Affordances of a Technology-Rich Teaching and Learning Environment

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A case study of how affordances are perceived and enacted by a teacher in a technology-rich teaching and learning environment (TRTLE) to maximise learning of functions by senior secondary students is reported. Three conditions were set up by the teacher to optimise students' current and future perceptions of affordances of TRTLE's. These were an exploratory approach, promotion of multiple solution strategies, and the engagement in mathematical discourse during the learning process.

In 1995, Crawford noted the slowness with which teachers "incorporate new technologies into their teaching practice. Nowhere is the reluctance to change from paper and pencil techniques more evident than in the case of mathematics" (p. 113). In explaining teachers' reluctance to use technology, Crawford turned to "new systemic approaches in psychology" (p. 113) being used by herself and others including Valsiner (1997) that suggest "people's beliefs and conceptions strongly shape their thinking, learning, and actions" (p. 113). These same approaches apply in instances where this reluctance is not the case, but instead teachers embrace the use of technology and are teaching within a *technology-rich teaching and learning environment* (TRTLE) they have established.

At ICME10, Kieren (2004) suggested ideas from other fields allow the emergence of new understandings of mathematics education as research occurs through different transformations of ideas from another field. Furthermore, a conversation based on selection and transformation of these ideas provides "new tools for languaging (distinction making) and new tools for portraying" (p. 4) within mathematics education research. Following Kieren's suggestion, the theoretical underpinnings of the study, which is the subject of this paper, draw on the notion of *affordances* (Gibson, 1966) from perceptual psychology and *zone theory* from developmental psychology (Valsiner, 1997; Vygotsky, 1934/1962).

Affordances of a TRTLE are the offerings of such an environment for both facilitating and impeding learning. For teachers and students to take up these affordances, both must "learn to perceive a perceivable affordance, that is, learn to become attuned to" (Scarantino, 2003, p. 954) what specifies it, but how is this possible? Enactment or promotion of these affordances by the teacher's efforts, and the future possibilities this allows for students will be examined using zone theory. Zone theory involves Vygotsky's zone of proximal development as well as Valsiner's *zone of free movement* and *zone of promoted action*. These zones will be used as an analytical framework to theorise teaching actions and student actions with respect to technology use within the TRTLE.

Valsiner's Zone Theory

Valsiner's Zone Theory has been applied to the development of algebraic reasoning in primary school mathematics (Blanton & Kaput, 2002), technology enriched teaching and learning settings (Galbraith & Goos, 2003), and teacher education (Blanton, Westbrook, & Carter, 2001). In the study reported in this paper, Valsiner's (1997) zone theory is being used to characterise teaching practice in one TRTLE, in particular the teaching actions promoting and constraining student use of technology during upper secondary students' study of functions in order to attune them to the affordances of such an environment.

Classrooms in which TRTLE's exist are formally designed learning systems orchestrated by knowledgeable "teachers [who] organise many sides of a child's environment in order to attain *their* goals in respect to the child's development" (Valsiner, 1997, pp. 314-5). The environments of interest incorporate formal and informal learning activities involving electronic technologies and learning artefacts specifically designed to promote development of an understanding of functions. The utility of Valsiner's zones is being investigated by the author for future use in the characterisation of teaching practice in several different TRTLE's in a larger study in order to construct a theory of how teachers and students perceive, consider, and enact affordances of a TRTLE to maximise learning.

The Essence of Valsiner's Zone Theory. "The Zone of Free Movement (ZFM) characterises the set of what is available (in terms of areas of environment, objects in those areas, and ways of acting on these objects) to the child's acting in the particular environmental setting at a given time" (Valsiner, 1997, p. 317). In TRTLE's these are parts of the classroom, technology and other learning artefacts, affordances and allowable actions, available to students at any given time. The Zone of Promoted Action (ZPA) is "the set of activities, objects, or areas in the environment, in which the person's actions are promoted" (Valsiner, 1997, p. 192). In TRTLE's these are teacher promoted actions. Vygotsky's zone of proximal development (ZPD)(1934/1986) describes possible learning states, something not directly observable. From a research perspective it is difficult to ascertain what lies within any individual's ZPD until after the fact (Meira & Lerman, 2001; Valsiner, 1997) and then this relies on actions being visible. Non-enactment does not infer a particular development was not within the current ZPD, hence, the focus will be on the other zones.

The Study

As a phenomenon and the relationships within it are being investigated, an instrumental multiple case study (Stake, 1995) is being used in a larger study of which the study described here forms a part. This phenomenon is the perception of affordances during the teaching and learning of functions in TRTLE's, with the focus for this paper being one case. The restriction to one case here is justifiable as the focus is not on the diversity that occurs in various TRTLE's but on verifying the suitability of Valsiner's zones to theorise teaching actions and to answer the following research question: What conditions are set up in a TRTLE by a teacher who embraces technology to optimise students' perception of affordances of the TRTLE to facilitate their understanding of, and working with, functions?

The Context of the Study

The primary unit of analysis is a TRTLE. In keeping with Gibson (1966) this includes both the animate and the inanimate parts of the environment. Hence, the case being studied is the technology-rich teaching and learning environment including one teacher and the students in his Year 11 mathematics class. This TRTLE was selected as the teacher is an experienced mathematics teacher, who had articulated the importance of integrating electronic technologies in his teaching and had demonstrated expertise with various technologies. He is one of four teachers at an Australian secondary school who are working towards developing technology use to facilitate students' mathematical understanding. The mathematical focus of the lessons in the establishing TRTLE was the study of functions (linear, quadratic, cubic). Students had studied linear and quadratic functions previously.

The class consists of 19 students, 10 female and 9 male. The teacher has taught five students previously for Year 9 Mathematics. The teacher and students have access to Texas Instruments graphing calculators (83/84 Plus models) and laptop computers on a daily basis, both in class and at home, as was the case the previous year. Despite this, some students had used the graphing calculator very little previously.

Each week two single periods (50 minutes each) and a double period are devoted to mathematics lessons. All lessons occurred in the same room, where a data projector, overhead projector, video player, and a View Screen allowing the projection of one graphing calculator screen for whole class viewing were available. Students generally sat wherever they chose, with the tables usually arranged in four rows, although these were rearranged into groups by the teacher on several occasions so students could work on tasks together.

Methods

To maximise complementarity of data sources several methods of data collection were used: teacher interviews, post-lesson teacher reflections, systematic observation of the classroom setting and events unfolding in it, and collection of documentary materials (student work including assessment scripts, handouts of teacher presentations, and student task sheets). Classroom observation was of a series of 26 lessons at the beginning of the school year devoted to a functions unit in students' penultimate year of secondary schooling; however, six of this teacher's lessons (2 in Year 11, 4 in Year 9) had been observed in the previous year, giving previous insight into the teacher's practice. At first, only observational notes were taken by the researcher. After three lessons, these were supplemented by audio recordings. Reflections by the teacher after class were also recorded. Transcripts of these recordings supplemented by observational notes and referenced to documentary materials collected form a record of each lesson. Three semi-structured teacher-interviews were conducted, both during this and the previous year, contributing to the articulation of the teacher's beliefs and explication of the purposes, both specific and general of his teaching, and his evaluation of particular aspects of this.

Transcripts and teacher interviews were entered into a NUD.IST database (QSR, 1997) 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. Open coding identified categories such as affordance perceived, affordance enacted, action promoting uptake of an affordance, and action constraining uptake of an affordance. After category identification the focus turned to identifying and specifying dimensional ranges of the general properties of each category (see Figure 1). 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? The focus was on conditions that gave rise to each category, the context, action/interactional strategies linked to particular phenomena, and the consequences of implementation of those strategies or actions (p. 128).

CATEGORY: Affordance Perceived	DIMENSIONAL RANGE
General Properties	
Affordance Type	(communicability, representability)
Purpose of Use	(real world interface-ability, explorability, check-ability, display-ability, discourse promote-ability)
No. of Methods Used	(1, several)
Enactment	(promoted/expected, free choice)
Action	(ignore, reject, enact)
Actor	(teacher, student)

Figure 1. Grounded theory definition of the category: Affordance Perceived.

Results and Discussion

As the conditions the teacher set up in the TRTLE to optimise students' perception of affordances to facilitate their understanding of, and working with, functions appear to stem from the beliefs/conceptions the teacher has about technology use in secondary mathematics and its impact on his teaching, these will be documented first.

Beliefs

Following Pehkonen and Törner (2004), beliefs are "mental constructs that represent the codification of people's experiences and understandings" (p. 22). These include "subconscious beliefs which lie behind the explicated conceptions" (p. 30). Hence, evidence for the teacher's beliefs in this study are provided by interview data and validated through actions observed in the classroom over time. The teacher's general beliefs about mathematics and its teaching fit the constructivist category as defined by Pehkonen and Törner, "doing mathematics is developing thought processes, building rules and formulas from experiences of reality, and finding relations between different notions" (p. 23).

Development of thought processes takes time and the teacher firmly believed access to electronic technologies should be part of students' experience from early on, not only in the development of the notion of functions, but in all areas of mathematics. However, this is not just a taste of things to come in later years but a total immersion from the start where the presence of technologies can be assumed at all times. In his Year 9 classes technology is "well, everywhere, in the sense that our students use graphing calculators as part of their armament." [June04]. For him student engagement in the context of a mathematics class, is

> Two students in dialogue. I've got a visual picture. It's on my wall of two students with a graphing calculator in hand looking down at the calculator, just punching numbers and discussing it between them and I'm no longer needed to scaffold, I can move out. I can move to another group so the engagement is that their knowledge is important. [Interview, April 2004]

However, this description does not yet fit the class in the TRTLE that is the focus of this study, as 2004 was the first year such extensive use of technology began in Year 9.

The teacher believes one power of "technology [is] as a pedagogic tool" [Feb05]. His ongoing focus is to "restructure the learning environment for students … to let us use the knowledge of all people in the group, in a learning environment to enrich the whole learning environment" [Feb05]. This is no simple task, "that juxtaposition of skill practice, technology, cognitive demand, or problem solving needs to be very carefully reflected by teachers.” [Feb05]. Technology use is a catalyst to rethink his teaching sequence.

> That sequence gets destroyed, that beautiful, by-hand sequence. [It] gets turned on its head. … And you are trying to find the new sequence. If you try to put the power of the new technology into an older sequence, it destroys both. You limit the technology to the sequence. … because the new technology doesn’t want the old sequence. [Interview, February 2005]

With less time allocated to mathematics, and less time to prepare, technology allows him to still provide students’ access to at least the same level of mathematics. He firmly believes the tasks that he can implement in a TRTLE bring more mathematics into the classroom in a single task than was previously possible. “I have got to do more with less” [30April04].

Perception of Affordances of the TRTLE

The teacher has a bipartite role in the perception, enactment and promotion of affordances in a technology-rich teaching and learning environment. Firstly, he takes up affordances where the purpose is teaching (e.g., using PowerPoint to bring pictures of real world examples into the classroom for illustration or mathematical analysis). Secondly, the teacher enacts and promotes affordances where the primary purpose is learning with a view to future independent use by students (e.g., using the graphing calculator to explore the effect of altering a particular parameter in a given equation of a cubic function on the graphical representation of the function, that is finding relationships and linking ideas). The former are not expected to be enacted by students whereas the latter are.

The teacher enacted several ‘technological - communication affordances’ (Kaput, 2004) for teaching involving various software ranging from relatively static PowerPoint to dynamic geometry applications. ‘Display’ technologies such as the View Screen were used to project the teacher’s or a student’s graphing calculator screens for whole class viewing. Affordances enacted included providing the exact visual (e.g., graphically as opposed to the inexactness of a hand sketch of a graph), check-ability, explore-ability, promoting discourse-ability, display-ability, and those that brought the real world into the classroom. The teacher’s goal in promoting student technology use was explicit furthering of their understanding through development of ideas including formulas to describe relationships.

To explain non-perceived of affordances by some actors in an environment, Scarantino (2003, p. 958) uses the notion of *goal* (or doing) affordances and *happening* affordances where the former involve intention while the latter do not. This teacher is actively and willingly *doing mathematics teaching with* the technology. He is not merely allowing it to happen because he has to. The students, on the other hand, were expected to enact many affordances offered by their graphing calculator but often this technology use was a happening event. They either watched the teacher use it, or used it in a manner similar to their teacher’s intention under his tightly promoted actions as he carefully orchestrated the learning environment, keeping the zones of promoted action and free movement tightly controlled. At other times, however, the teacher placed students in situations where they made choices and the zone of promoted action became a zone of choice across technology types (graphing calculators or laptops), technology methods, and by-hand.

Conditions for Optimising Students’ Perception of Affordances of TRTLE’s

The teacher established three conditions to optimise students’ current and future perception of affordances of TRTLE’s when learning about, and working with, functions.

These were (a) implementation of an exploratory approach to learning, (b) development of multiple strategies to solve and/or check problems, and (c) promotion of discourse through technology use to enhance student learning. The teacher's purpose was to establish a wide future zone of free movement when working in a TRTLE for all students. As students entered his class with varying technology experiences with some students having a very narrow zone of free movement, the teacher set up these conditions using a very tightly held zone of promoted action which was at all times purposefully focussed but not at the expense of being event-driven when the opportunity arose to broaden students' knowledge of alternative affordances.

Exploratory approach. One use of the technology was to allow an exploratory approach, in which ideas could develop, be explored, and relationships between them determined. Whilst this allowed students to make and test conjectures, time constraints and lack of student expertise with the technology led the teacher to take a guided discovery rather than truly exploratory approach. To this end students were provided with experiences that explored new ideas, challenged current understandings, or made links between past understandings and new ideas. As the following example shows, all of these can occur during a single task. Prior to this task, students had looked at cubic functions of the form $y = a(x-h)^3+k$ and making links between the effects of changing parameters in this general function and those of other functions (linear, quadratic, reciprocal) with equations in similar forms. Students' new conception of the shape of the graphical representation of a cubic function was challenged when they were required to graph $y = x(x+6)(x+9)$. The question posed was: "Does this look like the curve from last time?" This question was really redundant as the student reaction shows.

Hugh: No, it looks insane!
Tony: What is with the second curve? There are two of them?
Fay: Oh no, it is a straight line!
Tony: Why are there like 3 lines? [Lesson observation, 23 March 2005]

Each student could not help but notice the graph had two turning points, whereas all cubic functions previously considered had only a stationary point of inflexion. After adjusting the window settings of the calculator until a global view of the function was projected, the teacher sketched the function on the board. Two students then suggested correct values of the x intercepts, and a discussion followed where the connection was made that, as for quadratic functions, a linear factor of a cubic function (e.g., x-a) would identify an x intercept of a cubic function (e.g., at (a, 0)). These ideas were then verified algebraically.

Multiple strategies. The view of mathematics as having purpose for solving problems requires the teacher to empower students to do this. Providing students with multiple solution strategies allows flexibility when solving future problems, the option to evaluate a solution path and change strategies when needed, and allows opportunities for checking and verification of solutions. Frequent teacher demonstrations and discussion of alternatives, including different uses of technology and by-hand methods and comparison of the merits of these in various situations provided students with the opportunity to further their mathematical understandings as well as increase the number of possible strategies available in the future. Whilst exploring linear functions, for example, students had previously used by-hand algebraic methods to identify where pairs of medians of a triangle intersected. Using a dynamic geometry application projected onto the whiteboard for whole class viewing, the class verified their results. The teacher then asked how they could check the results on the calculator. Suggestions from the class included TRACE along one of the lines or use Intersect, both methods used features of the graphing calculator accessed when observing the graph of the function. The teacher proposed a third method, where the equations were entered into the function window of their graphing calculator then Value from the Calculate menu was used to find the y value of the function given the *x* value of their already determined solution. The benefits of using multiple strategies was immediately apparent with one student recognising other applications for this feature asking, “Does that mean you can find the *y* intercept that way?” [Classroom observation, 11 February, 2005]

Promoting discourse. Technology was used in various ways to promote mathematical discourse with the aim of improving, confirming, and extending understanding. During the work on quadratic functions for example, the teacher used a dynamic geometry application to promote discourse about possible relationships between various representations of the function and key values. The algebraic and graphical representations of two functions, $y = x^2$ and $y = ax^2 + bx + c$, were projected. Key values including parameter, *a*, *b*, and *c*, the turning point coordinates and value of the discriminant were also displayed dynamically. During this lesson, the teacher led the class in a series of mathematical discussions focussing on the effect of varying each parameter on each of the key values displayed and on the graph itself. This discourse, stimulated by the technology, allowed students to focus on the development of key ideas such as varying *c* shifted the graph in the vertical direction, directly identified the *y* intercept, had no effect on the axis of symmetry or the shape of the graph but effected the number of *x* intercepts, the coordinates of the turning point, and the value of the discriminant. Further, the students conjectured the sign of the discriminant indicated the number of *x* intercepts, a conjecture later explored and explained algebraically [Classroom observation, 18 February, 2005].

Conclusion and Implications

The teacher’s beliefs underlay the setting up of three conditions for learning in the TRTLE, namely an exploratory approach to learning, development of multiple strategies to solve and/or check problems, and promotion of discourse through technology use to enhance student learning. Although his ideal view of mathematics is constructivist, the teacher felt unable to implement such an approach in the technology-rich teaching and learning environment that was the focus of this study. Time constraints with respect to curriculum delivery and limited previous student experiences in using electronic technologies led to a guided discovery approach being implemented. Within the context of this TRTLE, the teacher’s beliefs about technology use in mathematics led to electronic technologies being integral to teaching and learning. The students’ limited experiences with these technologies resulted in the teacher constructing an additional condition, namely a tight zone of promoted action in order to optimise student experiences and developing expertise in enacting the affordances offered by the TRTLE. Although tightly controlled, the ZPA was far from narrow, during individual lessons and over the course of the unit of work. The students used myriad affordances offered by the TRTLE, however this was generally, but not always, as promoted by the teacher.

Throughout the observation period, promoted actions were tightly controlled as the teacher tended to limit the zone of free movement to his strongly promoted zone of promoted action. The breadth and depth of this zone of promoted action, however, resulted in a broader future zone of free movement. The tightness of the zone of promoted action ensured the zone of promoted action of one day could be actualised as the zone of free movement of future lessons. The promotion and enactment of affordances within an integrated use of electronic technologies and the ongoing discourse as to how, when, and why particular affordances of the TRTLE were considered within the mathematics being studied optimised the future choices of students as they became increasingly attuned to the affordances offered especially when the learning environment allowed happening rather than doing affordances to be enacted. Valsiner's zone theory has been a useful way to characterise teaching actions within a technology-rich teaching and learning environment. Time will tell if the students perceive and enact these affordances in the future as they make their own choices in solving problems. This will be pursued in the larger study.

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