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A Comparison of Traditional Homework to Computer-Supported Homework

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Abstract

This study compared learning for fifth grade students in two math homework conditions. The paper-and-pencil condition represented traditional homework, with review of problems in class the following day. The Web-based homework condition provided immediate feedback in the form of hints on demand and step-by-step scaffolding. We analyzed the results for students who completed both the paper-and-pencil and the Web-based conditions. In this group of 28 students, students learned significantly more when given computer feedback than when doing traditional paper-and-pencil homework, with an effect size of .61. The implications of this study are that, given the large effect size, it may be worth the cost and effort to give Web-based homework when students have access to the needed equipment, such as in schools that have implemented one-to-one computing programs.
(Keywords: online homework, intelligent tutoring systems, online tutoring, homework.)

Web-based homework assistance is already popular in colleges. Blackboard (www.blackboard.com), WebAssign, (www.webassign.com), MasteringPhysics (www.masteringphysics.com), and WebWorK (http://webwork.rochester.edu) are all systems that have thousands of student users at the college level, but K–12 Web-based homework assistance lags behind. Systems such as Study Island (www.studyisland.com) and PowerSchool (www.powerschool.com) are gaining popularity with K–12 teachers, and it seems likely that the use of Web-based homework assistance for K–12 will increase as the digital divide between students narrows, teachers become more comfortable with the technology, and teachers gain access to systems that are low cost or free. The important question is, do such systems help students learn more than traditional paper-and-pencil homework?

With recent advances in educational technology, teachers now have a multitude of tools to assist and enhance student learning and motivation. New intelligent tutoring systems that guide students through math problems much the same way human tutors do have been successful in helping students learn math in the classroom. Some systems attempt to imitate a human tutor by reproducing the interactive dialogue patterns and strategies that were likely to be used by a human tutor, whereas others provide immediate feedback by highlighting each step attempted in either red or green to indicate a right or wrong answer. They may also provide hint sequences to students asking for help.

A U.S. Congress–mandated study (Dynarski et al., 2007) reported that classrooms using selected math and reading educational software products did not differ significantly on standardized tests when compared to classrooms that did not use the products. This study has caused some to call into question the utility of educational software, which might suggest that we should stop wasting time producing computer-based systems. However, the Dynarski study looked at computers used during the school day and not as a homework-delivery system.

In this study, we attempt to determine if fifth grade students can learn more by doing their math homework with a Web-based intelligent tutoring system than when doing traditional paper-and-pencil homework. We conducted this experiment using the ASSISTment System, a Web-based system that provides both interactive scaffolding and hints on demand. We will review studies of Web-based homework assistance systems before describing the ASSISTment system used in this evaluation.

LITERATURE REVIEW

The Use of Web-based Systems for Homework

Web-based systems that allow students to do their homework online such as Blackboard, WebCT (www.webct.com), Homework Service (https://hw.utexas.edu/bur/overview.html), and WebWorK are becoming more widely used in higher education. At the K–12 level, systems such as Study Island and Power-School are gaining popularity among teachers.

Some states in the United States, including Maine, Indiana, Michigan, and Virginia, have begun to implement one-to-one computing (Bonifaz & Zucker, 2004) in schools where each child gets his/her own laptop to use during school hours and often to take home. For instance, the Maine Learning Technology Initiative (2002–2004) supplied every seventh and eighth grade student in Maine and their teachers with laptop computers, and 40% of the middle schools allow students to take their laptops home. Although few research studies on the effects of one-to-one computing on teaching and learning have been reported, teachers report that students in one-to-one computing programs are more engaged and motivated and interact better with teachers (Bebell, 2005; Silvernail, & Lane, 2004). At the same time, recommendations for abandoning one-to-one computing programs citing the high cost, potential access to inappropriate material, and lack of proven impact on student achievement (Hu, 2007; Vascellaro, 2006) have been widely published. Still, the number of U.S. schools adopting one-to-one computing programs continues to increase every year, according to a survey of the largest 2,500 school districts in the United States conducted by the Hayes Connection and cited in the *New York Times* by Hu (2007). The opportunities for students to do their homework online increase as the digital divide narrows and more states become committed to one-to-one computing. One important question is, do students learn more by using computers to do their homework than by doing traditional paper-and-pencil homework?

Some advantages of homework-assistance systems are immediate feedback to students and automatic grading and recording of grades for instructors. Automatic grading saves time for teachers who would like to grade all of their students' paper-and-pencil homework carefully by hand but do not have time. In turn, this can prompt students to take homework more seriously because they know it will be graded and the grade will be recorded. With these systems, students can often get immediate feedback on their answers and work and sometimes help toward solving problems.

Although these Web-based homework-assistance systems can provide benefits, they can have disadvantages, as well. Many of these systems do not take students' work into consideration when they require students to enter a single answer for each problem. Students may be less organized because they do less scrap work on paper and try to do more math in their heads. Teachers may be less able to figure out exactly where students are having difficulties without seeing their work. Finally, because these systems often do not consider student work, cheating may be easier among students because they could possibly get the answers from their friends without having to show how they arrived at them.

Web-based Homework Versus Paper-and-Pencil Homework

Previous research has shown positive results for using Web-based homework assistance instead of traditional paper-and-pencil homework. MasteringPhysics, a Web-based physics homework tutor developed at MIT, uses mastery learning to help students reach mastery when solving physics homework problems. Students can ask for hints on problems and receive feedback on common student errors. Some hints will ask the student a question that behaves like a "scaffolding question" in the ASSISTment system (described in the next section). Warnakulasooriya & Pritchard (2005) found that twice as many students could complete a set of problems in a given time with the help provided by MasteringPhysics when compared to students who worked on the problems without help (administered by MasteringPhysics but without hints or feedback).

The Andes system is an intelligent tutoring system that provides support for problem solving for physics homework. Students using Andes complete whole derivations step by step and receive feedback after each step. Students can also request hints for each step to find out where their errors are (What's Wrong Help) or to find out what to do next (Next Step Help). VanLehn et al. (2005) presented evidence from introductory physics courses taught at the U.S. Naval Academy from 1999 to 2003 that students who used Andes for homework got significantly higher exam scores than students in control groups who did paper-and-pencil homework. Other studies of Web-based physics homework versus paper-and-pencil homework did not find significant differences between the two homework conditions (Bonham, Deardorff, & Beichner, 2003; Pascarella, 2002). The Andes studies seem to be the most closely related to our comparison of ASSISTments and paper-and-pencil homework, and this study attempts to replicate Andes' positive results.

The ASSISTment System

Assistance and assessment are integrated in a Web-based system called the ASSISTment System, which offers instruction to students while providing a detailed evaluation of their abilities to teachers. Each time students work on the Web site, the system "learns" more about their abilities. The ASSISTment System is being built to identify the difficulties individual students—and the class as a whole—are having, and teachers will be able to use this detailed feedback to tailor their instruction to focus on those difficulties. Unlike other assessment systems, the ASSISTment system also provides students with intelligent tutoring assistance while assessment information is collected. Our hypothesis is that ASSISTments can do a better job of getting students to learn from homework than traditional paper-and-pencil homework by providing immediate feedback on answers and tutoring for items that students get wrong. Teachers can also assess their students' knowledge limitations better by noting the amount and nature of the assistance students need to finish their homework. The ASSISTment system was developed using grants from the U.S. Department of Education and the National Science Foundation and will be freely available for use by teachers and students.

The ASSISTment System provides students with two types of tutoring assistance, scaffolds and hints, when they answer a question incorrectly. With scaffolds, the student who answers an ASSISTment incorrectly receives the message, "Hmm, no. Let me break this down for you," and is immediately presented with a scaffolding question that the student must answer correctly in order to continue and receive the next scaffolding question. The scaffolding questions break the problem into steps, and students must answer the scaffolding questions before returning to the original question; that is, the student is forced to work through the problem. With hints, the student may request a hint by pressing the hint button. Students may request more hints until they reach the "bottom-out" hint, which will typically give them the answer to the question.

When students log in to the ASSISTment system, they are presented with math problems. Figure 1 shows a screenshot of an ASSISTment problem with three scaffolding questions. Solving this problem involved understanding congruence, perimeter, and equation solving. If the student had answered correctly, she would have moved on to a new problem. However, she incorrectly answered 23, and the system responded with, "Hmm, no. Let me break this down for you." It then presented the student with some questions that would help to isolate the skills with which she had difficulty and to tutor her so that she could figure out the correct actions. The tutor began by asking a scaffolding question that isolated the step involving congruence. Eventually she got the scaffolding question correct (by answering "AC") and then was given a question about perimeter. The figure shows that the student selected ½ * 8 * x as the formula for perimeter, and the system responded with a "buggy message" letting the student know she seems to be confusing perimeter with area. The student requested two hint messages, as shown at the bottom of the screen. The tutoring ends with a final question, which is actually the original question asked again. The student then will go on to do another math problem and will again get tutoring if she gets it wrong.

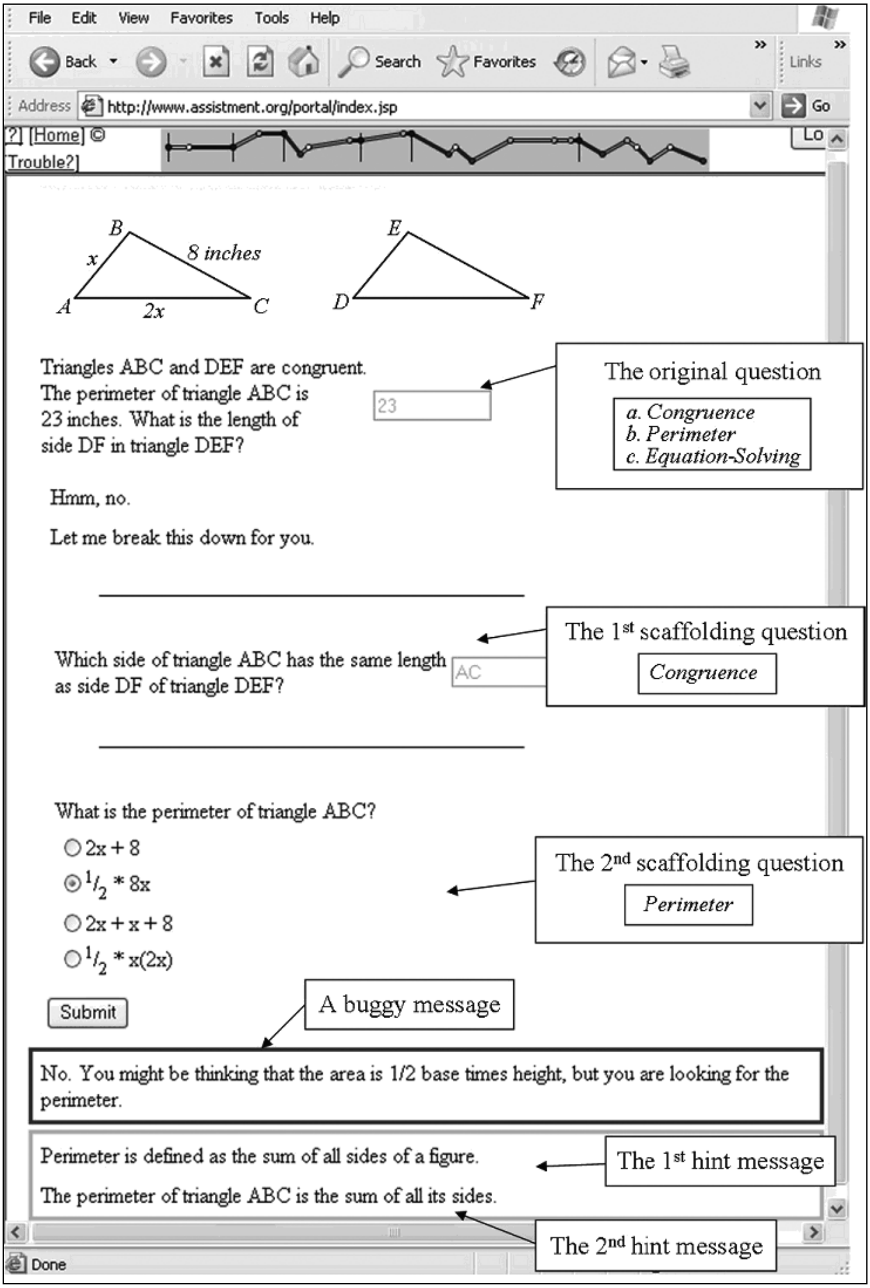

Figure 1. An ASSISTment showing three scaffolding questions.

The design of the ASSISTment system was informed by earlier systems such as Cognitive Tutors (Anderson et al., 1995) and Ms. Lindquist (Heffernan & Koedinger, 2002). These systems use "model-tracing" architectures that were invented by researchers at Carnegie Mellon University (Anderson, Boyle & Reiser, 1985; Anderson & Pelletier, 1991) and used extensively to build tutors. Each tutor is constructed around a cognitive model of the problem-solving knowledge students have and the knowledge needed to solve each problem. The model reflects the ACT-R theory of skill knowledge (Anderson, 1993), which assumes that problem-solving skills can be modeled as a set of independent production rules. Production rules are if–then rules that represent different pieces of knowledge.

Ms. Lindquist, developed by Heffernan and Koedinger (2002), is an intelligent tutoring system that uses dialog to help students write algebra expressions. Ms. Lindquist models both student behavior and tutorial behavior by combining a cognitive model of student behavior with a tutorial model of strategies observed in a human tutor. The cognitive student model has a set of production rules that model the problem-solving skills needed to write algebraic expressions, whereas the tutorial model is based on the observation of an experienced human tutor during a tutoring session and tries to capture tutorial strategies that were observed to be effective. Ms. Lindquist was the first intelligent tutor that had both a model of student thinking and a model of tutorial planning and is different from typical Cognitive Tutors in that it takes its cues more from the dialogues that human tutors have with students and is more flexible. For example, it can acknowledge that part of an answer is correct and then engage a student in a "sub-dialogue" to help him or her improve the incorrect path. It "breaks" problems down for students by asking questions and rephrasing questions but does not give students answers.

The ASSISTment system also breaks problems down for students in the way that Cognitive Tutors and Ms. Lindquist do, but it is not rule based. Koedinger et al. (2004) introduced example-tracing tutors that mimic Cognitive Tutors but are limited to the scope of a single problem. The ASSISTment system uses a further simplified example-tracing tutor called an ASSISTment that allows only a linear progression through a problem, which makes content creation easier and more accessible to nonprogrammers. Previous results show that our example-tracing-based system can reduce the time required to build a single hour of content from 100–1,000 hours to 10–30 hours (Razzaq et al., 2008).

During the design stage of the ASSISTment system, middle school math teachers were involved in the process (Razzaq et al., 2005). Heffernan and Razzaq met with these teachers weekly to do "knowledge elicitation" interviews, during which the teachers helped design the pedagogical content of the ASSISTment system. The knowledge elicitation interviews started by showing the teacher a problem and then asking a series of questions: "How would you tutor a student to solve the problem? How would you break the problem down? What hints would you give the student? What kinds of errors are expected, and what would you say when a student made an expected error?" They videotaped these interviews and used the recordings to fill out an "ASSISTment design

Table 1. Participants in the Study

	Class A	Class B	Class C	Class D	Total
Male students	13	12	9	12	46
Female students	10	13	13	10	46
Students with Internet at home	12	15	17	10	54

form," which they used to implement the ASSISTment. Teachers gave their opinions on the first draft of the ASSISTment and were asked to edit it. They also videotaped these review sessions and revised the design form as needed. When the teacher was satisfied, they released the ASSISTment for use.

Initial studies of the ASSISTment system (Razzaq et al., 2005) found that students were learning eighth grade math while using the system once every two weeks during their regular math classes. The purpose of this study was to determine if using the ASSISTment system for Web-based homework assistance is more useful (produces more learning) than traditional paper-and-pencil homework.

METHOD

Setting and Participants

The setting for this study was 4 fifth grade classrooms and students' home computers. The school was located in a small town in a rural county and was a sample of convenience. Approximately 350 students were enrolled in the school at the time of the study, with at least 50% receiving free or reduced lunch. All four classes were typical elementary classes with a mix of below-average, average, and above-average students. Teachers gave a total of 92 students (54 with Internet access at home) this homework assignment, depending on their access. The breakdown of the participants is shown in Table 1.

Content

We used two problem sets in both the Web-based homework and the paper-and-pencil homework assignments, each consisting of 10 problems. One problem set consisted of Number Sense problems, and the other was a mix of problems. The Number Sense problem set included problems for which students had to demonstrate understanding of numbers, ways of representing numbers, and relationships among numbers and number systems. The Mixed problem set included problems in the algebra, geometry, data analysis, and probability domains. Students had to demonstrate understanding of patterns, relations, and functions; describe spatial relationships using coordinate geometry and other representational systems; develop and evaluate inferences and predictions that are based on models; and apply and demonstrate an understanding of basic concepts of probability. (See Appendix B for the problems in both homework sets.) Students in the classes had prior learning experience with the homework material during the course of the school year. However, as the experiment took place at the end of the school year, it was not recent experience and was more of a review.

The worksheets that students completed for paper-and-pencil homework assignments were identical to the Web-based homework assignment problems, with the same formats (i.e., multiple choice or short answer). This was possible because each class did the Number Sense or Mixed problem set for computer homework and the opposite problem set for paper-and-pencil homework. This will be explained in detail in the Experimental Design section below. The pretest and posttest items were "morphs" of the Number Sense and Mixed problem sets and were designed to have different surface features, such as names and numbers, while keeping the same deep features or knowledge requirements, such as analyzing patterns. Finally, the same hints used in the problem sets on the Web-based tutor were used while going over paper-and-pencil homework problems in class to ensure that each class had the same instruction.

Experimental Design

We used a counterbalanced experimental design in which students in two classrooms participated in the Web-based homework condition first, whereas students in the other two classrooms participated in the paper-and-pencil condition first. All students participated in both Web-based and paper-and-pencil conditions, and all students received pretests and posttests for each condition in which they participated.

In the Web-based first group, one class received a pretest for the Number Sense problem set, and the other class received a pretest for the Mixed problem set. Students then received a homework assignment consisting of 10 problems in their respective problem sets on the Web-based system. After completing the Web-based homework, the students received posttests in class the next day. We then reversed the groups, with the Number Sense group receiving the Mixed pretest and the Mixed group receiving the Number Sense pretest. Both groups then received a paper-and-pencil homework assignment that consisted of 10 problems on a worksheet for their respective problem sets. They completed posttests the following day. The paper-and-pencil first group participated in the same overall experimental design. (See Table 2 for the overall experimental design.)

Our design counterbalances the content (number sense vs. mixed) as well as the order of condition (Web-based vs. paper and pencil) so that we can draw valid inferences that any gains students make will not be attributed to these outside factors.

Procedures

On day one of the experiment, students in all four classes received the appropriate pretest (two classes were administered the Number Sense pretest, and two were administered the Mixed pretest). (See Appendix A for sample pre- and posttests.) Thus, for both conditions, Web-based homework and paper-and-pencil homework, one class was completing the Number Sense assignment while the other class completed the Mixed assignment.

After completing the pretest, each class in the paper-and-pencil homework condition received worksheets with 10 problems to complete for homework.

Table 2. Experimental Design

Day	Web-based first group		Paper-and-Pencil First Group	
	Class A	Class B	Class C	Class D
Mon.	Pretest Number Sense Intro to ASSISTments Web-based assignment	Pretest Mixed Intro to ASSISTments Web-based assignment	Pretest Mixed Paper-and-pencil assignment	Pretest Number Sense Paper-and-pencil assignment
Tues.	Posttest Number Sense	Posttest Mixed	Review assignment Posttest Mixed	Review assignment Posttest Number Sense
Wed.	Pretest Mixed Paper-and-pencil assignment	Pretest Number Sense Paper-and-pencil assignment	Pretest Number Sense Intro to ASSISTments Web-based assignment	Pretest Mixed Intro to ASSISTments Web-based assignment
Thurs.	Review assignment Posttest Mixed	Review assignment Posttest Number Sense	Posttest Number Sense	Posttest Mixed

(See Appendix B for sample worksheet problems.) They instructed the students to bring the worksheets to school the following day so that they could go over them and answer any questions they had. Students in each class in the Web-based homework condition completed their pretests and then were taken to the media room, where they learned how to log in to and use the ASSISTment system. They all received a school identifier, which was the same for all students, then received an individual screen name consisting of their first name and last initial. After each student logged in to the system, they were shown how to select their teachers' names and how to select their homework for the evening. They also learned how to select and work on a demonstration problem to familiarize themselves with the system and how problems were presented. The demonstration problems were not a part of their homework problems. (See Appendix C for sample computer/ASSISTment problems.)

On day 2, the students in the paper-and-pencil condition received the answers to their worksheet problems and then had the opportunity to ask questions for review. (We are aware that our homework review procedure is susceptible to the fact that some students are more assertive than others when

Table 3. Group and Individual Class Completion Rates

	Class A	Class B	Class C	Class D	All Classes	Exclude Class D
% with Internet	17/24 70.8%	12/23 52%	10/22 45%	15/24 62.5%	54/93 58%	39/69 56.5%
% with Internet that completed WBH	13/17 76%	6/12 50%	7/10 70%	3/15 20%	29/54 53.7%	26/39 67%
% with Internet that completed PPH	15/17 88%	9/12 75%	7/10 70%	12/15 80%	43/54 79.6%	31/39 79%
% with Internet that completed both	12/17 70%	6/12 50%	7/10 70%	3/15 20%	28/54 52%	25/39 64%

asking questions, but we argue that our design is reasonable, as we have tried to replicate what happens in typical classrooms when going over homework.) When answering questions the teacher used the exact hints used in the computer-hints condition to ensure uniformity across groups. (See Appendix D for sample hints.) The review was limited to 10 minutes per group.

We designed the procedures used for the homework review to simulate a typical review that math teachers would use. For example, in a typical math class the teacher will usually go over the answers for the homework assignment and then ask students if they have any questions. If they do, the teacher will put the problems on the board for students to see or from time to time have students do problems on the board so the teacher can see where the students are having difficulty. The reviews usually last approximately 10 minutes. For this study we attempted to simulate those procedures as closely as possible, but with a few exceptions. For example, we went over the answers to the homework assignment, and then asked students if they had any questions. However, in lieu of doing the problems on the board, we chose to use overheads with the exact hints used in the ASSISTment problems. We did this because we wanted to ensure that each group received the same review.

The students then completed posttests. The two classes in the computer condition received posttests on day 2. Days 3 and 4 followed the same procedures as days 1 and 2, but the groups were reversed. That is, the two classes in the Web-based condition switched with the two classes in the paper-and-pencil condition, and the two classes that did number-sense problems switched with the two classes doing mixed problems.

Results

There were a total of 93 students in the four classes. Of the 93 students, 5 were absent during all or part of the study, another 6 missed part of the study due to activities in which they were involved outside of the classroom, and 6 students were nonreaders. These students did not participate in the study, which left a total of 76 students. Only 54 of those students, however, had Internet available at home and could participate fully in the study. Of these 54 students, 31 students (57%) started the Web-based homework, but 2 of them reported

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair	Gain1Compter	2.32	28	2.195	415
1	Gain2PPH	1.14	28	1.533	290

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Gain1Compter & Gain2PPH	28	-.322	.094

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 Gain1Compter Gain2PPH	1.179	-.322	.577	-.006	2.363	2.041	27	.051

Figure 2. Results on Web-based homework and paper-and-pencil homework for students who completed both.

technical difficulties and were not able to complete the assignment. Another student in this group did not complete his paper-and-pencil homework. Consequently, we analyzed the remaining 28 students (52%) when comparing Web-based homework to paper-and-pencil homework.

These percentages may be somewhat misleading because in Class D only 3 out of 15 students who had Internet did the assignment at home as instructed, but 10 of the 15 students completed the assignment in the morning on computers at the school. Because those 10 students did not actually do the Web-based assignment at home, we chose to count those students as not having completed the Web-based homework assignment. This class had a substitute teacher that day, and we speculate that the substitute may not have impressed upon the children the importance of doing the assignment at home, which may have accounted for the lower than expected participation rate in this class. When we exclude Class D from the above analysis, the participation rates increase, as shown in Table 3.

For the following analyses, *t*-tests were run on the Web-based gain scores from pretest to posttest and on the paper-and-pencil gain scores from pretest

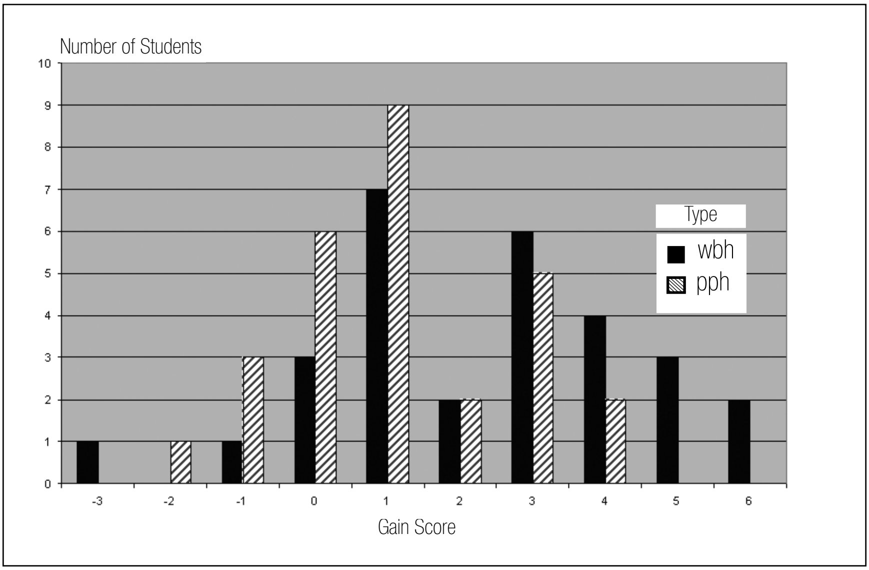

Figure 3. Results on Web-based homework and paper-and-pencil homework for students who completed both.

to posttest. There was learning in both conditions; however, when comparing the effect of Web-based homework and paper-and-pencil homework, including only those students who completed both the Web-based homework and the paper-and-pencil homework, there was a statistically reliable difference in favor of the Web-based homework condition. The paired t-test, $t(27) = 2.04$, $p = 0.051$, showed an effect size of .61 (see Figure 2). The 95% confidence interval for this effect size of .61 is (0.08–1.15). The mean gain for the Web-based homework group was 2.32 points out of 10 points, and for the paper-and-pencil homework group the gain was 1.14 points out of 10 points.

As shown in Figure 3, our analysis is not sensitive to one or two students. The weighted sum of gain scores, if we disregard negative scores, is 72 (Web-based homework) versus 36 (paper-and-pencil homework).

Implications

In this study, students learned significantly more with Web-based homework than with paper-and-pencil homework, and the effect size we reported of .61 is large compared to other possible interventions shown in an in-depth study of the effect sizes of more than 100 classroom innovations accumulated from thousands of studies (Hattie, 1999). In the absence of one-to-one computing programs, teachers could use Web-based homework-assistance systems in their school computer labs or assign them for homework to students who have Internet access at home, access to school computers after school, or access to computers at the local library. The implications of this study could be important to policy makers, particularly considering the popularity of one-to-one computing initiatives (Hu, 2007) and claims that laptops can now be produced for prices as low as $200 each (Bray, 2007). The cost of an intervention is of concern at a time when school budgets are already stretched thin, so policy makers need to see programs that can increase learning dramatically at low costs. In this study, we showed an intervention that led to a dramatic increase in student learning at a relatively low cost. For example, the Maine Learning Technology Initiative (2002–2004) was able to supply laptops to all of their seventh and eighth grade students for $300 per student per year, which is about one third of the cost of reducing class size. The cost of one-to-one computing programs could drop further, considering the new smaller and less expensive laptops being developed (Bray, 2007), and when excluding the growing number of students who already have computers at home.

Caveats are in order, of course. Our study looked at the impact of learning at home, not in the classroom, so this intervention would help kids learn from their homework, not learn more effectively during class time. Other studies have documented large gain scores when comparing traditional clsssroom instruction to computer-based tutoring (Kulik & Kulik, 1991; Razzaq, Mendicino & Heffernan, 2008), so it is perhaps not a leap to assume the computer would also help learning when doing homework. Our study was also short term, and we were not able to do a retention test afterward due to a lack of time, as this study took place at the end of the school year.

Our study was limited to fifth graders working on their math homework. We do not know if our results would generalize to students in other grades or other subjects. One limitation of the ASSISTment system is that it is not able to grade open responses or essay-type questions, and teachers are limited to multiple-choice or short-answer questions. Currently, this would limit us to tutoring subjects like math and science, and we do not know if our results would generalize to subjects such as English or history.

In this study, we were also limited by the number of students who did not have Internet at home. As the digital divide narrows and more K–12 students have access to computers and Internet at home, more teachers can take advantage of the promise of Web-based homework-assistance systems. With this paper, we believe we have taken a step toward justifying the cost of providing students with the means to do their homework via the Web.

CONCLUSION

By using a system such as the ASSISTment system, students can learn more than they would by doing their homework with paper and pencil. Students get immediate feedback on their answers and help when they need it. In addition to better learning results, teachers can take advantage of the convenience of having homework automatically graded and recorded. Students can also benefit from Web-based homework because they may take their homework more seriously when they know it will be graded.

With the ASSISTment system, teachers can also pinpoint exactly where students are having difficulties and get reports on which skills to address in class for individual students or the class as a whole (Feng, Heffernan & Koedinger, 2006), thus allowing teachers to address shortcomings. Content is relatively easy to develop in the ASSISTment system and can be created in a fraction of the time needed to develop content in other intelligent tutoring systems (Razzaq et al., 2008).

For future studies, we would like to determine if the results of this study have external validity. We would run the study with more students who have had more experience with the system. We would also like to find out if the results generalize for students in other grades and over longer periods of time.

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APPENDIX A: MIXED PRETEST & NUMBER SENSE PRETEST

Name________________________ Teacher______________________

1.
Turf Coverage

Pounds	Square Yards of Coverage
6	200
10	300
14	400
18	500

The table above shows the number of pounds of turf needed to cover a given area. Based on the pattern in the table, how many pounds of turf are needed to cover 800 square yards?

2. 2X + 2 = 14

What value of X makes the equation shown above true?

- o A) X = 6
- o B) X = 8
- o C) X = 10
- o D) X = 12

3. The radius of a circle is 18 inches. What is the diameter of the circle?

4. Mrs. Chipps wrote five numbers on the white board in her room.
After class, one of the numbers was erased. The four numbers left are shown below.

20 32 44 12 _?_

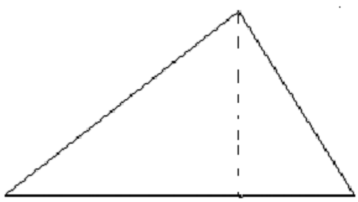
If the median of the five numbers that Mrs. Chipps wrote on the board was 20, which of the following could be true?

- o A) The number that was erased was greater than 44
- o B) The mode of the five numbers Mrs. Chipps wrote on the board was 31
- o C) The number that was erased was less than or equal to 20
- o D) The mean of the five numbers Mrs. Chipps wrote on the board was 56

5. Mr. Lamb drew an equilateral triangle. Which of the following statements is true about the triangle?

- o A) At least two angles are obtuse
- o B) At least one angle measures 90 degrees
- o C) All of the angles are less than 90 degrees
- o D) All of the angles have different measurements

6.



What is the area of the triangle shown above?

- o A) 220 cm^2
- o B) 156 cm^2
- o C) 125 cm^2
- o D) 225 cm^2

7.

Input	1	2	3	4	5	6	7
Output	6	10	14	18	22	26	30

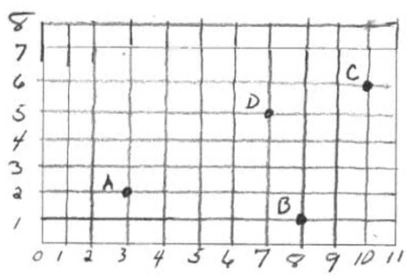
Shelby created the input-output table shown above. Which of the following rules is true for all values of Shelby's input-output table?

- o A) Input + 5 = output
- o B) Input times 5 = output
- o C) (Input times 4) + 2
- o D) (Input times 4) + 3

8. Joe is 22 years older than Bob. If Joe is 43 years old now, how old is Bob?

- o A) 12 years old
- o B) 18 years old
- o C) 65 years old
- o D) 21 years old

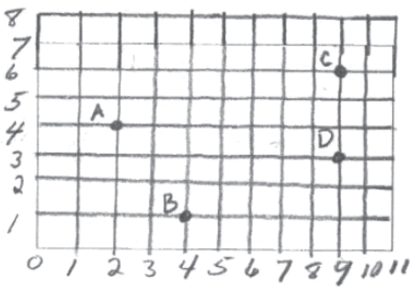
9.



On the coordinate grid above, which point is located at (7, 5)?

- o A
- o B
- o C
- o D

10.



What are the coordinates of point C?

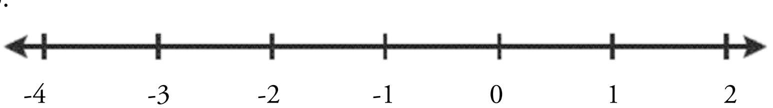
Number Sense Pretest

Name_____________________________ Teacher___________________

1. Which of the following is closest to the product of 397.8 * 10.3?
   - o A) 3,000
   - o B) 30,000
   - o C) 400
   - o D) 4,000

2. Which of the following shows the numbers in order from least to greatest?
   - o A) 0.452, 0.51, 0.432
   - o B) 0.452, 0.432, 0.51
   - o C) 0.432, 0.51, 0.452
   - o D) 0.432, 0.452, 0.51

3.



Jeffrey is plotting points on the number line above. Between which two numbers should Jeffery plot -3 ½?

4. What is 15/60 as a percent?

5. Write 10/25 as a decimal.

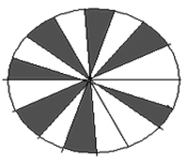
6. What is the value of the following expression?

7 * 6 + 3

7. Destinee has a total of 12 fish in her aquarium. Exactly 9 of the fish are goldfish. What percent of the fish in the aquarium are goldfish?

- o A) 70%
- o B) 55%
- o C) 75%
- o D) 25%

8.



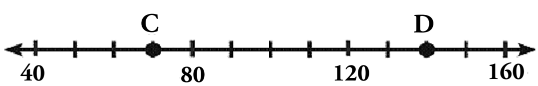
David made the circle shown below using gray and white triangles. What fractional part of the whole design is made up of gray triangles? Write your answer as a fraction.

9. Kendra is going on vacation. She packed the following clothes in her suitcase. How many different outfit combinations will Kendra have to choose from during vacation?

Suitcase for vacation

Tops	Pants
T-shirt Sweatshirt	Khaki pants Sweatpants Jeans

10.



What is the distance between point C and point D on the number line shown below?

APPENDIX B: HOMEWORK PROBLEM SETS

Homework/Mix Problems

Name:____________________ **Teacher:____________________**

Date:________________

1.

Fertilizer Coverage

Pounds	Square Yards of Coverage
4	100
8	200
12	300
16	400

The table above shows the number of pounds of fertilizer needed to cover a given area. Based on the pattern in the table, how many pounds of fertilizer are needed to cover 600 square yards?

2. 2x + 2 = 10

What value of x makes the equation shown above true?

- o A) x = 4
- o B) x = 6
- o C) x = 8
- o D) x = 12

3. The radius of a circle is 14 inches. What is the diameter of the circle?

4. Mr. Young wrote five numbers on the board in his classroom. After class, one of the numbers was erased. Four of the five numbers are shown below.
18 25 30 17 __?

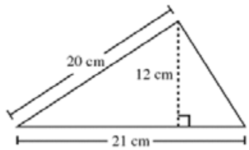
If the median of the five numbers that Mr. Young wrote on the board was 18, which of the following could be true?

- o A) The number that was erased was greater than 30.
- o B) The mode of the five numbers Mr. Young wrote on the board was 24.
- o C) The mean of the five numbers Mr. Young wrote on the board was 22.6.
- o D) The number that was erased was less than or equal to 18.

5. Mr. Donato drew an equilateral triangle. Which of the following statements is true about the triangle?

- o A) At least one angle is obtuse.
- o B) All of the angles are acute.
- o C) At least one angle measures 90 degrees.
- o D) All of the angles have different measurements.

6.



What is the area of the triangle shown above?

- o A) 126 cm^2
- o B) 210 cm^2
- o C) 252 cm^2
- o D) 420 cm^2

7.

Input	1	2	3	4	5	6	7
Output	4	6	8	10	12	14	16

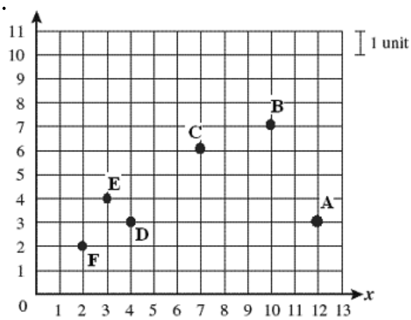
Bridget created the input-output table shown above. Which of the following rules is true for all values in Bridget's input-output table?

- o A) Input + 3 = Output
- o B) Input * 3 = Output
- o C) (Input * 2) + 1 = Output
- o D) (Input * 2) + 2 = Output

8. Sam is 37 years older than Dennis. If Sam is 55 years old now, how old is Dennis?

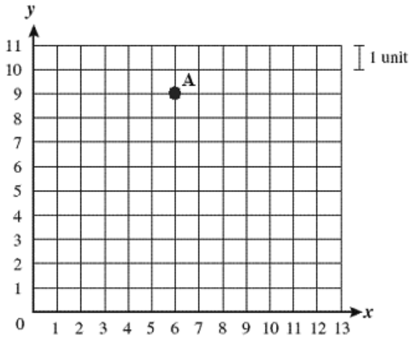
- o A) 12 years old
- o B) 18 years old
- o C) 28 years old
- o D) 92 years old

9.



On the coordinate grid above, which point is plotted at (4, 3)?

- o A
- o B
- o C
- o D
- o E
- o F

10. 

What are the coordinates of Point A?

- o A) (6, 10)
- o B) (5, 9)
- o C) (9, 6)
- o D) (6, 9)

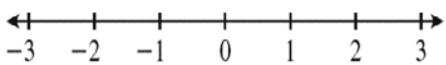
Homework/Number Sense Problems

Name:__________________ Teacher: ____________________
Date:____________

1. Which of the following is closest to the product 298.7 * 10.1?
   - o A) 300
   - o B) 2,000
   - o C) 3,000
   - o D) 20,000

2. Which of the following shows the numbers in order from least to greatest?
   - o A) 0.765, 0.82, 0.791
   - o B) 0.765, 0.791, 0.82
   - o C) 0.791, 0.82, 0.765
   - o D) 0.791, 0.765, 0.82

3\.



Marta is plotting points on the number line above. Between which two numbers should Marta plot -2½?

- o A) 1 and 2
- o B) 2 and 3
- o C) -2 and -1
- o D) -3 and -2

4. Write 12/30 as a percent.

5. Write 15/25 as a decimal.

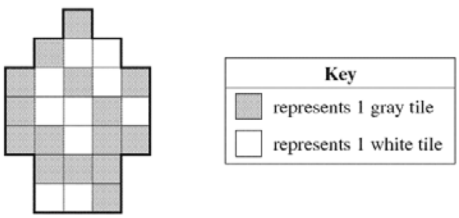
6. What is the value of the following expression?

$$3 + 6 * 4$$

7. Judith has a total of 8 fish in her aquarium. Exactly 6 of the fish are guppies. What percent of the fish in the aquarium are guppies?

- o A) 48%
- o B) 60%
- o C) 68%
- o D) 75%

8.



Shing made the design shown above using gray square tiles and white square tiles. What fractional part of the whole design is made up of **gray** tiles? Write your answer as a fraction.

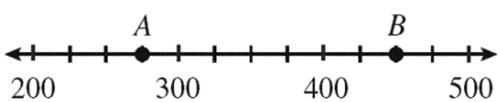
9.

Salad Ingredients

Lettuce	Vegetable	Dressing
Iceberg Romaine	Carrot Celery Broccoli Cauliflower	Ranch Italian Caesar Vinaigrette French

Rae is making a salad. The choices for the ingredients are shown in the chart above. What is the total number of different salads she can make using one lettuce, one vegetable, and one dressing?

10.



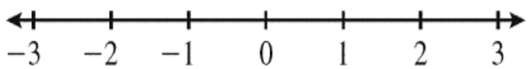
What is the distance between point A and point B on the number line shown above?

APPENDIX C: SAMPLE COMPUTER PROBLEMS

"2005_5_gr6" (Problem ID: 12330) [MA – 2005 – SPRING – 5]
Which of the following is closer to the product 298.7 * 10.1?
A) 300
B) 2,000
C) 3,000
D) 20,000

"2005_23_gr6" (Problem ID: 12395) [MA – 2005 – SPRING – 23]
Which of the following shows the members from least to greatest?
A) 0.765, 0.82, 0.791
B) 0.765, 0.791. 0.82
C) 0.791, 0.82, 0.765
D) 0.791, 0.765, 0.82

3. "2005_20_gr6" (Problem ID: 23332) [MA – 2005 – SPRING – 20]



Marta is plotting points on the number line above. Between which two numbers should Marta plot -2 ½?

- o A) 1 and 2
- o B) 2 and 3
- o C) -2 and -1
- o D) -3 and -2

2. "2005_6_gr6" (Problem ID: 12341) [MA - 2005 - SPRING - 6]

$$2x + 2 = 10$$

What value of x makes the equation shown above true?

- o A) x = 4
- o B) x = 6
- o C) x = 8
- o D) x = 12

3. "2005_12_gr6" (Problem ID: 12361) [MA - 2005 - SPRING - 12]
The radius of a circle is 14 inches. What is the diameter of the circle?

4. "2005_15_gr6" (Problem ID: 12366)
Mr. Young wrote five numbers on the board in his classroom. After class, one of the numbers was erased. Four of the five numbers are shown below.

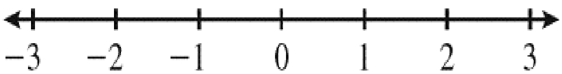
18 25 30 17 _?_

If the median of the five numbers that Mr. Young wrote on the board was 18, which of the following could be true?

- o A) The number that was erased was greater than 30.
- o B) The mode of the five numbers Mr. Young wrote on the board was 24.
- o C) The mean of the five numbers Mr. Young wrote on the board was 22.6.
- o D) The number that was erased was less than or equal to 18.

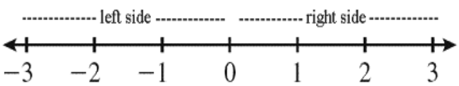
APPENDIX D: SAMPLE HINTS

3.)



Marta is plotting points on the number line above. Between which two numbers should Marta plot $-2^1/_2$?

<u>Answers:</u>
A) 1 and 2
B) 2 and 3
C) -2 and -1
D) -3 and -2



$-2^1/_2$ should be $2^1/_2$ units away from zero. What side of zero should $-2^1/_2$ be on?

<u>Answers:</u>
the left side
the right side

<u>Hint 1:</u>
The numbers to the right of zero on the number line are positive and are greater than zero. The numbers to the left of zero on the number line are negative and are less than zero.

<u>Hint 2:</u>
Marta should plot $-2^1/_2$ on the left side of zero because it's negative. Between which two numbers should Marta plot -21/2?

<u>Answers:</u> (Interface Type: RADIO_BUTTON)
A) 1 and 2
B) 2 and 3

C) -2 and -1
D) -3 and -2

Hint 1:
Marta should plot $-2^1/_2$ on the left side of zero, between two negative numbers.

Hint 2:
$-2^1/_2$ should be $2^1/_2$ units away from zero. Is that to the left of -2 or to the right of -2?

Hint 3:
$-2^1/_2$ should be plotted between -3 and -2. Choose D.
4. Write 12/30 as a percent.

Answers:
40%
40

First, it will help to reduce the fraction to tenths. What is 12/30 reduced?

Answers:
3/10
4/10
4/5
6/12
Hint 1:
What is a common factor between 12 and 30 that will give you 10 in the denominator?

Hint 2:
The common factor is 3. Divide 12 and 30 by 3.

Hint 3:
12/30 = 4/10

Hint 4:
Choose 4/10.
Good. What is 4/10 in percent?

Answers:
0.4%
0.04%
4%
40%

Hint 1:
There are several ways to change a fraction to a percent. One way is to divide the numerator by the denominator and move the decimal point 2 places to the right.

Hint 2:
What is 4 divided by 10?

Hint 3:
40%
4/10 = 0.4. Now move the decimal point 2 places to the right.

Hint 4:
0.4 = 40%. Choose 40%.

5. Write 15/25 as a decimal.

Answers:
0.6

First, it will help to reduce the fraction. What is 15/25 reduced?
Answers:
3/5

Hint 1:
What is the greatest common factor between 15 and 25?
Hint 2:
The greatest common factor is 5. Divide 15 and 25 by 5.

Hint 3:
15/25 = 3/5

Hint 4:
Type in 3/5
Good. What is 3/5 in decimal?

Answers:
0.6

Hint 1:
One way to change a fraction to a decimal is to divide the numerator by the denominator, but it is easier to convert this fraction to tenths first.

Hint 2:
3/5 * 2/2 = 6/10. To divide by 10, move the decimal point one place to the left. (Since there is no decimal point, think of 6 as 6.0 and move the decimal point one place to the left.)

Hint 3:
6/10 = 0.6 or 0.60

Hint 4:
Type in 0.6.