.

DISCUSSION

The recent ICMI study on task design reminds us that issues surrounding task design and teacher classroom implementation of tasks are complex but crucial to address. The challenges facing the teacher are highlighted in implementation of MEAs due to the greater variability of approach and possible student interpretation. This makes higher demands of the teacher in order to align the written MEA curriculum with the enacted one. Our study supports Stein et al.'s (2007) model of curriculum phases and confirms that teacher orientations play a crucial role in curriculum alignment. A teacher like Adam wants students to feel that they are able to tackle tasks successfully (Smith, 2000) and hence he believes he needs to prepare them thoroughly. However, this desire brought Adam's ROG into conflict with the MEA writer's ROG. The latter includes the belief that the warm-up should enable students to start the modelling phase of the MEA but then they need to struggle with it in order to learn. Adam's goal was to remove the necessity for this struggle by thorough preparation, and hence his decisions led to the lack of alignment. Other contributing factors included Adam's inexperience with the content and approach of the MEA and his unfamiliarity with both the mathematical content and the approach to be employed. Hence, although the time available was sufficient to cover the material in the MEA he did not utilise it in the manner he intended. A second, strong influence on Adam was the constant context of student preparation for the national assessment of the curriculum (NCEA). His belief that he should align the MEA work with this if at all possible led to an inability to separate the lesson from the wider assessment context. Hence, he decided to include as a substantial part of the lesson a revision component that aligned the enacted curriculum with the NCEA one, but caused a misalignment with the MEA curriculum. Thus, out of concern for his students, he was unable to reduce the amount of taught content in the warm-up, and hence the time spent on it, in order to allow the students time to struggle with the modelling activity in the MEA.

This case study of Adam's teaching suggests that including a mechanism for post-implementation lesson discussion in professional development could assist teachers to become more aware of their orientations and goals and the influence these have on decision making and curriculum alignment. Professional development activity that promotes such awareness may be one way to encourage pedagogical change. We believe that outcomes like those presented here could also be used to assist with lesson implementation, to motivate teacher discussion, and hence could supplement a teacher guide.

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