Low Achieving Mathematics Students' Attitudinal and Achievement Changes as a Result of Using an Integrated Learning System

Campbell McRobbie
Queensland University of Technology
<c.mcrobbie@qut.edu.au>

Annette Baturo
Queensland University of Technology
<a.baturo@qut.edu.au>

Tom Cooper
Queensland University of Technology
<tj.cooper@qut.edu.au>

This paper reports on a study to measure the effectiveness of an integrated learning system in improving mathematics achievement for low achieving Years 5 to 9 students. The study found that statistically significant gains on the ILS were not supported by scores on standardised mathematics-achievement tests. It also found that although student attitudes to computers decreased (significantly for some items), the students still liked the ILS and felt that it had helped them to learn.

One of the by-products of the growth of information technology in education has been the development of computer-based integrated learning systems (ILSs). These systems have three essential components, namely, *substantial course content*, *aggregated learner record system*, and a *management system*. They track learners' task responses and progress, and provides performance feedback to the learner and teacher (Underwood, Cavendish, Dowling, Fogelman, & Lawson, 1996, p. 33). This paper reports on a study to investigate how effective an ILS was on improving mathematics achievement for low-achieving mathematics students. The study compared achievement gains in mathematics learning as measured by standardised mathematics achievement tests with gains as measured by the ILS's management system. It also analysed changes in students' attitudes to computers in the classroom, and measured students' beliefs about the ILS.

According to the manufacturer, the core mathematics course of the ILS used by the students was developed to foster the development of foundation skills and concepts and to promote the use of higher-order thinking skills. It was designed to work with individual students in a closed manner, that is, the curriculum content and the learning sequences were not designed to be changed or added to by either the tutor or the learner (Underwood et al., 1996). Thus, the ILS marginalised the teacher's role and removed students' initiative and autonomy in the system's learning process (Bottino & Furinghetti, 1996). However, it should be noted that the manufacturers endorsed the ILS only as a tool for teachers to use to consolidate already introduced material and to diagnose student difficulties. They argued that it is the teacher's role to introduce the material to be practised on the ILS, and to remediate the difficulties identified by the ILS.

The core mathematics course was based on USA syllabi but correlated reasonably well with Australian syllabus requirements. It was divided into a range of *topics* (e.g., numeration, addition, multiplication, fractions, space) which were then sub-divided into collections of tasks that were sequenced in terms of performance at different *levels* (given in Years, e.g., 4.34). The difference between levels was constructed so that high mastery at one level (approximately 85%) is the same as mastery (above 60%) at the next level. The individual tasks were developed and placed in levels as a result of large-scale trials in the US.

For their initial *placement* on the ILS, students were given a large number of tasks at different levels until the system found the level at which they have reasonable mastery (about 65-75%). Students *progressed* when they achieved high mastery at one level; the system automatically raised them to the next level. To maximise the chance that task performance correctly represented level, the tasks within a level were presented randomly. The distributors argued that any reduction of randomness would affect the accuracy of placement and, therefore, the potential for students to achieve mastery. Without mastery, students may not experience the continual success, and therefore the motivation for achievement, that lay at the theoretical heart of the ILS. The ILS management system provided reports summarising students' levels of performance overall and for each topic area and giving the number of hours the students had spent on the ILS.

The mathematics tasks were in the form of electronic worksheets that were generally attractive in their presentation and sometimes creative in the way they probed understanding. They attempted to encourage the construction of knowledge by providing 2-D representations of appropriate teaching materials in mathematics (e.g., Multi-base Arithmetic Blocks, place value charts, fraction and decimal diagrams). Built into the core mathematics course were online resources that enabled students to get special help during a session should the need arise. However, use of the Help and Tutorial icons automatically graded performance as incorrect. The Toolbox icon made available calculators, rulers, tape measures and protractors for student use and also provided complex tools (e.g., graphing and drawing) for advanced levels.

For some topics and levels, there appeared to be insufficient task variety to prevent repetition. Furthermore, some tasks had novel presentation formats that students found difficult to interpret (e.g., spring scales used to determine number size, not object mass). Other tasks required inflexible and/or novel solution formats that sometimes resulted in students' correct answers being marked incorrect (e.g., failing to type the units digit first in operations, the omission of zero in decimal numbers such as 0.63). There was a tendency for questions to be closed (i.e., "find the right number") and based on speed (although the teacher could vary the time limits on answers). Time delays (e.g., while an algorithm was completed with pen and paper) could lead to the ILS's defaulting to incorrect. For each level and topic area, there were worksheets that could be printed to provide students with extra practice and teachers with a guide to the types of activities that needed consolidating.

Previous evaluations of the core mathematics course of the ILS have been mixed. Becker (1992) reviewed 32 evaluations and concluded that no independent evaluation had found significant gains from the use of the ILS. However, Underwood et al. (1996) found substantial positive gains from use of the ILS for mathematics performance in computation (although student numbers were small). Baturo, Cooper, McRobbie and Kidman (1999) and Baturo, Cooper, Kidman and McRobbie (in press) found that many classroom teachers felt that the ILS was successful in supporting mathematics learning in their classrooms, while Baturo, Cooper and McRobbie (1999) showed that it was possible to progress in the ILS without gaining any mathematics knowledge.

Method

The study reported here was essentially a pretest-posttest design without a control group (Campbell & Stanley, 1963). Instruments measuring achievement in mathematics, attitudes to computers, and beliefs about the ILS were administered, and progress ratings collected from the ILS's management program.

The study was part of a larger multimethod (Brewer & Hunter, 1989) project that also involved interviews with students and teachers and observations of classrooms. It ran for the last two terms of the year. Approximately 1000 Years 1-10 students from 23 primary and secondary schools (predominantly low socioeconomic status) throughout Queensland were involved in the larger study.

Sample

The subjects of the pretest-posttest design study were the 805 Years 5-9 cohort from the larger study. However, for a variety of reasons (e.g., time pressures, student nonattendance), the numbers of students varied for each instrument. For example, approximately 500 students completed the pretest, 135 students completed the pre-and post computer attitude survey, 350 completed the posttest, while 374 students responded to the questionnaire concerning students' perceptions of the ILS. Approximately 400 ILS reports were collected.

Data Sources

There were four data sources – *mathematics standardised achievement tests*, *computer attitude survey*, *student evaluation questionnaire,* and *ILS progress reports*. The three tests, Year 5/6, Year 7/8, and Year 9/10, had been developed by Education Queensland to monitor mathematics achievement in all Queensland state schools. Each test comprised two booklets with the first booklet containing items that were considered to be less difficult than those in the second booklet. These tests were used for both the pretest and the posttest. The 12-item survey measured students' attitudes to using computers at school and had been developed and used by Education Queensland in an earlier study of the ILS. Items were responded to on a six-point Likert Scale ranging from "very strongly disagree" (assigned value = 1) to "strongly agree" (assigned value = 6). The open-ended questionnaire was developed by the research team and sought students' perceptions of their experience with the ILS. Items of interest in this analysis included, "Did you like working on the ILS?" and "Did the ILS help you to learn?". Students were requested to answer the items "yes/no" and to give reasons for their response. The ILS progress reports were constructed by the ILS management system and provided information on the students in the study with respect to the levels they reached, their gains since placement, and the aggregated time they had spent on the ILS.

Procedure

The *tests* were administered at the beginning and end of the study by the classroom teachers. Because of the nature of the students, their low achievement levels, and the focus of most schools on remediation, many teachers chose to give a pretest that was below their class year level. Therefore, most students (primary and secondary) completed the Year 5/6 test (some Booklet 1, some Booklet 2, some both booklets). The *survey* was attached to the mathematics achievement tests and was therefore to be completed at the same time as the test (i.e., twice – at the beginning and the end of the study). The *questionnaire* was administered by the class teacher at the end of the trial. The ILS *reports* were collected by the class teacher at the end of the trial.

The classroom teachers organised the ILS sessions with their students to suit their schools' timetables and positions of computers. However, typically, students engaged with the ILS for about one-half to three-quarters of an hour each week over the 16 week period.

Analysis

The test, survey and ILS reports were analysed using analysis of variance and Pearson correlation. The questionnaire was analysed using Log Linear Analysis. Due to the number and types of responses, the results were analysed by instrument, rather than by school year level. As well, the mathematics results were analysed separately for each test booklet (Book 1 and Book 2) at each test level. Also, only students with test responses were included in the students whose progress reports were analysed.

Results

Mathematics Achievement

Table 1 summarises the statistical analysis of the pre- and posttest scores for the tests and the ILS. Analysis of variance of the Year 5/6 and Year 7/8 results showed statistically significant differences for ILS progress levels for each group and between the pre- and posttest mean scores for Book 1 of the Year 7/8 test. Of interest is the decline in mean scores pre- to posttest for Book 2 of the Year 7/8 test.

Further analysis of subgroups of students was undertaken according to the number of hours (less than 6 hours, 6-10 hours, more than 10 hours) they were involved with the ILS. The Year 5/6 test results were not statistically significant except for the 6-10 hours subgroup where there was a statistically significant gain in scores on Book 2 ($p < 0.05$). The Year 7/8 test results were not statistically significant for Book 2, but were for Book 1 for the less than 6 hours and 6-10 subgroups (the same as they were for the whole group). The scores for the more than 10 hours subgroup were not statistically significant ($p = 0.09$). The ILS progress reports were statistically significant for all year levels and subgroups and this more fine grained analysis also suggested a relatively constant rate of gain independent of number of hours the students were involved with the ILS.

Table 1
Pre- and Posttest Mean Scores and Analysis of Variance of Differences in Mean Scores for Mathematics Achievement and ILS Progress for Years 5/6 and 7/8

Test completed	Number of students	Pre test Mean (SD)	Posttest Mean (SD)	Difference Means	*t* statistic
All students Year 5/6					
Test Book 1	80	10.99 (3.49)	11.46 (3.03)	0.47	1.38
Test Book 2	69	09.75 (3.01)	10.32 (2.87)	0.57	1.58
ILS progress (year levels)	100	03.50 (0.74)	03.86 (0.76)	0.36	14.97**
ILS rate of gain = 0.047 yrs/h					
All students Year 7/8					
Test Book 1	46	14.26 (5.00)	17.11 (5.14)	2.85	5.28**
Test Book 2	35	12.23 (5.12)	11.17 (6.38)	-1.06	-1.03
ILS progress (year levels)	47	04.38 (1.11)	04.82 (1.19)	0.44	9.37**
ILS rate of gain = 0.062 yrs/h					

Note. *$p \leq 0.05$; **$p \leq 0.01$.

With respect to Years 5/6, the Pearson correlation between gain scores for ILS progress and Book 1 was -0.11 and between ILS progress and Book 2 was -0.20, which were not statistically significant. For the Year 7/8 data, the corresponding correlations were -0.03, and -0.08, which were also not statistically significant. This suggests that the tests and ILS may well have measured relatively unrelated aspects of mathematics. Yet analysis of the task objectives of the core mathematics course and the mathematics achievement test tasks showed there was considerable overlap. For example, both the Year 5/6 test and the computation strand of the ILS contained addition, multiplication, subtraction and decimals examples within the range of ability of the particular year levels. A similar degree of overlap was found between the ILS and the Year 7/8 test.

Computer Attitude Survey

Students completed a survey about their attitude to using computers at school pre- and post- their experience with the ILS. Table 2 reports the items of the survey, the mean pretest and posttest scores (standard deviations), difference in mean scores and analysis of variance of difference in mean scores (*t* statistic).

For all items in which the difference in mean scores (Pretest to Posttest) was statistically significant, the posttest mean score is lower than the pretest mean score. The results show statistically significant decreases in mean scores for Item 2 (*Using computers at school is interesting and enjoyable*), Item 5 (*Using computers at school helps me to think and understand better*), Item 8 (*Using computers at school is time well spent*), and Item 12 (*Using computers at school is important for getting a job*). As well, all items showed a decrease in mean scores from pretest to posttest reflecting a general decrease in attitude towards the use of computers in school. The number of statistically significant *t*-tests suggests the results are more than would be expected by chance alone. Nevertheless, because of the possibility of Type 1 errors, caution needs to be exercised in interpretation, in particular those mean differences statistically significant at $p < 0.05$. Item 2 is particularly interesting as it shows a large decrease in finding computers at school as "interesting and enjoyable," pre to post the ILS experience. This is also a relatively large effect of about 0.7 SD which is an educationally significant effect size.

Table 2

Mean Pretest and Posttest Scores, Items and Analysis of Variance of Difference in Mean Scores for Computer Attitude Survey (N=135)

Item	Pre test Mean (SD)	Posttest Mean (SD)	Difference Means	*t*-statistic
Using computers at school:				
helps me do my classwork better.	4.38 (1.52)	4.33 (1.56)	-0.05	1.98
is interesting and enjoyable	5.23 (1.26)	4.19 (1.65)	-1.04	-16.13**
makes me feel more confident about doing my schoolwork	4.32 (1.60)	4.06 (1.56)	-0.26	-1.85
helps me work at my own speed	4.60 (1.58)	4.20 (1.66)	-0.40	-3.58
helps me to think and understand better	4.57 (1.55)	4.12 (1.51)	-0.45	-4.03*
encourages me to learn	4.57 (1.59)	4.07 (1.63)	-0.50	-6.20*
helps me to do my homework better	4.05 (1.85)	3.58 (1.74)	-0.47	-1.11
is time well spent	4.82 (1.50)	4.18 (1.68)	-0.64	-6.61*
makes me feel happier about doing my schoolwork	4.45 (1.60)	4.04 (1.73)	-0.41	-0.31
helps me to make friends.	2.89 (1.78)	2.65 (1.78)	-0.24	-3.24
helps me learn difficult work.	4.57 (1.59)	4.18 (1.73)	-0.39	-2.35
is important for getting a job.	5.26 (1.28)	4.74 (1.61)	-0.52	-4.66*

Note. *$p < 0.05$; **$p < 0.01$.

Attitude to the ILS

Items 1 and 2 of the Student Evaluation Questionnaire respectively asked students to say whether they liked working with the ILS and whether they thought the ILS helped them learn. Each item required an explanation to support their response. Students' responses were categorised as follows in Table 3.

Table 3
Responses to Student Evaluation Questionnaire, Items 1-2 in Terms of Attitude and Learning Belief with Respect to the ILS and School Type (Primary School and Secondary School)

Attitude	Like		Dislike	
Belief	Primary(n=172)	Secondary (n=98)	Primary (n=53)	Secondary (n=51)
Learn	163	81	27	21
Not learn	9	17	26	30

The Log Linear Analysis found two statistically significant interactions between attitude and beliefs about learning (G = 89.64, df = 1, $p \leq 0.001$)and between school type, attitude and belief about learning (G = 6.24, df = 3, $p \leq 0.05$). Irrespective of school type, a significant majority of students liked the ILS and believed that it helped them learn. Furthermore, almost half of the students who disliked the ILS believed that it would help them learn.

Discussion and Conclusions

The crucial question under investigation in this study was: *Does the ILS improve students' mathematics learning outcomes*? To assess the ILS's impact on student learning, data were gathered via the ILS progress reports, pre and post achievement tests, pre and post attitude surveys, and diagnostic interviews. However, rather than clarifying the question under investigation, the data gathered on mathematics achievement, attitude and beliefs, and ILS progress revealed ambivalent findings and raised further questions.

Mathematics Achievement

The ILS progress reports showed that nearly every student made significant gains for all populations in mathematics. However, these statistically significant gains were not matched by gains made in the achievement tests (as for Becker, 1992), although there was one statistically significant result for Book 1 of the Years 7/8 test (as for Underwood et al., 1996). This ambivalence in findings from the achievement tests could be due to the small number of students who completed test, survey and ILS reports before and after the study. It does not seem to be due to differences between items in the tests and items in the ILS worksheets.

However, the following questions do arise with respect to why the ILS in each instance reported a significant gain:

- Does the ILS initially place students at a level below their true ability level and thus "inflating" gains?
- What actually is the ILS measuring when it determines correctness or progress?

The statistically-significant ILS gains were measured in terms of school years. In this investigation, most students gained less than half a year across the two terms of the trial (half a year). Therefore, most students did not progress enough to keep up with time. However, most students in the trial were predominantly low achieving, and many had ILS levels that were half their grade level. Hence, any reasonable gain for these students could be considered educationally significant.

Although the independent achievement tests did not support the ILS progress reports, teachers generally endorsed the ILS as helpful to their students (Baturo et al., 1999; Baturo et al., submitted). However, they were unable to say whether the ILS improvements were transferred to classroom performance. Thus, the following questions emerge with respect to teachers' perceptions of the ILS and with its actual effects:

- Is there any transfer of the ILS success to mathematics performance in the classroom?
- If there is no such transfer, then what is it about the ILS that impresses teachers?

Attitudes and Beliefs

1. One of the major reasons that teachers gave for endorsing the ILS was its perceived effect on affective traits. Teachers believed that it made students more confident, a behaviour which they argued was evidenced through increased participation in classroom discussion, promoted more engagement in the learning process, and improved general classroom behaviour. This belief of the teachers was supported by the questionnaire where 244 students out of 374 gave responses to the questionnaire indicating they liked the ILS and believed it was helping them learn. However, it was not supported by the survey that measured attitudes to computers before and after the trial. This showed few significant gains in affect across the trial but some significant losses, particularly in attitude towards computers. This ambivalence in the findings raises the following question:

- What in the ILS experience makes students like the ILS and believe they are learning?

Teachers tended to endorse the ILS if they felt that their students had "got better" on it. However, "getting better" had a lot of meanings. Differences were discovered at this point. For some teachers, getting better was equated with improved behaviours such as attending to tasks, participating in class discussions, and generally being less disruptive. As one teacher said, "He did more work on the computer in twenty minutes than he has done all day for me!" For other teachers, getting better was improved procedural performance, for example, being able to "do sums" correctly and quickly. For others, it was equated with improved cognitive performance although, as said earlier, all except one teacher were unable to provide specific examples of this. Thus, endorsement was based on a variety of perceived improvements in either the affective or cognitive domains of learning.

Progress Versus Achievement

Most students worked on the ILS for 45 minutes or less per week (8 hours or less over 16 weeks). This is a small time for the ILS to affect attitude and achievement, particularly when compared against the total weekly time spent on mathematics (usually 200-225 minutes in the classrooms studied). However, the ILS did report significant progress, which leads to the following question:

- Is there something in working with the ILS that enables progression to occur through experience with the program rather than through improved knowledge?

The ILS is reminiscent of the Individually Prescribed Instructional (IPI) packages that proliferated in the US in the 1970s with the ILS activities presented in electronic, rather than paper, form. Both systems have a management system which marks students' responses, directs unsuccessful students to other similar activities until "learning" takes place, and directs successful students to another higher level, and the process is repeated continuously. The only real difference between the two systems is that, in any ILS session, activities cover a variety of mathematical topics whereas in any IPI session, activities are presented in finely detailed sequences within the one topic. The pedagogical flaws in IPI systems were exposed by Erlwanger (1975). In a similar analysis of the ILS, Baturo, Cooper and McRobbie (1999) found that it was possible to progress on the ILS in fractions without improving fraction knowledge; a finding that echoed Erlwanger's earlier finding.

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