DOES THE LEARNING EQUATION HAVE A ROLE IN AUSTRALIAN MATHEMATICS EDUCATION? POSSIBLY YES!

Stephen J Norton and Tom J Cooper

Centre for Mathematics and Science Education, QUT, Brisbane, Australia sj.norton@qut.edu.au

This paper reports on a study ascertain the potential of a new generation ILS to play a role in Australian classrooms. The paper describes the pedagogical paradigm, and content match between Australian curriculum and TLE. It reports on the potential of TLE to foster mathematics performance and the changed roles of students and teachers. The results indicate that the software has potential to foster mathematical achievement at least as well as traditional teaching, and it changes the nature of student and teacher roles. Ironically the software that mimics instruction in learning prompted student construction of mathematics understanding.

This paper reports on a study of the potential of an Intelligent Tutoring System (ITS) software package called *The Learning Equation* (TLE) (IPT Nelson, 1999) to fill a niche in Australian secondary mathematics teaching. This study was completed in five stages. First, the pedagogical paradigm of TLE is compared with those of the Australian Educational Council (AEC) (1990) guidelines for syllabus construction by State bodies and some State syllabuses. Second, a content match is made between TLE and national guidelines. Third, the effectiveness of TLE in teaching mathematics is examined by comparing students' cognitive outcomes when working with it as distinct from those taught in the "school mathematics tradition" (Gregg, 1995, p. 443). Fourth, the nature of discourse within the classroom where TLE was used is examined and compared with the discourse in the comparison classes. Student evaluations of the software are described. Finally, the role of the teacher is described and analysed.

ITS software break down the content to be taught into small units, assesses progress, and then moves on to the next unit or provides remedial instruction (Maddux, Johnson, & Willis, 1997). Thus, by their nature, quality ITS software tend to reflect educational paradigms that Papert (1993) describes as *clean*, "Clean dancing reduces dance to formulas describing steps, and clean learning reduces math to formulas describing procedures to manipulate symbols" (p. 135). Typically, the operation of these software have been termed "training" (Integrated Learning Systems ILS, 2000); the computer provides a stimulus, individuals respond, the computer analyses the response and provides appropriate feedback then the computer or individual selects the next interaction. It has been reported that such training is like a patient instructor (ILS, 2000).

TLE software is a multimedia ITS environment that uses voice explanations, textual explanations, practice questions where text clues guide students who make mistakes, summary activities and self-test assessment options that teaches junior secondary mathematics. It aims to provide scaffolding to temporarily support students until they can perform the tasks on their own. Bennett, (1999, p. 1) believes software such as this has the potential to "solve the crisis in education." However, a number of authors have criticised the use of technology in a clean way. For example, Bracewell, Breuleaux, Laferriere, Benoit, and Abdous (1998) have described this form of software as "canned content." and consistent with a behaviourist approach to mathematics teaching and learning.

In contrast to clean learning, Papert (1993) described *dirty* learning as emotional, complex, and intertwined with the learner's social, cultural and cognitive context, and reflecting theories of learning consistent with major elements of social constructivist theory. That is, it recognised the importance of the learner (acknowledging Piaget) actively constructing their own knowledge from the environment (Luckin, 1999) and (acknowledging Vykotsky) socially interacting with peers and teachers (Vygotsky, 1987). Social constructivist thinking has found expression in "reform curricular" (Van de Walle, 2001) an important attribute of which is transferable problem solving.

Comparing educational paradigms of TLE and Australian syllabuses

The Australian Educational Council (AEC) guides the States of Australia in terms of syllabus construction. To this end, the AEC produced a statement titled *A National Statement on Mathematics for Australian Schools* (AEC, 1990). This statement does not articulate an epistemology, but one can be inferred from its contents. The document contains statements such as "students should develop their capacity to use mathematics in solving problems individually and collaboratively" (p. 12); and "learners (should) construct their own meanings from, and for the ideas, objects and events which they experience" (p. 16). While general in nature, these statements reflect purpose and active engagement consistent with "dirty" learning environments. As described above, TLE mimics quality instruction within clearly defined parameters typical of clean learning environments. Clearly, at face value, there exists a disjunction between the paradigm of TLE that manifests a clean approach to learning and the AEC statements that recommend a dirty approach.

Matching content between the Australian lower secondary curricula and TLE

The National Statement (AEC, 1990) breaks the content to be taught into strands: mathematical inquiry, choosing and using mathematics, space, number, measurement, and chance and data. In general, the State curriculum documents contain much the same content up until the final two years of high school. TLE divides the content into the following strands; number concepts, number operations, patterns and relations, space and measurement (and related subtopics), and statistics, probability and data analysis. There is considerable overlap between the National Statement and TLE content at the gross level. In the year 9 course that was the focus to this study, the school content and TLE content match was identical. A content match with a junior mathematics text series by Priddle, Davies & Pitman (1991) popular in Queensland revealed that TLE covered the same content and more. Given the flexibility afforded the Australian states, there is every reason to assume that TLE could meet the content requirements of Australian junior secondary mathematics classrooms.

Cognitive gains for TLE compared with the "school mathematics tradition"

In an attempt to determine TLE's potential to facilitate mathematical learning the package was trialled in secondary classrooms over 26 lessons each of 70 minutes. The subjects were Year 9 students in a secondary school of 650 students located in a middle class suburb in metropolitan Brisbane. The unit trialed was a Year 9 unit on *Patterns and Relations, Variables and Equations*. The results of a class of 28 students who studied using TLE (pairs of students on each computer) were compared with two matched control groups (traditional whole class "school mathematics tradition" instruction using a text book). The control classes had half the number of students, that is two classes of 13 students. Details of the research methods and the results of the comparison between TLE and control students have been published previously (Norton, Cooper & McRobbie, 2000).

TLE students were compared with control students in four cognitive dimensions: (1) operational algebra or problems that could be solved using arithmetic means (Sfard, 1991); (2) knowledge of the variable concept; (3) structural algebra which involved thinking in terms of abstraction (Sfard, 1991); and (4) word problems where students were required to represent the given verbal and diagrammatic information in algebraic form decide what operations were necessary and then preform these operations. Table 1 reports the findings.

Table 1
Post test Comparison.

	Control		TLE		
Subset	Mean	SD	Mean	SD	T
Operational algebra	5.08	2.26	6.34	1.79	2.09 *
Variable concept	4.16	1.40	5.36	1.30	3.03 **
Structural algebra	2.88	2.72	4.41	2.55	1.98
Word problems	3.62	2.89	5.84	3.31	2.46*

*$p < .05$. **$p < .01$

Norton, Cooper & McRobbie (2000) concluded that students who studied using TLE software outperformed the control class on all classes of questions and this was statistically significant on all except the structural algebra subset. In this regard the results of this study counters those reported earlier (Becker, 1994; Cooper, McRobbie & Baturo, 1998) but supports the findings of the Software Information Industry Association's (2000) meta analysis of student gains on standard tests.

Comparing classroom discourse and describing students' responses

The results and method related to this objective are contained in Norton & Cooper (in press). In brief, the following methods were used to collect data: observations, collection of artefacts, interviews and tests. In TLE class, data on discourse were collected at two levels: (1) general observations of all students in the classroom; and (2) particular, finer-grained, observations of six students (three pairs). The student pairs were observed over six lessons and split-screen videotape data (combining feed from the computer screen and a video of students) was recorded for two lessons.

In the control classes, the teachers taught the lessons consistent with descriptions of the "school mathematics tradition" (Gregg, 1995, p. 443). Most lessons began with a review of homework problems; then the teacher modelled the solution procedure step by step for the textbook examples. Students rarely asked questions during the modelling phase but attended to explanations. Following this, students worked on problems from the text book (Priddle, Davies & Pitman, 1991). The teachers moved among the students assisting individuals or sometimes pairs with problems. The discourse between the teachers and students was typical of what Lesh and Kelly (1997) called bug repair, that is, guiding students step by step in a manner that avoids error. The duration of these exchanges was brief. In TLE class, students sat and worked in pairs at small desks upon which the networked computers were located. Typically the lesson started with an overview of the tasks to be undertaken that day. Once students began to work on the computers there was considerable student communication both within pairs and between pairs. In the early stages, much of this related to technical details such as how to navigate about the program. As the study progressed, some students began to socialise as a result of frustration and inability to complete the tasks in part because it appeared that many students did not have the background knowledge to easily complete the tasks. Other students found the mathematics problems posed by the computer program too demanding because the challenge of doing a series of mental computations in order to complete a task was too hard for them. Some of these students resorted to simply randomly pressed responses until the program gave them the correct response so they could continue.

In the control classes, almost all girls stated that they wished to remain being taught by a teacher who carefully explained the content. However, almost all of the girls saw little relevance in mathematics study beyond school. About half the boys in the control classes expressed a desire to switch to TLE class and stated that the way mathematics was taught was "boring" and "not related to the real world." Some of the students liked the challenge of working out difficult mathematics problems. The student responses to TLE fell into three groups. The first group (about half the class) did not like the software and their comments indicated a concern for the diminished quality of student/teacher discourse, in particular they felt it is was the teachers' responsibility to give clear expositions of mathematics. The remaining students liked working with TLE and their comments showed that they liked the increased autonomy and control over their learning and approved of the interactive virtual environment. Students used different strategies while working with TLE. For example, a pair of boys would initially try to logically work out processes but if this failed they used guess and check strategies. They also repetitively practiced problems of similar structure types that they had difficulty with in order to develop familiarity with the problem structures. A pair of girls had long discussions and tried to work out the underlying structures before attempting to input into the computer. A second pair of girls found the learning too frustrating and the content beyond them and did very little mathematics for the entire study. They expressed very negative attitudes about mathematics and technology and wanted the social and cognitive scaffolding that a caring teacher could supply.

The changed role of the teacher when operating with TLE.

The central role of teachers in helping students move through their Zone of Proximal Development (Vygotsky, 1978) has been well recognised (Luckin, 1999). It has been also noted that when computing technology is introduced the role of the teacher is changed (ILS, 2000). This is particularly so when the computing technology is designed to provide cognitive scaffolding as is the case with new generation ILS programs. Gross (1997) found that the teacher's role changed from one of "sage on the stage" to facilitation. However, Bottino and Furinghetti (1996) argued that the very nature of ILS software such as TLE marginalised the teacher's role and removes students' initiative and autonomy.

One of the teachers taught both a control class and TLE class. His teaching of the control class was typically "traditional transmission" (Atweh & Cooper, 1995) and "teacher-centred" (Thompson, Philip, Thompson & Boyd, 1994), teaching methods associated with the "school mathematics tradition," (Gregg, 1995). This did not vary over the life of the study. The details of this teacher's discourse are reported in Norton, Cooper & Baturo (in press). The teacher's behaviour was very different in TLE class. Although he started the lessons with an over view of what he considered were the major concepts, he spend most of the lesson helping students who struggled with both technical and mathematical problems. The nature of discourse between the teacher and the students differed in that his discussions with pairs was typically of a much longer duration and of a different nature. Since each pair of students was working on a unique problem and often with different structures, the teacher did not did not have a prepared solution and often could not quickly provide cognitive scaffolding. Instead, he was forced to analyse the structures of each problem and, in doing so he modelled his own problem solving processes and, with more capable students, entered into a learning partnership. That is, students often made suggestions and became active contributors to the discourse. Not all students liked to work this way, some complained that the teacher did not know what he was doing and wanted more direct instructions and explanations.

Discussion and conclusions

At face value, the pedagogical paradigm of TLE is at odds with the pedagogical paradigm of the AEC. In states such as Queensland where mathematics syllabus writers have recommended a problem solving and investigative approach to teaching mathematics (Board of Senior Secondary School Studies, 1992), this could cause some educators to reject its use. However, in states such as NSW, where recommendations about teaching (in an investigative way) are much less overt, paradigm disjunction is likely to be less important (Board of Studies, NSW, 2000). Given the flexibility inherent within the Australian Educational system and the apparent good match between TLE and AEC content recommendations, it is likely that TLE could fulfil the content requirements of late primary and early secondary mathematics curricula.

The results of this study indicate that TLE is as least as able to help some students to pass pencil and paper mathematics tests as traditional teaching of algebra. It also shows that the teacher-student interactions within TLE were such that some students experience deep learning. Therefore, the study suggests that wider research ought to be conducted to compare the learning outcomes of students working with TLE with those developed in a dirty or reform learning environment. Student responses to TLE were mixed. The results suggest that some students needed greater social and cognitive scaffold from a teacher that was provided in this classroom while others adapted well to the more autonomous learning environment. The teachers' role was dramatically changed in that he was forced to abandon his whole class teacher centred pedagogy and formed learning partnerships with students. That he was challenged both pedagogically and in relation to the mathematics content suggests that in order to successfully manage the use of the software quality teachers are needed.

In summary, TLE software warrants further investigation as a possible content source and student learning resource within Australia. Preliminary results indicate it has potential to foster mathematical learning. Further research needs to be undertaken to ascertain the transferability of the mathematics learning and to determine the interactions between the software, students and teachers to further explore its potential. It is interesting that the introduction of clean software dirtied the learning environment.

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