Integrating iSTART into a High School Curriculum

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Abstract

This study examines the viability in the classroom of a tutoring system called Interactive Strategy Training for Active Reading and Thinking (iSTART). This study investigated the effects of teacher-guided and iSTART-guided extended practice (following initial reading strategy training with iSTART) including 78 high school students from four biology classes. Eight high school teachers were also trained to administer reading strategy training. The results supported the conclusion that teachers can successfully integrate educational technology in such a way that it compliments their traditional teaching roles while helping to meet the needs of their students.

Keywords: Intelligent tutoring systems; iSTART; AutoTutor; classroom; curriculum; educational technology; artificial intelligence; education; science.

Introduction

As a result of educational reforms and new standards, educational goals and instructional methods are changing. Traditionally, school districts defined their goals and methods in terms of students being exposed to large amounts of declarative knowledge - the more, the better. And, students' understanding and knowledge have generally been assessed in terms of explicit recall, primarily relying on fill in the blank and multiple choice tests: assessments that fail to assess deep level understanding. These techniques have often been supplemented by skill-based technologies centering on repetitive drills and practices that lack the benefits of feedback, adaptation, and knowledge construction.

More recently, school districts have begun adopting instructional measures that train students to learn, train students in methods of research, help students develop the motivation to pursue personal enrichment, and train students to be creative and innovative (Domingo et al., 2002). Consequently, educational technology is also changing, and must change to adapt to the evolving understanding of how to enhance the learning process.

Although policy-makers, educators, and researchers have invested large amounts of resources to meet the technological changes, successful integration at the rates hoped for has yet to occur for a number of reasons including a lack of teacher training as well as teachers' fears of replacement and threats to their traditional roles. Thus, in this study, we examine how training influences teachers' ability to successfully integrate an intelligent tutoring system called Interactive Strategy Training for Active Reading and Thinking (iSTART) into their science classrooms and curriculum.

Intelligent Tutoring Systems

Intelligent tutoring systems are part of the advancements in educational technology aimed at promoting student-centered learning. As an outgrowth of earlier computer-aided instruction systems (Lajoie & Azevedo, 2005), intelligent tutoring systems are designed to capitalize on the power of one-to-one tutoring. Research by Cohen, Kulik, and Kulik (1982) indicates that when compared to traditional classroom instruction, one-to-one tutoring by untrained tutors, such as peers, cross-age tutors, or paraprofessionals, can produce an effect size for learning of .4 sigma (i.e., .4 standard deviations). Research using trained tutors suggests varying effects. For example, Bloom (1984) reported an effect size of 2 sigma (2.0 standard deviations) for math skills training, whereas VanLehn and colleagues (2007) reported an effect size of only 1 sigma (1.0 standard deviation) for physics tutoring. Despite these variations, research indicates that overall, one-to-one tutoring is effective in producing learning gains but impractical to implement on a large scale because of cost and time requirements.

Intelligent tutoring systems can provide cost-effective one-to-one tutoring which is adaptable to individual students' needs and personalizable (Tsiriga & Virvou, 2004). With the help of a student model that is dynamically monitored and updated using assessment tasks, intelligent tutors are able to provide students with adaptive feedback (Lajoie & Azevedo, 2005). This feedback guides students in correcting misconceptions and errors while helping them to effectively progress through the system (Graesser et al., 2004).

iSTART is based on a human-delivered intervention called SERT (McNamara, 2004). It is an automated reading strategy trainer that teaches students to self-explain texts using five reading comprehensions strategies: comprehension monitoring, paraphrasing, elaboration, prediction, and bridging (McNamara et al., 2004). The system consists of both vicarious and interactive components to enhance learning and also consists of three phases: an introduction, demonstration, and practice, which are guided by pedagogical agents. In the introduction, students vicariously learn the five reading strategies by watching the instructor agent, Dr. Julie, use examples and definitions to teach two student agents, Mike and Julie. A short quiz follows each strategy. In the demonstration, two new agents, Merlin and Genie, demonstrate how the strategies can be used to self-explain science texts. Genie self-explains a science text presented sentence by sentence while Merlin provides feedback on the quality of the self-explanation. The student identifies the strategy being used and may also be asked to identify the part of the self-explanation containing a particular strategy. Merlin's feedback to both Genie and the student is designed to provide the student with appropriate scaffolding. During the practice phase, Merlin coaches the student in using a repertoire of strategies to self-explain texts. Merlin also provides the student with feedback that is moderated by the self-explanation quality as determined by word-based and LSA algorithms (McNamara et al., in press).

In addition to the regular practice session that includes only two texts, iSTART also contains an extended practice module which allows students the opportunity to practice their strategies and skills in weekly intervals. One focus of this study is to compare the effectiveness of using iSTART for extended practice to having a teacher guide extended practice in classroom discussions.

Several experiments indicate the success of iSTART in enhancing students' reading comprehension and self-explanation quality. For example, results from a study comparing iSTART and SERT (the live version) to a control condition in which students read a text without strategy training indicated that iSTART was as effective as SERT in terms of producing comparable self-explanation quality. Both the iSTART and SERT groups outperformed the control group. A reliable advantage for iSTART and SERT was also shown when students read a science text and answered comprehension questions 1 week after training (O'Reilly, Sinclair, & McNamara, 2004).

A second study involving 42 middle-school students also confirmed iSTART's effectiveness in increasing reading comprehension in students with low reading strategy prior knowledge (McNamara, O'Reilly, Best, & Ozuru, 2006). Half of the students received iSTART training prior to self-explaining a text about heart disease and half did not. Results suggest that iSTART's effectiveness was mediated by both students' prior knowledge of reading strategies and the level of comprehension assessed. More specifically, students in the iSTART group with low-prior knowledge of reading strategies performed better on text-based comprehension questions than their counterparts in the control condition. In contrast, students participating in the iSTART training with high-prior strategy knowledge showed comprehension gains when assessed by bridging inference questions. This pattern of results was also found in a third study involving 44 college students (Magliano et al., 2005).Students were asked to read and self-explain two texts before and after receiving iSTART training. As with middle-school students, better readers performed better on bridging inference questions, thereby gaining in terms of deeper comprehension levels. Again, less-skilled readers performed better on surface level or text-based questions.

Purpose and Predictions

In spite of research indicating the benefits of educational technology, an unprecedented allocation of resources for technology development and implementation, and the promotion of technology as being essential to improving education, mass integration into classrooms and curriculum has yet to occur. Researchers in the field of educational technology offer a myriad of explanations implicating numerous factors as barriers to greater, more successful integration. However, this study focuses primarily on the teacher, as research indicates that although the availability of technology is important, its use is primarily predicated on teachers' willingness and capability to use it (Tao & Wepner, 2002). We focus on teacher training and pedagogical beliefs about instruction and teacher roles as two of the main barriers to more successful integration.

Our current goal is to explore whether an intelligent tutoring system can be successfully integrated into the classroom meeting the needs of both the teacher and students, while at the same time complimenting teachers' pedagogical beliefs about instruction and their roles. In our study, teachers were trained to use iSTART to better understand the rationale behind its development, how it works, why it works, and how it meets their needs and those of their students. Our question is whether such scaffolding helps teachers to successfully integrate the system into their curriculum in such a way that it both compliments and gradually changes traditional teacher roles to meet new educational standards.

We answer our question using two experiments. In the first study, teachers receive iSTART training. In the second study, students either participate in extended practice led by the teacher who received training (teacher-guided extended practice) or led by iSTART (computer-guided extended practice). We use the extended-practice module in this experiment because unlike the other iSTART phases, it has not been tested against live training to assess its benefits.

Based on previous research indicating iSTART's ability to improve reading comprehension in low-prior strategy knowledge readers when assessed by text-based questions (McNamara et al., 2006) and observational data suggesting high levels of participation and engagement by high-knowledge students during live training (McNamara & the CSEP Lab, 2006), we make a number of predictions and hypotheses. First, we predict that low-strategy knowledge students will continue to benefit from iSTART or computer-guided extended practice and that high-knowledge students will benefit more from the teacher-guided extended practice than low-knowledge students. Specifically, we hypothesize that low-knowledge readers in the computer-guided extended practice condition will show greater reading comprehension improvements when assessed by text-based comprehension questions, moreso than low-knowledge students in the teacher-guided condition. We also hypothesize that because high-knowledge students tend to be more engaged and participatory during live training, those in the teacher-guided condition will show greater improvements on deeper level comprehension measures than high-knowledge students in the computer-guided condition.

STUDY 1

Participants

Participants were 8 high school teachers from two high schools including three science teachers, two English teachers, one reading lab director, and one computer technician (a former teacher) who received monetary compensation for their participation.

Materials

A 2-day workshop was designed by the experimenters to train teachers in administering reading strategy training using iSTART. The workshop focused on providing teachers with the theoretical basis for iSTART including the cognitive processes involved in text comprehension and models of text processing and how the models and processes relate to the reading strategies taught by iSTART. The workshop also provided teachers with an opportunity to go through the iSTART training. A 10-item, open-ended response questionnaire was used to assess teachers' background knowledge about text processing, perceived usefulness of iSTART, and the system requirements needed to implement iSTART in a regular high-school classroom.

Procedure

The teacher training took place during the summer prior to the beginning of the academic year. During the training, the teachers participated in a 2 day workshop at the University of Memphis which lasted approximately 6 hours. On the first day, an experimenter presented the theoretical basis for the development of iSTART which included session on the cognitive processes involved in text comprehension and models of text processing and how these related to the reading strategies taught with iSTART. On the second day, teachers went through the iSTART training and completed a questionnaire. This study reports the teachers' impressions of iSTART as revealed on the questionnaire.

Results

Responses from the workshop questionnaire gauging teachers' opinions of the workshop and perceived usefulness of iSTART were classified as either positive (i.e., "yes") or negative based on the content. A frequency of positive responses was calculated. Positive frequencies for teacher opinions regarding the workshop are reported in Table 1.

Table 1: Number of positive responses regarding the reading strategy workshop

Question	Positive Responses
Was the presentation clear and comprehensible?	8
Did you find the information useful to your learning about and understanding iSTART?	6 **
Did you find the information beneficial/useful beyond how it might be applied to iSTART training?	7 *
Have you been exposed to any of the presented concepts previously? If yes, which concepts?	8
Do you already use/apply any of the presented concepts when teaching? If yes, which concepts?*	7
Do you think you would use the presented information in some non-iSTART capacity in your classes?	7 *

Notes: * 1 teacher did not answer; ** 2 teachers did not answer

The data indicate that overall, the teachers felt positive about the workshop. All teachers found the presentation clear and comprehensible. Teachers who answered found the information beneficial and indicated that they would use the information gleaned from the training in a non-iSTART capacity in their classes – meaning that they intended to incorporate reading strategies into their courses. The majority of teachers also indicated that they were already using some of the iSTART strategies. In this study, however, we did not follow up on the validity of their responses. That is, we did not confirm that they incorporated the strategies or that they already taught some of the strategies.

We also asked teachers about the perceived usefulness of iSTART in addition to information regarding the context and frequency of its use. When asked "Did you find the iSTART training left you with a clear understanding of how and why iSTART can facilitate text comprehension?", all of the teachers indicated that they understood how and why iSTART would facilitate text comprehension. When asked "Do you foresee using iSTART in the classroom after the IIS intervention at your school?", the majority of respondents (7 out of 8) indicated that they could see themselves using the system after the initial intervention. Half of the teachers who indicated that they would use iSTART indicated that they would use it with all students and half indicated that they would use it with lower-level students. When asked "How often would you use iSTART and/or its related concepts (i.e., training only, training and extended practice, once a week, daily, etc.)?", four teachers indicated that they would use iSTART for weekly practice and one teacher indicated that it would be used monthly. Overall, the data indicates that teachers had a positive perception of iSTART and were willing to use it in classrooms.

Albeit a small sample, this study provided information to us regarding teachers' impressions of iSTART. It was important for us to establish that teachers understood and resonated toward the utility of iSTART and that they would be willing to use iSTART in the classroom.

STUDY 2

Participants

Participants were 78 high-school students selected from four 9th grade biology classes taught by one of the teachers who had participated in the first study. All students received self-explanation training via iSTART. After the initial training, there were 6 weeks of extended practice training occurring once per week. Two classes (n=33) participated in the teacher-guided extended practice condition whereas the other two classes (n=45) participated in the computer-guided extended practice condition. Not all students were present for each of the assessments, and thus the number of participants varies somewhat by dependent measure.

Materials

A number of measures were used to assess students' comprehension skills, reading ability and prior knowledge. A modified 48-item multiple choice version of the Gates-MacGinitie reading skill test was used to assess students' reading comprehension. Students' prior science knowledge was assessed using a 20-item, four-alternative, multiple-choice test that covered biology, chemistry, earth science, research methods and math. Items were selected from high school science texts collected from several states.

Pretest passage comprehension was measured using a science text on earthquakes (words=334, sentences=23, Flesch Reading Ease=56.4, Flesch-Kincaid grade level=8.8) and the origins of the universe (words=299, sentences=18, Flesch Reading Ease=45.7, Flesch-Kincaid Grade Level=10.7). Texts were counterbalanced such that half the class read the earthquake text and the other half read the text on the origins of the universe. Eight open-ended questions were developed for each passage, with four being text-based and four being bridging. Text-based questions are those whose answers can be found within a single sentence of the passage. Bridging questions are those whose answers require students to combine information contained in two or more sentences of the passage.

Finally, students' delayed posttest passage comprehension was measured using 4 open-ended text-based and 4 bridging inference questions about a red blood cell passage (words=281,sentences=20, Flesch Reading Ease=56.1,Flesch-Kincaid grade level=8.9).

Procedure

There were four phases: pretest, training, immediate posttest, extended practice, and delayed posttest. The pretest, training, and posttests were identical for both conditions. Prior to training, students completed the pretest material in the following order: metacognitive awareness of reading strategies inventory, metacomprehension index, prior science knowledge, Gates-MacGinitie, and the passage on either earthquakes or the origins of the universe, along with the set of appropriate comprehension questions.

During the training, students progressed through the three phases of the iSTART program over the course of three class periods on three consecutive days. On the fourth day, students were administered the immediate posttests, which consisted of a comprehension test on a science text about heart disease and a self-explanation quality assessment on a text about body temperature.

Students began the extended strategy practice phase the following week. Extended practice lasted for 6 consecutive weeks. Teachers selected texts (about 20 sentences in length) corresponding to the topics taught during the regular class period. Students participated in either the teacher-guided or computer-guided practice sessions. In the teacher-guided practice, the teacher asked students to self-explain the texts and called on several students to provide self-explanations for each sentence of the text. For the computer-guided practice, the students used iSTART which provided individualized feedback to their typed self-explanation. Students in both groups took a quiz on the self-explanation texts each week. Both experimenters and teachers made observations.

During the delayed posttest, students were administered the posttest measures in the following order: metacognitive awareness of reading strategies inventory, Gates MacGinitie reading measure, and a comprehension test on a passage about red blood cells.

Results

We confirmed that there were no differences between the two conditions in terms of reading skill and prior knowledge. Thus, the two groups were of equal ability levels. There were also no differences on any of the dependent measures right after initial training. Thus, we focus here on the measures that are indicative of differences between the two conditions after the extended practice sessions – the delayed posttest.

The students completed a comprehension test on a text about red blood cells after the extended training period. An ANOVA including the within-subjects variable of question type and the between-subjects factor of condition (teacher-guided vs. computer-guided) was conducted. As shown in Table 1, there was a main effect of question type, $F(1,72)=8.44$, $p=.005$. The effect of condition was marginal, $F(1,72)=2.57$, $p=.113$, with an advantage for the teacher-guided condition. The interaction was not significant, $F<2$.

Table 1: Proportion correct on the delayed posttest for comprehension

		Mean	SD	N
Text-based	Computer	0.41	0.23	43
	Teacher	0.52	0.28	31
	Total	**0.45**	**0.26**	**74**
Bridging	Computer	0.51	0.27	43
	Teacher	0.57	0.26	31
	Total	**0.53**	**0.26**	**74**

We further examined whether these effects differed as a function of students' individual differences by including those variables as dichotomous variables in separate analyses. The effect of prior knowledge was reliable, $F(1,68)=11.22$, $p<.001$ ($M_{high}=0.61$; $M_{low}=0.43$), and interestingly, the effect of condition was reliable in this analysis, $F(1,68)=5.94$, $p=.017$. There were no interactions, however.

There was an effect of reading skill, $F(1,65)=6.70$, $p=.012$ ($\underline{M}_{high}=0.61$; $\underline{M}_{low}=0.43$), and condition, $F(1,65)=5.24$, $p=.025$, and a marginal interaction of condition and reading skill, $F(1,65)=2.92$, $p=.092$. The advantage for the teacher condition was absent for less skilled readers ($\underline{M}_{computer}=0.43$; $\underline{M}_{teacher}=0.46$), $F<1$. In contrast, the advantage for the teacher-guided practice condition for the skilled readers was quite substantial ($\underline{M}_{computer}=0.46$; $\underline{M}_{teacher}=0.70$), $F(1,32)=9.91$, $p=.005$.

Table 2: Mean ratings of student motivation and difficulties with iSTART

Topic	Observer ratings Mean (SD)	Teacher ratings Mean(SD)
Student motivation	2.8(0.5)	2.5(0.8)
Student enjoyment	2.3(0.6)	2.4(0.8)
Student difficulties	0.3(0.6)	0.7(1.0)
Teacher difficulties	0.3(0.6)	0.3(1.0)

Observations were made by both the experimenters and teachers administering iSTART to gauge student reactions and engagement and to examine whether and how teachers can administer training and the extended practice sessions. Table 2 shows the mean ratings from the observers and teachers based on a 0-4 (0=low; 4=high) scale regarding student motivation, enjoyment, and difficulties. These constructs were defined in terms of students' levels of participation, on-task comments, and question asking. Scores were assigned by subjectively noting the various levels of each construct by two experimenters who achieved adequate inter-rater reliability.

The ratings indicate that students' motivation and enjoyment were above average, whereas student and teacher difficulties were low. However, notes made by the researchers suggested that high-ability learners were more participatory and engaged during the teacher-guided sessions than were low-ability learners. High-ability learners were also more likely than low-ability learners to complain of boredom and engage in "off task" activities during computer-guided practice.

Observations were also made by two experimenters to determine which methods teachers used to assist students during the teacher-guided and computer-guided extended practice.. Table 3 reports the mean scores for each teaching method used in the teacher-guided and computer-guided practice sessions based on a 0-4 scale (0=not at all; 4=always). The scores were assigned by objectively noting which methods teachers used throughout the sessions. Experimenters achieved adequate inter-rater reliability. The data indicates that teachers spent more time providing feedback to students, explaining the iSTART strategies, and teaching the students to self-explain during the teacher-guided practice. Also, during teacher-guided practice, teachers focused on content teaching, such as explaining word meanings, sentence meanings, and global text understandings. To expand on these findings, notes made by the researchers regarding the quality of both conditions suggested that during the teacher-guided sessions, teachers continuously talked about the strategies in terms of explaining their meanings and providing content relevant information. Overall, the results suggest that live training offered teachers the opportunity to provide more strategy instruction and topic related content than the computer-guided practice. On the other hand, researchers also noted a few instances in which teachers provided inaccurate information and deviated from the teaching protocol set forth by iSTART.

Table 3: Mean score for methods used in the extended practice sessions

Teaching method	Teacher-guided practice Mean (SD)	Computer-guided practice Mean(SD)
Self-explanation instruction	3.0(1.4)	1.8(1.7)
iSTART strategies instruction	3.2(1.2)	1.3(1.4)
Other strategy instruction	0.8(0.9)	0.1(0.6)
Word meanings	1.5(0.9)	0.1(1.3)
Sentence meanings	1.5(1.6)	0.5(1.3)
Whole text meaning	1.3(1.8)	0.1(0.3)
Teacher feedback	3.6(0.9)	0.006(0.3)
Peer feedback	0.5(0.6)	0

Discussion

The purpose of this study was to explore whether an intelligent tutoring system can be successfully integrated into the classroom meeting the needs of both the teacher and students, while at the same time complimenting teachers' pedagogical beliefs about instruction and their roles. We hypothesized that low-knowledge readers in the computer-guided extended practice condition would show greater reading comprehension improvements when assessed by text-based comprehension questions and more so than low-knowledge students in the teacher-guided condition. We also hypothesized that because high-knowledge students tend to be more engaged and participatory during live training, those in the teacher-guided condition would show greater improvements on deeper level comprehension measures than high-knowledge students in the computer-guided condition. The results supported our hypotheses. The data indicates that low-knowledge students benefited more from the iSTART extended practice than high-knowledge students who benefited more from the teacher-guided extended practice. Results from observational data also indicate that higher-knowledge students in the teacher-guided condition were more engaged and participatory than the low-knowledge readers. Research on prior knowledge and engagement shows that when learners engage in deeper levels of critical thinking, prior knowledge is activated, which invariably enhances learning (Sharma & Hannafin, 2004). In light of this research, the observational data may explain why students in the teacher-guided group outperformed their counterparts during live training. Results from the observational data indicating the rare tendency of teachers to provide misinformation and deviate from iSTART's teaching protocol provides information as to which strategies and procedures researchers need to devote more attention to during training.

Our results add to the research showing that with training, teachers can successfully integrate educational technology into their classrooms and curriculum. Results indicating that computer-guided practice was more beneficial for low-knowledge readers than high-knowledge readers suggest the need for the integration of educational technology. At the same time, results indicating that high-knowledge readers benefited more than low-knowledge readers from teacher-guided practice suggest the continued importance of traditional classroom teaching. Together these results suggest that educational technology can be integrated in such a way that meets the needs of each student. The technology could be used in such a way that augments traditional teaching roles instead of replacing them. For example, in keeping in line with current teacher-centered classrooms, teachers can be trained to administer training to high-knowledge students while low-knowledge students learn using iSTART.

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