STUDENT STRATEGIES IN ENACTING AFFORDANCES

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This paper reports an instrumental case study of the strategies employed by Year 11 students engaged in solving a functions population task. The task was implemented as part of a study of students studying functions in a Technology-Rich Teaching and Learning Environment (TRTLE). Student strategies related to the perception and enactment of affordances of the TRTLE that would be useful during task solution. The number and nature of strategies used and the combinations of affordances perceived and enacted were diverse. This was true even when students had the same function related intention, for example, find a model to represent data.

THEORETICAL FRAMEWORK AND RELATED LITERATURE

A *Technology-Rich Teaching and Learning Environment* (TRTLE) is a classroom environment where both teachers and students have access to, and teachers' professional development support for, a range of electronic technologies. To qualify as 'rich' the environment includes unrestricted access to electronic technologies that enable mathematical explorations. See Brown (2005) for further details.

The term *affordance*, prominent in educational literature, has a proliferation of different uses and meanings. In the research reported, following Gibson (1979) who invented the term, "*affordances of a TRTLE*…are the offerings of the environment for facilitating and impeding teaching and learning. Affordance bearers are those specific objects within the environment that enable an affordance to be enacted" (Brown, 2006, p. 241). Being opportunities, affordances need to be perceived and acted upon if the opportunity is to be taken up. In this study affordances were described in the same linguistic form used by Gibson (e.g., *Communicate-ability, Represent-ability*). Gibson saw affordances as a precondition for activity defining allowable actions between the object and actor; however, the existence of an affordance does not necessarily imply that activity will occur. The language form '-ability' is intended to convey this potentiality. *Affordance bearers*, a term coined by Scarantino (2003), can be described in general terms or more particularly as specific features of the particular technology being used as is the case here (e.g., ZOOM).

The number of studies focussing on function appears to have declined over the last two decades. Those that are reported tend not to involve real world contexts, situations where students are required to determine what function to use, nor often consider student actions in a normal classroom environment. For example, Kouropatov and Dreyfus (2012) in a study of advanced-level mathematics student volunteers learning integral calculus report on the accumulation function concept as core to developing "a flexible proceptual understanding of the integral and integration" (p. 11). An

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interesting study is reported by le Roux and Adler (2012) with a group of four “first-year undergraduate students solving a function problem” (p. 51). Although this function task is situated in the real world (chemical reaction) the function type (quadratic) is specified. Analysis focuses on “the interplay between students’ ways of talking about and looking operationally and structurally at the quadratic function” (p. 57). Watson and Harel (2013) follow up Harel’s earlier analysis of the weak treatment in US textbooks of functions to investigate the impact of teacher mathematical knowledge on their teaching. With respect to TRTLE’s, Brown (2007) reported on Year 9 students’ early conceptions of function whilst Minh (2012) reported on Year 11 and 12 students in a French technology-rich geometrical and symbolic environment learning about functions through modelling geometric dependent situations. Minh found “joint development of knowledge about the artefact’s capabilities together with mathematical knowledge about functions during the instrumental genesis” (p. 217) takes time.

METHODOLOGY

An instrumental approach to collective case study (Stake, 1995, pp. 3-4) was used in this study. The research question that is the focus of this paper is: In a TRTLE, where myriad affordances are present and would be useful, what strategies do students employ in solving real world functions tasks? The strategies relate to the perception and enactment of affordances that would be useful during task solving. Affordances that would be particularly useful in determining and subsequently using models for the task included: *Data Display-ability, Function View-ability, Represent-ability*, and *Check-ability*. These affordances are briefly illustrated from the lesson sequence on functions prior to task implementation; the focus then becomes the strategies employed during task solving.

The data reported[1] here involved students in two Year 11 classes of 16-17 years olds solving a function task, *The Platypus Task* (see Figure 1), as part of a larger study (Brown, 2006, 2013). Platypus are found in the Yarra River close to the school where the study took place. Teachers and students had access to both TI-graphing calculators and laptops with a selection of mathematical software. The initial units of analysis were TRTLE’s: P11 - 17 students taught by Peter and J11 – 20 students taught by James (all names are pseudonyms).

The task was implemented during term 2, after the classes had completed course work related to the area of study of functions (including linear, quadratic, and cubic functions and relations). The task was introduced by the researcher and students worked on the task independently with little interaction with other students or the teacher. Data sources included task scripts, a post task record sheet - seeking to ascertain information that may not have been recorded (i.e., consideration of multiple

[1] Data were collected in RITEMATHS, an ARC funded Linkage Project – LP0453701 at The University of Melbourne.

function types, checking), and audio and video recording of at least one student pair in each class. In addition, key recordings were made (using a *Key Recorder App* that recorded user button presses). Sixteen students were interviewed post-task.

> The platypus is an endangered species that may become extinct unless action is taken to save it. An annual survey held in a nearby national park showed an alarming decrease in the number of platypus over the years 1993-1998. The Save the Platypus Project commenced in 1999. Two sets of data representing the platypus population, before and after the intervention project, were provided.
>
> Part A: Use any method you feel is appropriate to determine a model to represent platypus numbers over time (a) before and (b) after the beginning of the project.
>
> Part B: Analysis included: did the intervention improve the situation, what was the predicted population a decade later, when would the population return to the initial value, and if successful when will the population return to the 1993 level?

Figure 1: Details of The Platypus Task.

Analysis of the data followed a grounded theory approach (Strauss & Corbin, 1998). After data collection, audio recordings were transcribed. These transcripts and video and key screen recordings were re-read, re-listened to and re-watched to immerse the researcher in the data. Screen shots were used to re-create student actions. Open and axial coding followed. The former identified categories such as affordance perceived, affordance enacted, and action promoting uptake of an affordance (Brown, 2013). Axial coding (Strauss & Corbin, 1998, p. 127) focused on discovering relationships amongst categories by answering questions such as: Who used the technology, how, for what purpose, and what was the consequence of use? Thus sets of combinations of affordance enacted, strategies employed, and affordance bearers used emerged.

AFFORDANCES ILLUSTRATED

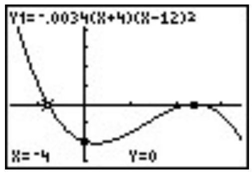
Given the varied use of the term affordances in the literature, an understanding of the author's use of this term is critical. This section illustrates what the term meant in practice in this study. Classroom situations (e.g., attempting tasks, discourse, and other interactions) often involved perceiving and enacting multiple affordances, as was the case here.

One affordance identified in all TRTLE's in the study *was Communicate-ability*. The affordance *Communicate-ability* is defined as Affordances of a TRTLE involving support of/for communication between humans through electronic technologies. Each affordance can be manifest in a variety of ways, for different purposes within the broad purpose enabled by the particular affordance. *Communicate-ability* was manifest through *display of screens, lesson flow, program sharing, and vicarious experiences. Lesson flow* and *vicarious experiences* were manifestations of this affordance for teaching, always initiated or enacted by the teacher. The others were both teaching and learning manifestations initiated by both teacher and students at different points in time. *Display of screens*, for example, involved sharing electronic displays for the purposes of communication in TRTLE's supporting teaching and learning. The display to be shared could belong to teacher or student. Sharing displays could be deliberately planned or occur spontaneously as the lesson unfolded. Figure 2 presents a short dialogue between two students and a recreation of their graphing calculator screens. This occurred when Hugh and Tony were trying to find a function in the form $y = \mathrm{A}(x + \mathrm{B})^2(x + \mathrm{C})$, to model curves in a wooden strip. However, Tony did not correctly match the repeated factor to the correct root, and hence found an incorrect function.

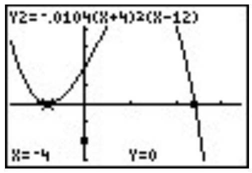
Tony: Check it [the function graph] hits the points.

Hugh: $y = -.0034(x + 4)(x - 12)^2$.

Hugh: Mine looks right. [Comparing his plot to the correct function, he observes the function graph passing though his plot of the data, and having the required features.]



Hugh: [Looks at screen of Tony.] You had a square on the wrong line. [Indicating the wrong factor has been squared rather than the wrong 'line']



Lesson 32 Lines 169-175

Figure 2: Illustration of *Communicate-ability*.

Figure 2 shows an example of *display of screens* where each student shared their screen with the other for the purpose of *Communicate-ability*. The dialogue illustrates that both students were expecting the correctly identified function to pass through their plot of the data. Following their sharing of Hugh's screen showing the plot and function graph, Hugh was able to identify the source of Tony's error. Thus screen sharing facilitated collaborative work, which enabled informed error correction.

Multiple affordances were often perceived and enacted in the same instance. Three other critical affordances are apparent in Figure 2, for example. These are *Data Display-ability* (affordances of a TRTLE to provide a graphical display of data, i.e., plot of numerical data), *Function View-ability* (affordances of a TRTLE to identify type of function to fit given data or identify a specific function) and *Check-ability* (affordances of a TRTLE allowing local or global checking or verification).

ANALYSIS AND RESULTS

Analysis of the data identified sets of combinations of affordance enacted, strategies employed, and affordance bearers used. A particular affordance could be used in employing a range of strategies and/or with a selection of affordance bearers. Equally many strategies could be employed using different selections of affordances. A student may consciously perceive an affordance first or a strategy first, or this may occur simultaneously, however it is generally impossible to determine (see Figure 3).

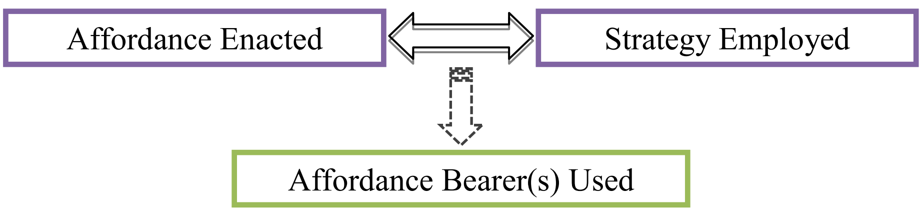


Figure 3: Relationship between categories.

The specification of affordances is based on the critical ones being perceived and enacted for the particular strategy. One affordance may be enacted individually or concurrently with others. In some cases, enactment of an affordance implies enactment of previously perceived affordances. One affordance can be associated with several strategies, and vice versa, and in enacting any particular affordance, one usually has a choice of affordance bearers. For example, in enacting *Data Display-ability* several strategies were identified. These included: View plot of data to consider appropriate function type given shape; View plot of data after function graph has been viewed (i.e., in already set up window); View plot of data after function graph has been viewed, set up new window; and View plot of data simultaneously with function graph. However, a strategy involved both a purpose and the use of particular affordance bearers. For example in Viewing a plot of data to consider appropriate function type given shape, three different choices of affordance bearers were identified (a) LIST, STAT Plot, ZOOM Stat; (b) LIST, STAT Plot, WINDOW; and (c) LIST, STAT Plot, WINDOW + ZOOM Out.

Model Finding

Students took quite different approaches as they began the task. For example Len (P11) began by entering the population data before the intervention project in Lists 1 and 2. He found a linear regression model and pasted it into the function window as shown in Figure 4 (first 3 screens). Pressing GRAPH, no part of the function graph was visible. He edited the Window Settings, clearly informed by the data, and immediately saw the function graph (Figure 4, final screens). Hence, Len began the task by first enacting *Function Identify-ability* followed by *Function View-ability*. His strategy in the former was Identify functions using linear regression (using affordance bearers LIST and STAT CALC LinReg), and for the latter View the graph of model by editing window settings directly (using affordance bearers function window y=, WINDOW, and GRAPH).

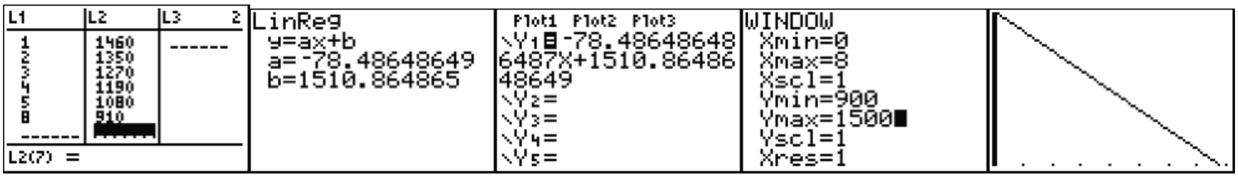


Figure 4: Evidence of enacting *Function Identify-ability* and *Function View-ability*.

In contrast, Cam (J11) entered all the data provided into Lists 1 and 2. He correctly set up the plot, pressed GRAPH and saw the standard viewing window with no part of the plot visible. Selecting ZOOM Stat the data were displayed in the viewing window. Thus he had begun the task by enacting *Data Display-ability* as shown in Figure 5. His strategy was to View the plot of data to consider appropriate function type given shape using affordance bearers LIST, STAT Plot, and ZOOM Stat.

The number of strategies in each TRTLE for these affordance combinations and the total number of times the affordance(s) for each part of the tasks are shown in Table 1. Row 1 shows that in P11, in Part A of the task seven affordances were perceived and enacted with eight different combinations. In enacting these, 16 different strategies were used. Some students enacted multiple affordance combinations and strategies and hence the number of instances, 52, is greater than the number of students (17). In addition, models were found for two sets of data. In Part A, students in J11 enacted the same affordances although not necessarily the same combinations. Values in the final columns for Part B of the task less than 17 and 20, respectively, indicate that not all students completed all parts of the task.

Figure 5: Evidence of Cam enacting Data Display-ability.

Part of Task	Affordance(s) Perceived and Enacted				Number of strategies		Number of Instances	
	Number		No. of Combinations					
	P11	J11	P11	J11	P11	J11	P11	J11
A: Model Finding	7	7	8	9	16	24	52	103
B: Q1	4	4	3	6	5	9	11	15
B: Q2	3	4	3	7	8	13	16	17
B: Q3	3	3	2	2	4	6	10	9
B: Q4	4	3	2	5	2	6	6	9

Table 1: Number of affordances enacted and strategies used during task solving.

As Part A of the task allowed greater diversity of approaches, as evidenced in row 1 of Table 1, more detail is provided with respect to affordance combinations and strategies. There were 10 combinations of affordances in total, eight in P11 and nine in J11. Those combinations of affordances with number of strategies used (s) and instances occurring (N) are shown in Table 2, which indicates that some affordances were distinguished at a more specific level, that is, *Check-ability* was specified to be either local (shaded cells) or global. For *Data Display-ability* where the focus was multiple plots rather than a single plot and similarly for *Function View-ability* where the focus was multiple function graphs. All three relate to strategies being employed. *Check-ability* (local) was evident when Tabya employed the strategy: Perform a local check of function value(s) and compare with corresponding data value(s) using affordance bearer CALC Value. *Check-ability* (global) occurred, in conjunction with *Data Display-ability* and *Function View-ability* when Cam and others employed the strategy: View plot and graph simultaneously to see if the model matched the data using affordance bearers, ZOOM Stat and GRAPH. Multiple plots occurred when students viewed all the data at the same time. Multiple graphs occurred in two situations, either when students considered different function models for one set of data or when they compared a model for the data before intervention and a model for the data after intervention.

Affordance Combination	*s*		*N*	
	P11	J11	P11	J11
Data Display-ability	3	5	8	20
Function Identify-ability	4	6	16	17
Function View-ability	3	3	16	16
Check-ability (global) with *Data Display-ability* and *Function View-ability*	2	2	8	15
Degree of Fit-ability with *Represent-ability* and *Function View-ability*	0	1	0	12
Check-ability	1	2	1	8
Represent-ability with *Data Display-ability* (multiple plots)	1	2	1	7
Represent-ability with *Function View-ability* (multiple graphs)	1	2	1	7
Degree of Fit-ability with *Calculate-ability*	1	1	1	1

Table 2: Additional details for the model finding phase of task solution.

DISCUSSION AND IMPLICATIONS

A greater number of affordance combinations were identified in J11 and a greater number of strategies used in enacting the various affordance combinations. Whilst this is in part a result of a greater number of students in J11, this is not the only reason. Students in J11 made more diverse use of function types and had an increased tendency to consider multiple function types when identifying models for the data, or a combination of these factors.

Approximately half of the students in P11 compared to most students in J11 (i) enacted *Data Display-ability*, (ii) viewed at least one model graphed simultaneously with a plot of the data, enacting *Data Display-ability* in conjunction with *Function View-ability*, and (iii) did so for at least one model before intervention and one model after intervention thus perceiving the usefulness of plotting the data and graphing a model of the function together. In addition, in P11, one student found multiple models for both sets of data and six did so for only one set (1 before, 5 after). In contrast in J11, eight students found multiple models for both sets of data and eight for one set only (7 before, 1 after). This was a contributing factor in the larger number of affordances enacted and strategies employed in this TRTLE.

Whilst it is interesting to compare students in the two TRTLE's, this study is using an instrumental approach rather than the cases themselves being of primary interest (Stake, 1995, p. 171). For teachers and researchers, several implications arise. Firstly, the great diversity of approaches taken by students may be an eye opener to teachers of senior secondary mathematics students. These approaches relate to both affordances perceived and enacted and to strategies employed by students. Secondly, the number of students who found only one possible model for a data set that clearly could not be perfectly modelled by a polynomial or exponential model was surprising. Thirdly, related to this, was the number of students who failed to either perceive affordances of the TRTLE for, or the need to, either compare a function model to data, to compare multiple models for the one set of data – to each other and the data – or to compare the two sets of data or the models for these. This researcher wonders if these students are simply assuming their model must be a perfect fit and hence there is no need to view the plot? Further research is needed to consider this.

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