Using a technology-based learning tool to differentiate instruction Factors influencing student assignment to multi-media learning objects in mathematics[1]

Tim Sibbald
Ontario Institute for Studies in Education
of the University of Toronto

John A. Ross
Ontario Institute for Studies in Education
of the University of Toronto

Cathy Bruce
Trent University

Abstract

Previous research has examined factors influencing teacher decisions to integrate technology using between-teacher designs. This study used a within-teacher design to compare students who were assigned multi-media learning objects for learning fractions with students taught by the same teachers who were not assigned to the technology. There were two conditions: (1) teachers were asked to limit the number of assigned students to 25% of their class (N=375 grade 7-10 students) and (2) teachers could assign as many students as they wanted (N=149 grade 7 students). In the constrained decision setting, students assigned to the technology were more likely than students not assigned to score lower on a fractions achievement test, have dysfunctional attitudes toward mathematics learning, have low self-efficacy, exert low effort, and be male. In the unconstrained decision setting 70% of students were assigned the technology and the only statistically significant predictor was prior achievement. Teachers' criteria were congruent with research identifying correlates of mathematics achievement and comfort with technology.

[1] Paper presented at the annual meeting of the Canadian Society for the Study of Education, Ottawa, May 2009. To appear in the *Journal of Computer Assisted Learning*. The research was funded by grants from the Ontario Ministry of Education, Math GAINS initiative. The views expressed in the paper do not necessarily represent those of the Ministry. Send comments to Dr. John A. Ross, Professor & Field Centre Head, OISE/UT Trent Valley Centre, Box 7190, 1994 Fisher Dr., ON K9J 7A1.

Introduction

Researchers investigating the integration of technology into classroom instruction have searched for factors influencing classroom use. For example, Tondeur, Valcke, and van Braak (2008) identified structural and cultural factors operating at the school and teacher level that influenced instructional uses of technology. In our research we continued the search for factors influencing teacher decision making, examining one type of use (the computer as a learning tool) in one subject (mathematics). We focused on the use of computers as a learning tool because classroom integration of technology promotes deeper understanding of mathematical concepts, makes instruction more student-centered, provides students with realistic mathematical experiences, promotes student reflection through interactive feedback, and broadens epistemological authority in the classroom (Heid, 1997).

Previous studies report positive effects for differentiated instruction (Mastropieri et al., 2005; Odgers, Symons, & Mitchell, 2000; Reis et al., 2007). Differentiation of instruction has multiple meanings, ranging from variations in instructional materials (e.g., Mastropieri et al., 2005) to a network of plug-in programs, assessments, multiple lesson preparations and shared teaching (e.g., Valli & Buese, 2007). In our study technology was used to differentiate instruction at three levels identified by McTighe and Brown (2005): the software addressed essential skills not mastered by a portion of the class; presented content in a way not previously encountered by students; and tightened alignment of assessment and instruction.

We selected as our domain of learning part-whole relationships (fractions) because students have difficulty learning fraction concepts (National Assessment of Educational Progress, 2005), these difficulties persist into adulthood (Reyna & Brainerd, 2007), failures of understanding have negative consequences for adult health (Estrada, Martin- Hryniewicz, Peek, Collins, & Byrd, 2004) and threaten performance in careers such as pediatric nursing (Grillo, Latif, & Stolte, 2001).

Methodologically, we chose a different approach than that of previous research in the field. First, we identified within-teacher factors rather than between-teacher influences. We investigated why teachers assigned some students but not others to technology. In contrast, researchers typically identify factors that discriminate teacher users of technology from non-users (Meelissen & Drent, 2008) or differentiate teachers at different levels of use (Oncu, Delialioglu, & Brown, 2008). Second, we inferred teachers' decision-making by examining the decisions they made about individual students. We compared the characteristics of students assigned to the technology to students, taught by the same teachers, who were not given access to the resource. In contrast, most researchers surveyed or interviewed teachers about their integration of technology, searching for associations between technology practices and teacher characteristics (e.g., Forgasz, 2006).

Our conceptual framework is based on the concentric circles model developed by Veenstra, adapted by several European researchers to investigate student and teacher attitudes to technology. In the innermost circle of the model is the dependent variable, student achievement (Veenstra & Kuyper, 2004), student attitudes to computers (Meelissen & Drent, 2008) or teacher attitudes to technology integration (Drent & Meelissen, 2008; Tondeur et al., 2008). The next set of circles identifies student characteristics that influence the dependent variable. For example, student attitudes toward computers are influenced by general student characteristics such as personal experiences with computers, characteristics of family interaction such as parent use of computers, and student structural characteristics such as gender. The outermost circles identify teacher and school influences on the dependent variable. For example, student attitudes toward computers are influenced by cultural teacher characteristics such as teaching style, structural teacher characteristics such as teachers' personal experience with computers, cultural school characteristics such as school policies on computer integration, and contextual characteristics of schools such as demographics of the student population served by the school. In our study, the dependent variable in the innermost circle was access to fractions learning software. We investigated factors from the student level (general and structural student characteristics) as potential predictors of whether students were assigned the technology.

Background

The Learning Resource

The Ontario (Canada) Ministry of Education developed online learning activities in fractions to support struggling Grade 7-10 learners. CLIPS (Critical Learning Instructional Paths Supports) is a set of learning objects, i.e., "interactive web-based tools that support the learning of specific concepts by enhancing, amplifying, and guiding the cognitive processes of learners" (Kay & Knaack, 2007, p. 6). The Ministry design team drew upon research on teaching fractions (particularly Gould, Outhred, & Mitchelmore, 2006; Moss & Case, 1999; Streefland, 1993) to develop interactive activities addressing student deficits identified through a needs assessment that integrated student achievement data, teacher perceptions, and student self-efficacy (Ross, Ford, & Bruce, 2007).

Students begin by viewing a video which shows why students should care about fractions. Students are presented with a menu of five sets of activities: (i) representing simple fractions; (ii) forming and naming equivalent fractions; (iii) comparing simple fractions; (iv) forming equivalent fractions by splitting or merging parts; and (v) representing improper fractions as mixed numbers. Within each set of activities there are introductory instructions, interactive tasks, consolidation quizzes and extension activities. The CLIPS provide lessons of 20-40 minutes per day for five days but each can stand alone and teachers may assign less than five on the basis of their assessment of student needs.

The fractions CLIPS are available at: http://oame.on.ca/CLIPS/index.html. Previous research found that completion of the fractions CLIPS contributed to student achievement (Ross & Bruce, in press) and that student success was enhanced when enabling conditions were in place (Bruce & Ross, 2009).

Factors Affecting Student Assignment to CLIPS

Teachers could assign particular students to all, some or none of the five CLIPS. To identify potential predictors of their decisions we examined recent research that seeks to explain why some teachers integrate computers into their classrooms while others do not (Forgasz, 2006), why some teachers use computers more frequently than others (Hermans, Tondeur, van Braak, & Valcke, 2008; Mueller, Wood, Willoughby, Ross, & Specht, 2008; Wood, Mueller, Willoughby, Specht, & Deyoung, 2005), why there is a gap between teachers' commitment to technology integration and their observed practice (Chen, 2008; Deaney, Ruthven, & Hennessy, 2006), influences on a teacher's decision to implement a deep rather than superficial use of technology (Drent & Meelissen, 2008; Goos & Bennison, 2007; Tondeu et al., 2008; Wozney, Venkatesh, & Abrami, 2006**),** and factors which predict a teacher's placement on an evolutionary scale of use (Hsu, Wu, & Hwang, 2007; Oncu et al., 2008).

Themes that emerged from investigations conducted ten and twenty years ago re-appear in current studies: Teachers are more likely to integrate technology into their instruction if there is a good fit with their beliefs, experience, and curricular goals. Wozney et al. (2006) drew on expectancy-value theory (Vroom, 1964) to integrate the findings from this research into a parsimonious explanation: teachers use technology when they expect to be successful (a function of prior experience with computers, attitudes to technology, computer self-efficacy and low computer anxiety); when they value the curriculum outcome (a function of pedagogical beliefs such as constructivist learning); and the cost is perceived to be reasonable (a function of access to hardware, software, and training). The implication for our study is that when teachers use technology to differentiate instruction the key factor determining whether a student is assigned CLIPS will be the teacher's perception of that student's learning need. We provided teachers with an achievement test that measured the learning objectives addressed by the software. We anticipated that students scoring low on the test would be more likely than high scorers to be assigned to CLIPS.

We reviewed recent literature on student factors that predict technology outcomes such as student performance, attitudes, anxiety, self-confidence, and use. We again found themes familiar to readers of earlier research. Computer experience, computer self-efficacy, and positive computer attitudes continued to predict computer expertise and use (Durndell & Haag, 2002; Bovee, Voogt, & Meelissen, 2007; Morahan-Martin & Schumacher, 2007; Joiner, Brosnan, Duffield, Gavin, & Maras, 2007). Gender differences are weaker now than in the past. Some researchers continued to report gender differences favoring males over females across all computer outcomes (Meelissen & Drent, 2008; Oosterwegel, Littleton, & Light, 2004; Morahan-Martin & Schumacher, 2007), while others found that gender differences were non-existent (Bovee et al., 2007; Jennings & Onwuegbuzie, 2001), salient for one outcome or age group but not others (Christensen, Knezek, & Overall, 2005; Hargittai & Shafer, 2006; Joo, Bong, & Choi, 2000), or decreasing in size (Schumacher & Morahan-Martin, 2001). The implication for our study is that teachers might consider student attitudes, experience and self-confidence when deciding whether to assign students to CLIPS. Although gender differences with regard to computer attitudes, use and outcomes appear to be declining, we anticipated that teachers would be more likely to assign males than females to CLIPS.

Finally, we reviewed studies examining relationships among students' beliefs and mathematics achievement. We found strong and consistent relationships between achievement and students' beliefs about themselves as learners: Students with higher math self-efficacy are more likely than students with lower self-efficacy to perform well in mathematics (Borman & Overman, 2004; Lee, 2006; Ryan, Ryan, Arbuthnot, & Samuels, 2007; Stevens, Olivarez, Lan, & Tallent-Runnels, 2004). Students with dysfunctional beliefs about mathematics and mathematics learning (e.g., that learning occurs quickly or not at all) have lower achievement (Schommer-Aitkins, Duell, & Hunter, 2005), while those with functional beliefs (e.g., that you can learn from other students as well as the teacher) score higher (Mason, 2003; Mason & Scrivani, 2004; Muis, 2004). We anticipated that teachers would consider these variables when deciding which students to assign to CLIPS, although the direction of influence was unknown.

In summary, we predicted that teachers' decisions to assign students to CLIPS would be influenced by student characteristics. We anticipated that the primary consideration would be the fit between students' learning needs and the content of the software. We speculated that teachers would assign more boys to CLIPS than girls, because boys are perceived to be more comfortable with computers than girls. We further anticipated that teachers would be influenced by student beliefs about themselves, technology and mathematics. We decided to focus on attitudes toward mathematics rather than to technology because teachers in our experience are more concerned with students' views toward the former than the latter. Previous research has found that student attitudes toward computers are similar to student attitudes toward mathematics (Vale & Leder, 2004).

Purpose

The purpose was to identify student factors influencing teacher decisions to assign students to technology that taught understanding of fractions. Our study differed from previous investigations in that we focused on within- rather than between-teacher factors and we inferred teacher decision-making by comparing students who were assigned to the software to students who were not. We searched for student factors in two conditions: when the number of students who could be assigned to CLIPS was limited and when it was not. The first condition simulated a school context in which teachers had access to a small number of computers in their classroom; the second condition simulated a lab condition in which a whole class could be accommodated.

Methodology

Participants

We drew samples from two school districts serving students from the same geographic area. We removed classrooms in which teachers assigned CLIPS to all students or none, leaving classrooms where CLIPS was used to differentiate instruction. The public school sample consisted of 375 grade 7-10 students assigned by 14 teachers to CLIPS (N=91) or no-CLIPS conditions (N=284). Teacher choice was constrained by our recommendation to teachers that they assign 25% of their students to CLIPS: 25% of students in the constrained condition were assigned CLIPS.

The Catholic district sample consisted of 149 grade 7 students assigned by eight teachers to CLIPS (N=105) or no-CLIPS conditions (N=44). Teacher choice was unconstrained: we recommended that teachers assign CLIPS to as many students as might benefit from the software: 70% of the students in the unconstrained condition were assigned to CLIPS.

Both districts served a student population in which 98-99% were Canadian born, 1% spoke a language other than English at home, 24-26% were identified as having special needs, and average family income was near the mean for the province of Ontario.

Instruments

Teachers recorded the number of CLIPS completed by each student. Students who completed at least one were in the *CLIPS condition*; those who completed none were coded as *no-CLIPS*.

Student Achievement was measured with ten fractions items drawn from the PRIME placement tests for Number and Operations (PRIME, 2005) that matched the provincial curriculum. Teachers used the PRIME rubric to assign 0-2 scores to each item. The achievement variable was the mean item score assigned by teachers. All items were independently remarked by a team of trained markers. Chance-adjusted agreement was high between teachers and trained markers (Kappa=.76 and .80 for the two samples) and among the trained markers (Kappa=.86 and .95).

Students completed a survey that produced seven variables. *Math self-efficacy* consisted of eight Likert items measuring expectations about future mathematics performance (from Ross, Hogaboam-Gray, & Rolheiser, 2002; e.g., "as you work through a math problem how sure are you that you can…explain the solution"). There were six response options, anchored by "not sure" and "really sure". *Functional beliefs about mathematics learning* consisted of five statements about participating in mathematical discussions adapted from Jansen (2006) and four items from Schoenfeld (1985). The items were Likert scales; e.g., "If you are there throwing out your ideas, you could find a new way of doing a math problem." with six response options, anchored by "strongly agree" and "strongly disagree". *Dysfunctional beliefs about mathematics learning* consisted of eight items from Schommer-Aitkins et al. (2005) measuring belief in quick/fixed learning (i.e., that learning occurs quickly or not at all and that intelligence is fixed rather than incremental); e.g., "If I cannot understand something quickly, it usually means I will never understand it." There were six response options, anchored by "strongly agree" and "strongly disagree". *Fear of failure* consisted of six items (e.g., "I worry a lot about making errors on my math work") from Turner, Meyer, Midgley, and Patrick (2003). There were six response options, anchored by "not at all true" and "very true". *Effort* was measured with eight items from Ross et al., 2002 (e.g., "how hard do you study for your math tests?"). There were six response options, anchored by "not hard at all" and "as hard as I can". Students reported their *gender* and *grade* (7-10).

Analysis

After establishing the reliability of the measures used in the study, we used multivariate analysis of variance and cross tabs to identify predictors of teacher decisions to assign CLIPS to particular students. We followed with binomial logistic regression to estimate the percentage of students accurately placed by student characteristics into CLIPS and no-CLIPS groups. Logistic regression is of three types: binomial (when the dependent variable is dichotomous), multinomial (when the dependent is nominal with more than two categories), and ordinal (when the dependent variable is rank order scores). In logistic regression maximum likelihood estimates are applied to the dependent variable after it is transformed into a logit variable (the natural log of the odds of an event occurring or not) (Garson, n.d.).

Results

Reliability of Data

Tables 1 and 2 display the mean item scores, standard deviations, and reliability of study variables for CLIPS and no-CLIPS students. In both samples the internal consistencies of the variables were acceptable (i.e., Cronbach's alpha=.70+) except for functional beliefs about mathematics learning which was marginal (alpha=.64 and .61). All variables were normally distributed: skewness and kurtosis were less than 1.0. The last row of each table displays the distribution of each gender to CLIPS and no CLIPS conditions; Table 1 shows that 29% of the males in the sample were assigned to CLIPS and 71% of males were not, while 19% of females were assigned and 81% were not.

Table 1 Means, Standard Deviations, and Reliability of Study Variables for CLIPS and N0-CLIPS students in the Constrained Decision Condition

	Alpha	CLIPS (N=91)		No-CLIPS (N=284)	
		Mean	SD	Mean	SD
Student achievement	.71	0.97	.43	1.53	.37
Math self-efficacy	.85	3.58	.87	4.31	.85
Functional beliefs about math	.64	3.59	.84	3.79	.93
Quick/fixed learning	.81	2.59	.96	2.37	.87
Fear of failure	.81	3.05	1.19	3.13	1.06
Effort	.86	3.90	1.05	4.27	.86
Gender		29% male, 19% female		71% male, 81% female	

Table 2 Means, Standard Deviations, and Reliability of Study Variables for CLIPS and N0-CLIPS students in the Unconstrained Decision Setting

	Alpha	CLIPS (N=105)		No-CLIPS (N=44)	
		Mean	SD	Mean	SD
Student achievement	.78	1.39	.51	1.58	.43
Math self-efficacy	.88	4.22	.89	4.39	.88
Functional beliefs about math	.61	4.20	.82	4.47	.76
Quick/fixed learning	.82	2.21	.99	2.02	.85
Fear of failure	.81	3.41	1.01	3.51	.88
Effort	.89	4.20	.92	4.35	.80
Gender		70% male; 71% female		29% male; 30% female	

Students Assigned to CLIPS in the Constrained Decision Setting

We conducted a multivariate analysis of variance using GLM in SPSS 16.0. The dependent variables were the continuous student variables identified as possible predictors of teacher decisions to assign students to CLIPS: Student achievement, mathematics self-efficacy, functional beliefs about math, dysfunctional beliefs about mathematics (quick versus fixed learning), fear of failure, and effort. The independent variable was CLIPS versus no-CLIPS condition.

There was a statistically significant relationship between student characteristics and teacher assignments to CLIPS [$F(6,352)=23.56$, $p<.001$] in the multivariate analysis. The top panel of Table 3 shows that four of the six univariate relationships were statistically significant. The strongest relationship (27% of the variance) was student achievement: teachers were more likely to assign students to CLIPS if they performed poorly on the fractions test. The median score on the achievement pretest for all CLIPS users was 9 out of 20. The proportion of students who received CLIPS declined from 40% of those given low scores on the pretest (0-7), to 29% of those with medium scores (8-11), to 8% of those with high scores (12-20).

Table 3 Relationships Between Assignment to CLIPS and Student Attributes, in Constrained and Unconstrained Decision Settings

Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta^2	Observed Power
Teacher Decisions Constrained							
math self efficacy	33.72	1	33.72	45.74	<0.001	0.11	1.00
beliefs about math	2.60	1	2.60	3.15	0.077	0.01	0.42
quick fixed learning	3.29	1	3.29	4.17	0.042	0.01	0.53
fear of failure	0.52	1	0.52	0.44	0.508	0.00	0.10
effort	8.76	1	8.76	10.56	0.001	0.03	0.90
achievement	19.54	1	19.54	132.31	<0.001	0.27	1.00
Teacher Decisions Unconstrained							
math self efficacy	2.61	1	2.61	3.58	0.061	0.03	0.47
beliefs about math	2.35	1	2.35	3.69	0.057	0.03	0.48
quick fixed learning	0.76	1	0.76	0.83	0.363	0.01	0.15
fear of failure	0.00	1	0.00	0.00	0.948	0.00	0.05
effort	1.03	1	1.03	1.37	0.244	0.01	0.21
achievement	1.01	1	1.01	4.22	0.042	0.03	0.53

Although teachers had access only to the achievement data, they had knowledge of their students from everyday interactions that corresponded to the surveys we administered. There was a strong effect for student beliefs about themselves: students with low mathematical self-efficacy were more likely than students with high scores to be assigned CLIPS (11% of the variance). Students who reported that they exerted low effort in math class were more likely than others to be assigned to the technology. Students with high scores on the dysfunctional beliefs measure, in contrast with those with low scores, were more likely to be assigned to CLIPS. The other variables in the analysis (functional beliefs about math learning and fear of failure) were not statistically significant. Both these variables were significantly correlated with dysfunctional beliefs about mathematics: functional beliefs [$r=-.33$] and fear of failure [$r=.32$]. It is likely that the shared variance was taken by the stronger predictor of CLIPS group membership (dysfunctional beliefs). The last column of Table 3 shows that observed power for these variables was well below the .80 required to detect a statistically significant relationship.

To examine the relationships between CLIPS and non-continuous variables (gender and grade) we conducted cross-tabs of each student characteristic with CLIPS assignment. There was a statistically significant gender effect [$\chi^2(1,374)= 4.38$, p=.036]: males were more likely to be assigned to CLIPS than females. Grade (7-10) was not a statistically significant factor [$\chi^2(4,371)= 7.66$, p=.105].

In summary, students were more likely to be assigned to technology if they were performing poorly on the learning objectives addressed by the resource, if they were male, and if they held beliefs about themselves and mathematics learning that were impediments to success.

Students Assigned CLIPS in the Unconstrained Decision Setting

The second sample differed from the first: they were in Catholic rather than public schools; they were all grade 7 students; and there was no limit on the number of students that could be assigned to CLIPS. We conducted the same analysis as for the first sample, producing weaker results. The multivariate results showed no significant relationship between student characteristics and membership in CLIPS and no-CLIPS groups [$F(6,132)=1.16$, p=.334].

The bottom panel of Table 3 displays univariate results. Only student achievement was significantly related to teacher decisions to assign students to CLIPS. As in the constrained decision setting, students with low scores on the fractions test were more likely than students with high scores to be assigned to CLIPS. None of the other relationships were statistically significant. In the cross-tabs, males were no more likely than females to be assigned CLIPS [$\chi^2(1,148)= 1.001$, p=.971].

Re-analysis

We repeated the analysis using a binomial logistic regression in which student characteristics were entered as predictors of the dependent variable, CLIPS versus no-CLIPS assignment. After deleting two variables to reduce multicollinearity, we entered as predictors: gender, grade, mathematics as quick/fixed learning, fear of failure, effort, and fractions achievement. When all six predictor variables were in the equation, 39% of the variance in CLIPS assignment was explained. Four of these variables were statistically significant predictors when considered in isolation: fixed/quick learning (p=.042), effort (p=.001), achievement (p<.001), and gender (p=.041). Students were more likely to be assigned CLIPS if they had low fractions achievement, dysfunctional beliefs about math learning, reported exerting low effort on mathematical tasks or were male. However, the left panel of Table 4 shows that when all the predictors were entered into the model simultaneously, only achievement was statistically significant. The table shows that the odds of being assigned CLIPS decreased for every unit increase of the achievement pretest (i.e., low achieving students were more likely to be assigned CLIPS). The model predicted 43% of those who were assigned CLIPS and 95% of students who were not, compared to 25% and 75% that could be predicted by chance.

We deleted two variables from the second sample due to multicollinearity. The variables in the logistic regression were: gender, math as quick/fixed learning, fear of failure, effort, and fractions achievement. Only achievement (p=.018) was a statistically significant factor when entered separately. The other variables were not statistically significant predictors. The right panel of Table 4 shows that when all the predictors were entered into the model simultaneously, only the achievement score was statistically significant. The odds ratio shows decreased likelihood of receiving CLIPS for each increase in achievement. The model predicted 99% of those who were assigned CLIPS and 6% of students who were not, compared to 70% and 30% that could be predicted by chance.

Table 4 Logistic Regression Predicting Which Students will be Assigned CLIPS

	Constrained Decision Setting			Unconstrained Decision Setting		
	B	Sig.	Odds Ratio	B	Sig.	Odds Ratio
quick/fixed learning	-0.02	0.92	0.98	0.20	0.42	1.22
fear of failure	-0.06	0.68	0.94	0.02	0.94	1.02
effort	-0.16	0.35	0.85	-0.36	0.20	0.70
Achievement	-0.33	<0.01	0.72	-1.54	0.02	0.21
Gender	-0.44	0.15	0.64	0.30	0.52	1.34
Grade	0.22	0.24	1.25	NA	NA	NA
Constant	4.01	<0.01	54.91	4.05	0.03	57.44

NA=Not Applicable (all students were in grade 7)

Discussion

Key Findings

Our main finding is that teachers used technology to differentiate instruction, selecting those students whose needs best fit the affordances of the software. We were able to infer three influences on teacher decision-making: The most important was students' learning need: teachers assigned to CLIPS students who had not mastered core fractions concepts. Teachers may have done so because the CLIPS activities constituted a rigorous, research-based learning sequence (Gould et al., 2006; Moss & Case, 1999; Streefland, 1993). Closely related to achievement deficits were deficiencies in student beliefs. Teachers assigned students that had lower mathematics self-efficacy, held dysfunctional beliefs about mathematics learning, and reported exerting low effort in mathematics class, than students not assigned to CLIPS. These three variables constitute a cluster of beliefs that inhibit persistence. Students with low self-efficacy do not persist because they believe that exerting effort will not increase their likelihood of success (Bandura, 1997). Fear of failure contributes to performance avoidance (Elliot & Muryama, 2008); i.e., students are less likely to engage in an activity if they are worried they will perform poorly on it. Persistence is also unlikely with students who believe that success in mathematics class comes quickly or not at all and that some are endowed with the ability to do mathematics while others are not (Schommer-Atkins et al., 2005; Shoenfeld, 1985). Teachers may have believed that students' dysfunctional beliefs about themselves and mathematics learning could be overcome by two features, graphics and interactivity, that were central to CLIPS; students find these features of learning objects particularly motivating (Kay & Knaak, 2007). Finally teachers were more likely to assign males than females to CLIPS. Recent research, although mixed, continues to demonstrate males have more experience and are more comfortable with technology than females (Meelissen & Drent, 2008; Oosterwegel et al., 2004; Morahan-Martin & Schumacher, 2007).

Our second finding is that student characteristics were much stronger predictors in the constrained decision making condition in which the number of students that could be assigned to CLIPS was limited, than in the condition in which teachers could assign as many students as they wanted. In the unconstrained condition the only statistically significant predictor was prior student achievement: Teachers were more likely to assign students to CLIPS who performed poorly on the fractions achievement test. More students in the Catholic sample may have been assigned CLIPS because all students in this condition were in grade 7 where fractions are more central than in the higher grades included in the public school sample.

Our third finding was methodological: we were able to capture the decision making policies of teachers by analyzing the characteristics of students who were assigned to technology. This approach complements the predominant research paradigm which examines teacher characteristics to explain technology use in between-teacher designs. We also found it helpful to analyze the data in two ways: with student characteristics as dependent in MANOVA and then with teacher decisions as dependent in logistic regression. More factors were significant in the MANOVA because it has greater statistical power than regression. Examining teacher decisions in two decision conditions, constrained and unconstrained, was also helpful.

Directions for Future Research

Kim and Reeves (2007) categorized technology by its purpose, classifying cognitive technology tools in terms of their distribution of executive control of student production among the tool, the user, and the environment. In Kim and Reeves'taxonomy, the context for our study was (i) a domain-specific learning tool in which (ii) executive control of student thinking was largely distributed from the learner to the software and (iii) there was relatively little interaction between teacher and student after the software had been assigned. Researchers need to examine whether the student characteristics that influenced teachers' assignment of students to software in the current study will generalize to other contexts identified by Kim and Reeves, such as the use of (i) generic learning tools, (ii) with varying distributions of executive control among tool, student and learning environment, and (iii) with varying levels of interaction among student, teacher and other learners. For example, we anticipate that the direction of the predictors we identified for CLIPS might reverse if we examined teachers' decisions to assign students to dynamic modeling tools such as StarLogo (Resnick, 1996). Teachers might assign students who were high achievers, confident of their abilities, with functional attitudes toward the discipline, and persistent because the StarLogo technology requires high levels of executive control by students.

The second direction for future research is methodological. Researchers need to conduct investigations in which they examine the effect on teachers' differentiation decisions of variables drawn from multiple levels Veenstra's concentric circles model (as adapted by Meelissen & Drent, 2008), including teacher and student characteristics in nested models. To use multilevel modeling in the analysis a larger number of teachers would be required, at least 40 based on the power analysis of Bloom, Richburg-Hayes and Black, 2007. It would be helpful to include a measure of students' attitudes to learning mathematics with technology (Pierce, Stacey, & Barkatsas, 2007 looks promising) as well as measures of teacher beliefs about the value of technology integration, teachers' confidence in their ability to use technology well, and their perception of its costs.

Conclusion

This study is a good news story, with a concern. A particular technology, fractions CLIPS, contributed to teachers' ability to differentiate instruction, a practice that school improvement proponents strongly recommend. The criteria that guided teachers' decision-making, inferred from the characteristics of students who completed CLIPS, were compatible with research findings. The most important consideration was students' learning needs, based on a valid and reliable achievement test. Particularly noteworthy was the finding that teachers assessed student performance accurately, as shown by high levels of agreement with an expert panel of markers. Inconsistency in assessment could lead to inaccurate instructional placement which would reduce the benefits of formative assessment. Teachers assigned students with beliefs and habits that inhibited persistence through learning obstacles.

Teachers assigning more males than females to CLIPS is a concern, but predictable given research indicating that males continue to be more comfortable with technology than females. However, gender differences in comfort with technology are shrinking, simultaneously with gender differences in mathematics achievement. The latter have virtually vanished in Canada, with females achieving as well males on most assessments (Lloyd, Walsh, & Yailagh, 2005). This is an equity issue: In our previous research (Ross & Bruce, 2008) we found that females learned as much as males from CLIPS. Denying females access to software that contributes to their learning is deeply unfair.

The persistent research focus on why some teachers, and not others, integrate technology is not yielding new information or insights. What is yielding new information is the examination of conditions that contribute to a good fit of the affordances of particular technologies to students' needs. The implication for future research is that a shift is required to conducting studies that reveal decision-making factors related to student use of technology and learning objects, and the outcomes of these decisions.

References

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman.

Bloom, H. S., Richburg-Hayes, L., & Black, A. R. (2007). Using covariates to improve precision for studies that randomize schools to evaluate educational intentions. *Educational Evaluation and Policy Analysis, 29*(1), 30-59.

Borman, G. D., & Overman, L. T. (2004). Academic resilience in mathematics among poor and minority students. *Elementary School Journal, 104*(3), 177-195.

Bovee, C., Voogt, J., & Meelissen, M. (2007). Computer attitudes of primary and secondary students in South Africa. *Computers in Human Behavior, 23*(4), 1762-1776.

Bruce, C. D., & Ross, J. A. (2009). Conditions for effective use of interactive on-line learning objects: The case of a fractions computer-based learning sequence. *Electronic Journal of Mathematics and Technology* [Online Series], 3(1), 12-29.

Chen, C.-H. (2008). Why do teachers not practice what they believe regarding technology integration? *Journal of Educational Research, 102*(1), 65-75.

Christensen, R., Knezek, G., & Overall, T. (2005). Transition points for the gender gap in computer enjoyment. *Journal of Research on Technology in Education, 38*(1), 23-37.

Deaney, R., Ruthven, K., & Hennessy, S. (2006). Teachers' developing 'practical theories' of the contribution of information and communication technologies to subject teaching and learning: an analysis of cases from English secondary schools. *British Educational Research Journal, 32*(3), 459-480.

Drent, M., & Meelissen, M. (2008). Which factors obstruct or stimulate teacher educators to use ICT innovatively? *Computers and Education, 51*, 187-199.

Durndell, A., & Haag, Z. (2002). Computer self efficacy, computer anxiety, attitudes towards the Internet and reported experience with the Internet, by gender, in an East European sample. *Computers in Human Behavior, 18*(5), 521-535.

Elliot, A. J., & Murayama, K. (2008). On the measurement of achievement goals: Critique, illustration, and application. *Journal of Educational Psychology, 100*(3), 613-628.

Estrada, C. A., Martin-Hryniewicz, M., Peek, B. T., Collins, C., & & Byrd, J. C. (2004). Literacy and numeracy skills and anticoagulation control. *American Journal of the Medical Sciences, 328*, 88-93.

Forgasz, H. (2006). Factors that encourage or inhibit computer use for secondary mathematics teaching. *Journal of Computers in Mathematics and Science Teaching, 25*(1), 77-93.

Garson, G.D. (n.d.). "Title of Topic", from *Statnotes: Topics in Multivariate Analysis.* Retrieved 04/14/2009 from http://www2.chass.ncsu.edu/garson/pa765/statnote.htm.

Goos, M., & Bennison, A. (2007). *Technology-enriched teaching of secondary mathematics: Factors influencing innovative practice*. Paper presented at the Proceedings of the 30th annual conference of the Mathematics Education Research Group of Australasia, Sydney.

Gould, P., Outhred, L., & Mitchelmore, M. (2006). *One-third is three quarters of one-half.* Paper presented at the annual meeting of the Mathematics Education Research Group of Australia, Australia.

Grillo, J. A., Latif, D. A., & Stolte, S. K. (2001). The relationship between preadmission indicators and basic math skills at a new school of pharmacy. *The Annals of Pharmacotherapy, 35*(2), 167-172.

Hargittai, E., & Shafer, S. (2006). Differences in actual and perceived online skills: The role of gender. *Social Science Quarterly, 87*(2), 432-448.

Heid, M. K. (1997). The technological revolution and the reform of mathematics. *American Journal of Education, 106*, 5-61.

Hermans, R., Tondeur, J., van Braak, J., & Valcke, M. (2008). The impact of primary school teachers' educational beliefs on the classroom use of computers. *Computers in Education, 51*, 1499-1509.

Hsu, Y.-S., Wu, H.-K., & Hwang, F.-K. (2007). Factors influencing junior high school teachers' computer-based instructional practices regarding their instructional evolution stages. *Educational Technology & Society, 10*(4), 118-130.

Jansen, A. (2006). Seven graders' motivations for participating in two discussion-oriented mathematics classrooms. *Elementary School Journal , 106*(5), 409-4028.

Jennings, S. E., & Onwuegbuzie, A. J. (2001). Computer attitudes as a function of age, gender, math attitude, and developmental status. *Journal of Educational Computing Research, 25*(4), 367-384.

Joiner, R., Brosnan, M., Duffield, J., Gavin, J., & Maras, P. (2007). The relationship between Internet identification, Interner anxiety and Internet use. *Computers in Human Behavior, 23*(3), 1408-1420.

Joo, Y.-J., Bong, M., & Choi, H.-J. (2000). Self-efficacy for self-regulated learning, academic self-efficacy, and internet self-efficacy in web-based instruction. *Educational Technology Research and Development, 48*(2), 5-17.

Kay, R. H., & Knaack, L. (2007). Evaluating the learning in learning objects. *Open Learning, 22*(1), 5-28.

Kim, B., & Reeves, T. C. (2007). Reframing research on learning with technology: In search of the meaning of cognitive tools. *Instructional Science, 35*(3), 207-256.

Lee, J. (2006, April). *Effects of noncognitive variables on mathematics performance among U.S. students using PISA 2003 data.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Lloyd, J. E. V., Walsh, J., & Yailagh, M. S. (2005). Sex, differences in performance attributions, self-efficacy, an achievement in mathematics: If I'm so smart, why don't I know it. *Canadian Journal of Education*, *28*(3), 384-408.

Mason, L. (2003). High school students' beliefs about math, mathematical problem-solving, and their achievement in math: a cross-sectional study. *Educational Psychology, 23*, 73-85.

Mason, L., & Scrivani, L. (2004). Enhancing students' mathematical beliefs: An intervention study. *Learning and Instruction, 14*, 153-176.

Mastropieri, M. A., Scruggs, T. E., Norland, J. J., Berkeley, S., McDuffie, K., Tornquist, E. H., & Connors, N. (2006). Differentiated curriculum enhancement in inclusive middle school science: Effects on classroom and high-stakes tests. *The Journal of Special Education, 40*(3), 130-137.

McTighe, J., & Brown, J. L. (2005). Differentiated instruction and educational standards: is détente possible? *Theory into Practice, 44*(3), 234-244.

Meelissen, M. R. M., & Drent, M. (2008). Gender differences in computer attitudes: Does the school matter? *Computers in Human Behavior, 24*, 969-985.

Morahan-Martin, J., & Schumacher, P. (2007). Attitudinal and experiential predictors of technological expertise. *Computers in Human Behavior, 23*(5), 2230-2239.

Moss, J., & Case, R. (1999). Developing children's understanding of the rational numbers: A new model and an experimental curriculum. *Journal for Research in Mathematics Education, 30*(2), 122-148.

Mueller, J., Wood, E., Willoughby, T., Ross, C., & Specht, J. (2008). Identifying discriminating variables between teachers who fully integrate computers and teachers with limited integration. *Computers and Education, 51*, 1523-1537.

Muis, K. (2004). Personal epistemology and mathematics: A critical review and synthesis of research. *Review of Educational Research, 74*(3), 317-378.

Murdock, T. B., & Miller, A. (2003). Teachers as sources of middle school students' motivational identity: Variable-centered and person-centered analytic approaches. *Elementary School Journal, 103*(4), 383-400.

National Assessment of Educational Progress. (2005). *Online assessment in mathematics. Report from the NAEPtechnology-based assessment project, Research and development series*. Retrieved January 29, 2008, from http://nces.ed.gov/nationsreportcard/pdf/studies/2005457.pdf

Odgers, S., Symons, A., & Mitchell, I. (2000). Differentiating the curriculum through the use of problem solving. *Research in Science Education, 30*, 289-300.

Oncu, S., Delialioglu, O., & Brown, C. A. (2008). Critical components for technology integration: How do instructors make decisions? *Journal of Computers in Mathematics and Science Teaching, 27*(1), 19-46.

Oosterwegel, A., Littleton, K., & Light, P. (2004). Understanding computer-related attitudes through an idiographic analysis of gender- and self-representations . *Learning and Instruction, 14*(2), 215-233.

Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers and Education, 48*(2), 285-300.

PRIME (Professional Resources and Instruction for Mathematics Educators). (2005). *Number and Operations Diagnostic Tests*. Toronto: Thomson Nelson.

Reis, S. M., McCoach, D. B., Coyne, M., Schreiber, F. J., Eckert, R. D., & Gubbins, E. J. (2007). Using planned enrichment strategies with direct instruction to improve reading fluency, comprehension, and attitude toward reading: An evidence-based study. *Elementary School Journal, 108*(1), 3-23.

Resnick, M. (1996). Beyond the centralized mindset. *The Journal of the Learning Sciences, 5*(1), 1-22.

Reyna, V. F., & Brainerd, C. J. (2007). The importance of mathematics in health and human judgment: Numeracy, risk communication, and medical decision making. *Learning and Individual Differences, 17*(2), 147-159.

Ross, J. A., & Bruce, C. D. (in press). Student achievement effects of technology-supported remediation of understanding of fractions. *International Journal of Mathematical Education in Science and Technology*.

Ross, J. A., Ford, J., & Bruce, C. D. (2007). Needs assessment for the development of learning objects. *Alberta Journal of Educational Research.*, *53*(4), 430-433.

Ross, J. A., Hogaboam-Gray, A., & Rolheiser, C. (2002b). Student self-evaluation in grade 5-6 mathematics: Effects on problem solving achievement. *Educational Assessment*, *8*(1), 43-58.

Ryan, K. E., Ryan, A. M., Arbuthnot, K. N., & Samuels, M. C. (2007). Students' motivation for standardized math exams. *Educational Researcher, 36*(1), 5-13.

Schoenfeld, A. H. (1985). *Mathematical problem solving*. Orlando: Academic Press.

Schommer-Aitkins, M., Duell, O. K., & Hutter, R. (2005). Epistemological beliefs, mathematical problem-solving beliefs, and academic performance of middle school students . *Elementary School Journal , 105*(3), 289-304.

Schumacher, P., & Morahan-Martin, J. (2001). Gender, Internet and computer attitudes and experiences. *Computers in Education, 17*(1), 95-110.

Stevens, T., Olivarez, A., Lan, W. Y., & Tallent-Runnels, M. K. (2004). Role of mathematics self-efficacy and motivation in mathematics performance across ethnicity. *Journal of Educational Research, 97*(4), 208-222.

Streefland, L. (1993). Fractions: A realistic approach. In T. P. Carpenter, E. Fennema, & T. A. Romberg (Eds.), *Rational numbers: An integration of research* (pp. 289-325). Hillsdale, NJ: Earlbaum.

Tondeur, J., Valcke, M., & van Braak, J. (2008). A multidimensional approach to determinants of computer use in primary education: Teacher and school characteristics. *Journal of Computer Assisted Learning, 24*, 494-506.

Turner, J. C., Meyer, D. K., Midgley, C., & Patrick, H. (2003). Teachers' discourse and sixth graders' reported affect and achievement behaviors in two high-mastery/high-performance mathematics classrooms. *Elementary School Journal, 103*(4), 357-382.

Vale, C. M., & Leder, G. C. (2004). Student views of computer-based mathematics in the middle years: Does gender make a difference? *Educational Studies in Mathematics, 56*(3), 287-312.

Valli, L., & Buese, D. (2007). The changing roles of teachers in an era of high-stakes. *American Educational Research Journal, 44*(3), 519-558.

Veenstra R., & Kuyper H. (2004). Effective students and families: The importance of individual characteristics for achievement in high school. *Educational Research and Evaluation, 10*(1), 41-70.

Vroom, V. (1964). *Work and motivation*. New York, NY: Wiley.

Wood, E., Mueller, J., Willoughby, T., Specht, J., & Deyoung, T. (2005). Teachers' perceptions: Barriers and supports to using technology in the classroom. *Education, Communication & Information, 5*(2), 183-206.

Wozney, L., Venkatesh, V., & Abrami, P. C. (2006). Implementing computer technologies: Teachers' perceptions and practices. *Journal of Technology and Teacher Education, 14*(1), 173-201.