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Characteristics of students assigned to technology-based instruction

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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 towards 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.

Keywords Learning objects, fractions, teacher decision making, self-efficacy.

Introduction

Researchers investigating the integration of technology into classroom instruction have searched for factors influencing classroom use. For example, Tondeur *et al*. (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 (Odgers *et al*. 2000; Mastropieri *et al*. 2006; Reis *et al*. 2007). Differentiation of instruction has multiple meanings, ranging from variations in instructional materials (e.g. Mastropieri *et al*. 2006) 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

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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 *et al*. 2004) and threaten performance in careers such as paediatric nursing (Grillo *et al*. 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 *et al*. 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 towards 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 towards 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. Critical Learning Instructional Paths Supports (CLIPS) 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's design team drew upon research on teaching fractions (particularly Streefland 1993; Moss & Case 1999; Gould *et al*. 2006) to develop interactive activities addressing student deficits identified through a needs assessment that integrated student achievement data, teacher perceptions, and student self-efficacy (Ross *et al*. 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: (1) representing simple fractions; (2) forming and naming equivalent fractions; (3) comparing simple fractions; (4) forming equivalent fractions by splitting or merging parts; and (5) 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 min 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 (Wood *et al*. 2005; Hermans *et al*. 2008; Mueller *et al*. 2008), why there is a gap between teachers' commitment to technology integration and their observed practice (Deaney *et al*. 2006; Chen 2008), influences on a teacher's decision to implement a deep rather than superficial use of technology (Wozney *et al*. 2006; Goos & Bennison 2007; Drent & Meelissen 2008; Tondeur *et al*. 2008), and factors which predict a teacher's placement on an evolutionary scale of use (Hsu *et al*. 2007; Oncu *et al*. 2008).

Themes that emerged from investigations conducted 10 and 20 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 *et al*. 2007; Joiner *et al*. 2007; Morahan-Martin & Schumacher 2007). Gender differences are weaker now than in the past. Some researchers continued to report gender differences favouring males over females across all computer outcomes (Oosterwegel *et al*. 2004; Morahan-Martin & Schumacher 2007; Meelissen & Drent 2008), while others found that gender differences were non-existent (Jennings & Onwuegbuzie 2001; Bovee *et al*. 2007), were salient for one outcome or age group but not others (Joo *et al*. 2000; Christensen *et al*. 2005; Hargittai & Shafer 2006) or were 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; Stevens *et al*. 2004; Lee 2006; Ryan *et al*. 2007). Students with dysfunctional beliefs about mathematics and mathematics learning (e.g. that learning occurs quickly or not at all) have lower achievement (Schommer-Aitkins *et al*. 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 towards mathematics rather than to technology because teachers in our experience are more concerned with students' views towards the former than the latter. Previous research has found that student attitudes towards computers are similar to student attitudes towards 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. The specific research questions addressed in the study were:

1 What student factors influence teacher decisions to assign students to instructional technology when differentiating instruction?
2 Are teachers influenced by the same student characteristics when they are working in constrained and unconstrained contexts?

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 10 fraction-items drawn from the Professional Resources and Instruction for Mathematics Educators' (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 = 0.76 and 0.80 for the two samples) and among the trained markers (Kappa = 0.86 and 0.95).

Students completed a survey that produced seven variables. *Math self-efficacy* consisted of eight Likert items measuring expectations about future mathematics performance (from Ross *et al*. 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 *et al*. (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 = 0.70+) except for functional beliefs

Table 1. Means, standard deviations, and reliability of study variables for CLIPS and no-CLIPS students in the constrained decision condition.

	Alpha	CLIPS (N = 91)		No-CLIPS (N = 284)	
		Mean	SD	Mean	SD
Student achievement	0.71	0.97	0.43	1.53	0.37
Math self-efficacy	0.85	3.58	0.87	4.31	0.85
Functional beliefs about math	0.64	3.59	0.84	3.79	0.93
Quick/fixed learning	0.81	2.59	0.96	2.37	0.87
Fear of failure	0.81	3.05	1.19	3.13	1.06
Effort	0.86	3.90	1.05	4.27	0.86
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	0.78	1.39	0.51	1.58	0.43
Math self-efficacy	0.88	4.22	0.89	4.39	0.88
Functional beliefs about math	0.61	4.20	0.82	4.47	0.76
Quick/fixed learning	0.82	2.21	0.99	2.02	0.85
Fear of failure	0.81	3.41	1.01	3.51	0.88
Effort	0.89	4.20	0.92	4.35	0.80
Gender		70% male; 71% female		29% male; 30% female	

about mathematics learning which was marginal (alpha = 0.64 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.

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 [$F(6,352) = 23.56$, $P < 0.001$] 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 pre-test 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 pre-test (0–7), to 29% of those with medium scores (8–11), to 8% of those with high scores (12–20).

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 [$r = -0.33$] and fear of failure [$r = 0.32$]. 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 0.80 required to detect a statistically significant relationship.

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

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 [$\chi^2(1,374) = 4.38$, $P = 0.036$]: males were more likely to be assigned to CLIPS than females. Although there were no gender differences in achievement, there were gender differences in affect. Males were more likely than females to score high on functional beliefs [$F(1,375) = 4.94$, $P = 0.027$], to score lower than females on fear of failure [$F(1,375) = 11.11$, $P = 0.001$], and on effort in math class [$F(1,375) = 5.10$, $P = 0.025$]. The latter was an important result because students who exerted low effort in math class were more likely to be assigned to CLIPS. Grade (7–10) was not a statistically significant factor [$\chi^2(4,371) = 7.66$, $P = 0.105$].

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 [$F(6,132) = 1.16$, $P = 0.334$].

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 [$\chi^2(1,148) = 1.001$, $P = 0.971$].

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 multi-collinearity, 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 ($P = 0.042$), effort ($P = 0.001$), achievement ($P < 0.001$) and gender ($P = 0.041$). 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

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).

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 pre-test (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 with 25% and 75% that could be predicted by chance.

We deleted two variables from the second sample due to multi-collinearity. The variables in the logistic regression were gender, math as quick/fixed learning, fear of failure, effort and fractions achievement. Only achievement ($P = 0.018$) 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 with 70% and 30% that could be predicted by chance.

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. The software addressed a wide range of student misconceptions related to understanding part–whole relationships that commonly occur with young children but also persist through ages 12–15 and into adulthood. 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 (Streefland 1993; Moss & Case 1999; Gould *et al*. 2006). 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 & Murayama 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 (Schoenfeld 1985; Schommer-Aitkins *et al*. 2005). 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 & Knaack 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 (Oosterwegel *et al*. 2004; Morahan-Martin & Schumacher 2007; Meelissen & Drent 2008).

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

A limitation of the studies reported here is that addressed a particular type of software. We cannot tell from these data whether the results would generalize to other software. 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 (1) a domain-specific learning tool in which (2) executive control of student thinking was largely distributed from the learner to the software and (3) 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 (1) generic learning tools, (2) with varying distributions of executive control among tool, student and learning environment, and (3) 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 towards 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 *et al*. (2007). It would be helpful to include a measure of students' attitudes to learning mathematics with technology (Pierce *et al*. 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 assigned more males than females to CLIPS perhaps because teachers matched research finding 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 as males on most assessments (Lloyd *et al*. 2005), although this might not be true in all countries as indicated by the Trends in International Mathematics and Science Study (TIMSS) 2007 analysis by Thomson *et al*. (2008). This is an equity issue. In our previous research (Ross & Bruce 2009), 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.

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