Teaching Roles in Technology-Rich Teaching and Learning Environments (TRTLE's)

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This paper reports part of a study of secondary mathematics teachers in *Technology-Rich Teaching and Learning Environment* (TRTLE's). Three TRTLE's, two year 11 and one year nine class and their teachers were the focus of the study. Seven *Teaching Roles* were identified as teachers acted to allow students to perceive and enact affordances of TRTLE's appropriate to the learning of functions. Each role is important in allowing future independent perception and enactment of affordances by students.

Hoyles and Lagrange (2010), noted at the time of the 17th International Commission on Mathematical Instruction study (ICMI17), on digital technologies in mathematics teaching and learning, that whilst

> digital technologies were becoming ever more ubiquitous and their influence touching most, if not all, education systems… the challenges of the use of digital technologies and their potential for the improvement of mathematical teaching, learning and curriculum, remains a matter of debate. (p. 2)

Healy and Lagrange (2010, p. 288) in the same volume point out the challenges that arise for teachers (and students) as a result.

> Modifying teaching practices to include new tools is no mean feat for teachers. In addition to mastering the various possibilities for doing mathematics offered by different digital tools, they are also faced with the need to rethink a number of classroom management issues, adapt their teaching styles to include new forms of interactions–with students, between students and between students and mathematical ideas–take a more prominent role in designing learning activities for their students and confront a range of epistemic issues… It is not surprising then that the process of orchestrating technology-integrated mathematics learning is neither a spontaneous nor rapid one.

Tall, Smith, and Piez concur noting, "the teacher plays a significant role in how the technology is used in learning" (2008, p. 225) . Heid and Blume also emphasise the important role of the teacher, noting that the ways the technology is used in the TRTLE are "determined by the choices the teacher makes" (2008, p. 420). Passarelli and Kolb (2011) name four teaching roles facilitator, expert, evaluator, and coach, within the context of experiential learning as a framework for its implementation. To these authors, a teaching role "is a patterned set of behaviors that emerge in response to the learning environment, including students and the learning task demands" (p. 18).

Affordances and TRTLE's

This paper presents part of a larger study involving teachers and Years 9-11 students of mathematics. The study was situated in Victoria, where electronic technologies were increasingly expected as part of the teaching and learning of secondary mathematics, in particular functions. The aim of the study was to ascertain what *affordances* of *Technology-Rich Teaching and Learning Environments* (TRTLE's) were being considered by teachers and students in this topic. In this study, the term affordances builds on the work

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of Gibson (1966, 1979). It is used as a construct from the field of psychology to provide a better way to understand particular aspects of the mathematics classroom environment. For further discussion of the construct in general see Brown, Stillman, and Herbert (2004) and in a TRTLE, see Brown (2005). Affordances of a technology-rich teaching and learning environment are taken to be the offerings of such an environment for both facilitating and impeding learning. The affordance is the opportunity for interactivity between the user and the technology for some specific purpose. The affordance, *Function View-ability*, for example, is the affordances of a TRTLE allowing some or all of a function to be viewed. Affordance bearers (Scarantino, 2003) are the things in the environment that offer the affordance. On a graphing calculator the Graph key, for example, offers *Function View-ability* assuming a function has been entered and the current window settings of the screen include some or all of the function. To be useful, affordances must be perceived and enacted. This is the case for both teachers and students.

The general aim of the study was to ascertain what affordance of TRTLE's, specific to the teaching of functions in secondary mathematics classrooms were being considered. One research question from the study was: What affordances of technology-rich teaching and learning environments (TRTLE's) do teachers perceive as useful in developing students' understandings of functions and how do they act to allow students to perceive and enact these affordances? Sixteen affordances were identified as being perceived and/or promoted by the teachers in the TRTLE's that were the focus of analysis. Most affordances observed were manifest in a variety of ways for different purposes within the broad purpose of the particular affordance. For example, the affordance *Function View-ability* could be manifest via global function viewing or local function viewing. Most, but not all, affordances were observed in all TRTLE's. To answer the second part of the research question, several sub-questions were posed, one of which is the focus of this paper: What roles do teachers take on with respect to technology use by students in learning about functions in enacting these affordances? Roles describe the way a teacher behaves or acts in a particular circumstance. In contrast to the roles of Passarelli & Kolb (2011), these *Teaching Roles* focus at a more macro level and emerge from the analysis of the data rather than being theoretical roles. Findings related to teaching roles are the focus of this paper.

Methodology

The research process and methodology of the study reported follow a qualitative inquiry approach. This involved an instrumental case-based approach (Stake, 2005; Yin, 1994) where the initial units of analysis were Technology-Rich Teaching and Learning Environments. It also included embedded cases where the focus was the teachers themselves. The overarching intent was to develop a grounded theory (Strauss & Corbin, 1998) establishing how teachers and students managed the perception and enactment of affordances of TRTLE's for the teaching and learning of functions. "Grounded theory depends on methods that take the researcher into and close to the real-world so that the results and findings are grounded in the empirical world" (Patton, 2002, p. 125). This was the resaercher's intent for the study.

The particpants in the study reported here were involved in three focus TRTLE's from one school. The teachers, Peter and James (pseudonyms), both experienced teachers of secondary mathematics, were purposively selected (Stake, 2005) for the analysis as being able to provide rich data for the purposes of the study. They were experienced and confident users of technology in mathematics teaching. The focus TRTLE's were Peter and his Year 11 Mathematical Methods class (19 students, average age 16)(P11); James and his

Year 11 Mathematical Methods class (21 students, average age 16)(J11); and Peter and his Year 9 mathematics class (27 students, average age 14)(P9). Students and teachers in the TRTLE's had their own laptops and TI83/83Plus graphing calculators.

Data collection focused on TRTLE's during the teaching of functions, using functions, and using technology. Relevant data involved classroom observation (including several teacher pre-lesson and post-lesson reflections) during lesson sequences for the teaching of function, and in addition for P9 observation and implementation of teacher-designed tasks involving the application of functions. The lesson sequence observations were for a total of 29 hours in P11, 14 hours in J11, and 9 hours in P9. Observations of task implementations were for an additional 10 hours in P9.

Video and audio recording accompanied some of the lesson sequence observations and all of the lessons involving extended tasks. Video (and audio) recordings have been described as "what provide the richest possible data" (Peräkylä, 2005, p. 875), allowing researchers to "capture rich behaviour and complex interactions" (Powell, Francisco, & Maher, 2003, p. 407)—two key elements of technology-rich classroom environments.

All recordings of classroom activity, lesson sequences and extended task implementations were transcribed and entered into an NVivo data base (QSR, 2002) and a preliminary coding system developed. The first stage of data analysis involved open-coding (Strauss & Corbin, 1998) of the case record particularly with respect to teacher actions. A second analysis stage included scanning coded data, and re-analysing the case record to identify critical conditions regarding the phenomenon of interest (e.g., enactment of affordances). This involved axial coding (Strauss & Corbin, 1998, p. 127) whereby relationships amongst categories were discovered by answering questions such as: Who used the technology, how was the technology used, what was the purpose of the use, and what was the consequence of the use?

Findings

A primary issue for mathematics teachers in a teaching environment where technology is seamlessly integrated is the management of the enactment of affordances of TRTLE's by students as they attempt to solve a mathematics task, in this study a function task. The comparison and contrasting of data led to the identification of several grounded theory categories and sub-categories with respect to the *Development of Student Function Understanding in the TRTLEs*. Groups of categories were gradually organised into larger categories based on similarities and a set of abstract provisional categories forming the basis of a substantive theory were related.

A conceptual overview of initial category relationships is shown in Figure 1. The categories are *Function Situation in a TRTLE*, *Student Competence in Enacting Affordances*, *Student Strategic Decision Making*, and *Teaching Roles*. The interaction between these facilitates the *Development of Student Understanding of Function in a TRTLE*. *Student Competence in Enacting Affordances* plays a key role as students engage with a *Function Situation in a TRTLE*. *Student Competence in Enacting Affordances* influences *Student Strategic Decision Making* and triggers the *Teaching Roles* subsequently enacted by the teacher. It became evident from the analysis that the teachers undertook a variety of approaches (roles and tactics) both planned and in-the-moment, as they introduced particular affordances to students and prepared students to independently enact these affordances in the future. *Teacher Management of Student Enactment of Affordances* focused on student perception of affordances, scaffolded enactment of affordances, and ultimately independent enactment of affordances.

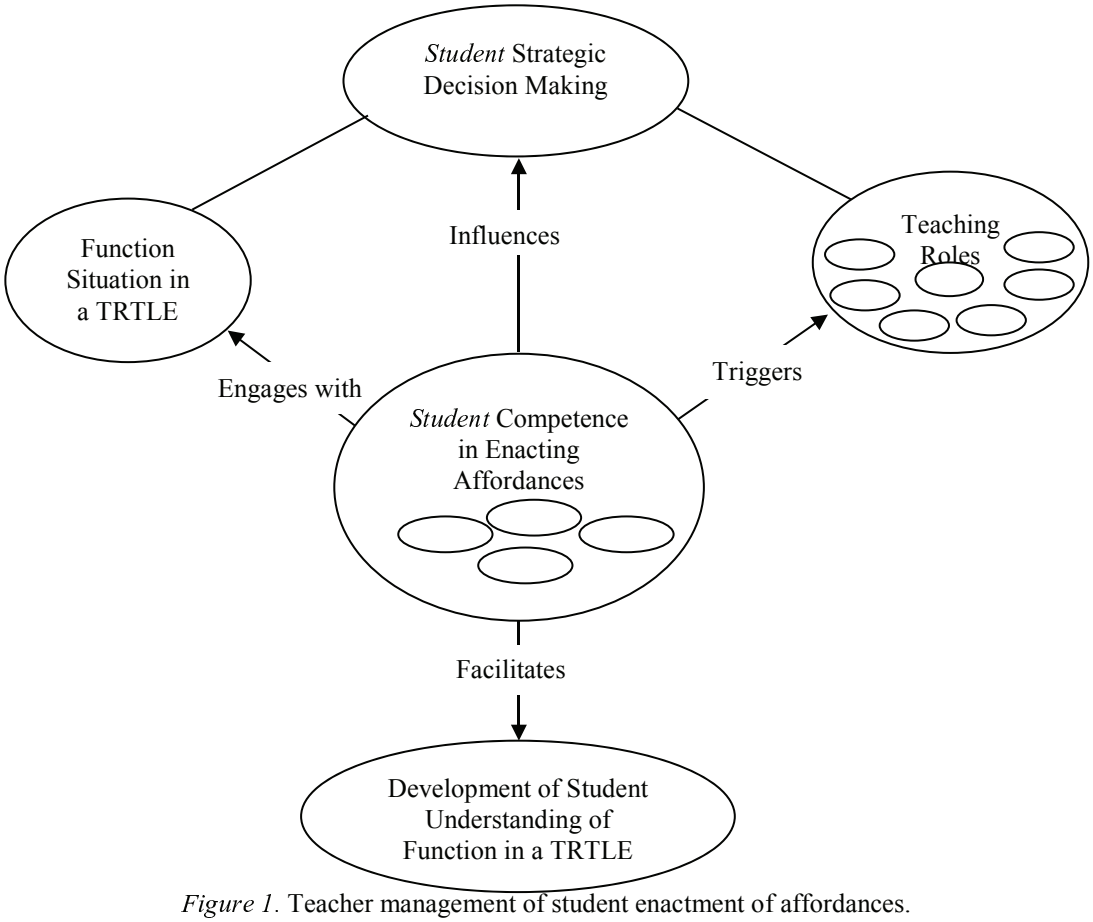

Figure 1. Teacher management of student enactment of affordances.

Teaching Roles

Student Competence in Enacting Affordances triggered different *Teaching Roles* subsequently enacted by the teacher. Furthermore, *Student Strategic Decision Making* occurring within the context of the particular function situation in a TRTLE influenced the particular *Teaching Roles* the teacher adopted in-the-moment. Each of these roles corresponds to a specific teaching intention. Roles varied from those diagnosing student misunderstandings to those intended to enable enactment of a particular affordance. The length of time a teacher took on a particular *Teaching Role* also varied. Seven roles were identified: *Scaffolder*, *Promoter* of affordance bearers or affordances, *Enabler*, *Evaluator*, *Follower*, *Interpreter*, and *Hermeneutic facilitator.* The last occurred when the teacher relinquished control and took on a co-investigator role genuinely allowing students to determine particular pathways in task-solving situations including the choice of affordances and affordance bearers.

The teaching intention of each role as gleaned from the practice of these teachers is presented in Table 1. The first three roles focus on classroom discussion (i.e., how the teacher listens to students, the questions asked by the teacher in these roles, and the teacher's response to student comments). These roles observed in the TRTLEs in this study are used from the work of Davis (1997) where his specific focus was on the manner in which a teacher listens to students, and how this impacts on teaching and learning practices. These three roles are ordered, from evaluator to interpreter to hermeneutic facilitator, by the responsibility for undertaking the intellectual work shifting from the teacher to the student. Teaching Roles also have different foci with respect to perception or

enactment of affordances. Some teaching roles focus more on perception or more on enactment whereas others focus relatively equally on both perception and enactment. In addition some are focussed on affordance bearers.

Table 1
Teaching Roles and Corresponding Teaching Intention in a TRTLE

Teaching Roles	Teaching Intention in a TRTLE
Evaluator	Diagnosing student misunderstandings and correcting these [tends to focus on enactment]
Interpreter	Eliciting student explanations of their understanding, clarifying through articulation, … [tends to focus on enactment]
Hermeneutic Facilitator	Emphasis on students explaining choices of affordances and/or affordance bearers [focus shifts to perception (and enactment)]
Enabler	Teacher providing tasks allowing students to perceive and enact affordances. Expectation is that the student does the perceiving. [Support is offered]
Follower	Following student pathways in task solving situations including choice of affordances and affordance bearers rather than teacher's original teaching intent
Promoter	Encouraging development of understanding of affordances or affordance bearers by suggesting or urging the use of a particular affordance or affordance bearer
Scaffolder	Provide scaffolds-with-fading (Pea, 2004) reducing complexity of task through channeling, the complexity of the task is reduced by teacher, for example, through specific (reducing degrees of freedom) or in a more restricted way by focusing student attention on relevant task features

As previously pointed out, roles describe the way a teacher behaves or acts in a particular circumstance. These roles are intimately related to management of students' enactment of affordances with the purpose that students will be able to do t his independently in the future. Given space restictions only three roles will be elaborated further. These are Teacher as Interpreter, Teacher as Enabler, and Teacher as Promoter. Across the three TRTLE's, at least five of the roles were evident in each TRTLE observed.

Teacher as Interpreter: In the *Interpreter* role, teachers focus on w hat students understand with respect to affordances of TRTLEs. There is an "increased opportunity for interaction, both between teacher and learner and among learners… such opportunities for presenting and re-presenting ideas [are] intended as a m eans of 'getting at what they're thinking'" (Davis, 1997, p. 363). Questions asked by the teacher tend to seek information, elaboration, and explanation. Students may be asked to provide detailed instructions re their enactment of affordances.

An example of this occurred during the extended task, *Shot on Goal,* in the Year 9 TRTLE. One student, Sandra, had taken a novel approach in determining the required shot angle. (This specifically related to her subsequent strategy use as well as the way in which she used the selected affordance bearers, that is, the List feature.) On discovering this, Peter asked her to explain. His questions indicate his genuine interest in understanding her

approach and the thinking behind it, rather than imposing his approach on her. His questions included:

> Peter: Where did that [25.67 on one triangle] come from? Where did you get that from? I am not saying it's wrong but where did that come from? I want to know how you got that. Can you walk me through the steps of how you got that?

At no point in their interaction, did Peter suggest that Sandra alter her approach to that of the rest of the class. He simply made sure he was able to interpret her thinking.

Teacher as Enabler: As *Enabler*, the teacher acts in ways that allow students to take the major responsibility for doing intellectual work. The tasks selected or designed by the teacher allow students to perceive and enact affordances. Help offered by the teacher may focus on activating mathematical and/or technical knowledge, or choosing appropriate options regarding affordances and/or affordance bearers. In addition, the actions of the teacher reflect the view that students are able to seriously attempt the task without teacher assistance. An example occurred when James posed the following investigation.

> Investigation 2: The basic quadratic polynomial is given by $y = ax^2 + bx + c$. If $b = 0$ the rule becomes: $y = ax^2 + c$. Use your calculator to investigate graphs with rules of this type. Write a brief report on graphs of this type commenting on maxima and minima, intercepts and shape. Use sketches to illustrate your report.

This task is predicated on the expectation that students perceive the relevant affordances, *Function View-ability*, and *Calculate-ability*, and enact these unaided. Their use is not stated or telegraphed in how the investigation is posed.

Teacher as Promoter: In the *Promoter* role, a teacher encourages the development of understanding (of an affordance or affordance bearer) by publicly suggesting or urging the use of a particular affordance or affordance bearer. This can be done by exclusively promoting a particular affordance or affordance bearer, or by promoting one at the expense of another. For example, James, drew students attention to *Function View-ability* when he suggested, 'Then what you do is to have a look at the graph?', or in another lesson, 'Can you show me a bit more of your graph by fixing your Window a bit?' On the other hand, in the following exchange Peter promotes the use of one affordance bearer over another.

> Peter: The x intercept. How do you find the x intercept on your calculator?
> Len: Use Intersect.
> Peter: You could …. But the best way is to go to CALC again, not Value, go to Zero.

Peter promotes the use of CALC Zero over CALC Value. Both could be used in the situation but the students are not given a reason for this promotion as he would have done in an *Enabler* role. On another occasion where two affordance bearers were suggested (one by Peter and the other by a student) Peter again promotes one over the other.

> Peter: How can I make sure I see it all?
> Hugh: Zoom [pause] Fit.
> Peter: Yes or Zoom Stat. Zoom Stat is better.

In this circumstance, Peter did not point out that that Hugh's suggestion was not appropriate, as the selection of Zoom Fit would have no impact on *Function View-ability*.

Discussion and Implications

Across the three TRTLE's, teachers took on seven *Teaching Roles* (Evaluator, Interpreter, Hermeneutic Facilitator, Enabler, Promoter, Scaffolder, Follower) with at least five evident in each TRTLE observed. These roles are intimately related to management of

students' enactment of affordances with the purpose that students will be able to do this independently in the future. Both focus teachers in this study adopted each role at times with the exception of *Follower*, although there were distinct differences in the emphasis given to each, and for Peter this varied according to the year level of the students in the TRTLE. James did not take up the *Follower* role with his Year 11 TRTLE. *Teaching Roles* tended to be deliberately planned, for example, in the development and use of particular tasks, but also in the intended lesson plan; however, they were also taken up in-the-moment of a lesson in response to student actions. Given that the teachers in this study were experienced, undertaking a specific *Teaching Role* may well have been an unconscious decision. The use of multiple roles by the teachers concurs with Passarelli and Kolb suggestion that "highly effective educators do not rely solely on one role" (2011, p. 19).

It is argued that teachers (in-service and pre-service) and hence future students would benefit from being aware of these findings. It is conjectured that teachers would benefit from knowing about *Teaching Roles.* No claim is being made that the *Teaching Roles* identified in this thesis are exhaustive. Teachers of secondary mathematics in contexts where mathematics technologies have become the norm and the classroom environment transformed into a TRTLE, are aware that the complexities of teaching and learning have increased many-fold. Hence, these teachers appreciate that not only is the potential for students to develop deeper understanding of mathematics possible, but also this will not occur by simply being in a TRTLE. The increased complexity, introduced by the presence of mathematically-able electronic technologies, requires changes in teaching to allow students to maximise the potential to benefit from these increased opportunities. This is not a simple task for teachers as new tools are taken up (Healy & Lagrange, 2010). Increasing knowledge of, and focus on, *Teaching Roles* could support many in-service teachers in achieving these goals.

Increasing awareness of teachers as to their own practice is likely to lead to an increased consideration by individuals of each of the *Teaching Roles*. This should result in more purposeful selection of an intended role in a given circumstance and perhaps greater awareness of whether the intended role became the implemented role as the lesson unfolded. In addition, teachers will be in a better position to reflect on the time spent employing each role. An over-emphasis on any one role, or an exclusion of a role, may be detrimental to the learning of some students.

Both affordances and affordance bearers need to be attended to by teachers as they manage student perception and enactment of affordance. For example, in determining if a model for platypus population predicted extinction, percieving and enacting *Function View-ability* would be advantageous. Awareness of the *affordance bearer* (Scarantino, 2003) (e.g., GRAPH and Window Settings), the object in the environment that offers this affordance, also must be present and it attended to. This necessitates the use of a range of Teaching Roles as was the case by teachers in this study. Increased knowledge of, and attention to, affordances, relevant affordance bearers, and the critical nature of Teaching Roles in the management of student perception and enactment of affordances would be beneficial to both teachers and their students.

As Gibson noted in his theory of affordances, "the learning of new meanings is an education of attention rather than an accrual of associations" (1966, pp. 320-321). Thus, perception, a special kind of noticing is essential in learning. This is echoed by Heid and Blume (2008) who call for reflection, both on actions and on the consequences of these. Appropriate mathematical and technological language is required for productive reflection

and this develops best where the articulation of mathematical reasoning in a TRTLE is expected. This is precisely what an increased awareness of Teaching Roles should allow to occur in TRTLE's as teachers become increasingly aware of the intention of their actions and the need to attend to the variety of roles if students are to successfully and independently perceive and enact affordances of TRTLE's.

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