The Effect of Competition and Contextualized Advisement on the Transfer of Mathematics Skills in a Computer-Based Instructional Simulation Game

□ Richard Van Eck
Jack Dempsey

This study was designed to determine the effect of contextualized advisement and competition on transfer of mathematics skills in a computer-based simulation game in which participants helped their "aunt and uncle" fix up a house. Contextualized advisement referred to whether the participant had access to video-based advisement delivered by the aunt and uncle about how to solve the problem, and competition referred to whether or not the participant was playing against a computer character. A total of 123 seventh- and eighth-grade students were randomly assigned to one of five conditions formed by crossing the two independent variables and adding a control group. Results indicated an interaction between competition and contextualized advisement. Participants in the noncompetitive condition had higher transfer scores when they had access to contextualized advisement, while participants in the competitive condition had higher transfer scores when they had no access to contextualized advisement.

□ The primary purpose of this study was to determine whether transfer of learning could be promoted using a computer-based instructional simulation game with built-in advisement and what role competition and contextualized advisement would play in promoting transfer. It was hypothesized that such a module could promote transfer by relying on the principles of anchored instruction (Cognition and Technology Group at Vanderbilt [CTGV], 1992a), that is, by situating the transfer opportunities in a meaningful, authentic context, and also by including built-in advisement. Because transfer is context-dependent, (e.g., Black & Schell, 1995; Perkins & Salomon, 1989), it was further hypothesized that the advisement would be most effective in promoting transfer if it were part of that same meaningful, authentic context as the game, rather than as a separate element (e.g., a help menu) as is often done in computer-based instruction

Despite the importance of transfer of learning in education, learners in general rarely demonstrate positive transfer (Asch, 1969; CTGV, 1992a, 1992b; Gick & Holyoak, 1980; Perfetto, Bransford, and Franks, 1983; Reed, Ernst, & Banerji, 1974; Simon & Hayes, 1976; Thurman, 1993; Van Haneghan, 1990; Weisberg, DiCamillo, & Phillips, 1978). This may be because problem solving and transfer are largely domain and context specific (e.g., Bransford, Franks, Vye, & Sherwood, 1989; Bransford, Sherwood, Vye, & Rieser, 1986; Brown, Collins, & Duguid, 1989; Perkins & Salomon, 1989), and thus require multiple practice opportunities in a variety

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of contexts (Gagné, Briggs, & Wager, 1992). Such opportunities may be limited in formal education.

Royer (1979) defined transfer as "the extent to which the learning of an instructional event contributes to or detracts from subsequent problem solving or the learning of subsequent instructional events" and stated that "transfer of learning is evidenced by the ability to apply a particular skill, or bit of knowledge, to situations differing from those encountered during original learning" (p. 53). Another common definition categorized transfer as either vertical or horizontal. Vertical transfer happens when learning "contributes directly to the acquisition of a superordinate skill or bit of knowledge," (p. 54) while lateral or, as what Gagné (1965) called horizontal transfer, refers to "the sort of transfer that occurs when a child recognizes that the fractions he is learning about in school are relevant to the problem of deciding how to divide up a prized, but jointly owned, marble collection" (Royer, 1979, p. 54). Royer also discussed *near transfer,* in which prior knowledge is transferred to a similar context (e.g., knowledge of water flow and dams is similar to knowledge about a hydraulic system) and *far transfer,* in which prior knowledge is transferred to a highly novel and dissimilar context (knowledge of water flow and dams vs. diagnosing a short circuit in an electrical device).

Transfer in this study is categorized as positive, horizontal transfer. Students who had studied area, perimeter, addition, subtraction, multiplication, division, and calculation of equivalent measurements were asked to apply this prior learning to determine the amount of paint and wallpaper border needed to remodel a room in a house in a computer simulation or simulation game.

One way to encourage transfer is through the use of authentic learning paradigms such as anchored instruction. Instructional simulations and games present an excellent means for accommodating anchored instruction principles. Anchored instruction requires that the learning take place in a realistic problem-solving situation and that the learner be able to explore the environment. Computer-based games allow for the former through the use of graphics, sound, text, and video, and for the latter through navigational options (e.g., clicking on different parts of the screen to navigate to different places in the environment). Learning events, or "anchors," are embedded in problem-solving environments. Anchored instruction has been experimentally shown to promote performance and transfer and to be more effective in teaching mathematical problem-solving skills than is traditional instruction (CTGV, 1993; Sherwood & CTGV, 1991; Van Haneghan et al., 1992). From the research on anchored instruction and transfer, it is reasonable to expect that any computer-based instruction that embeds instruction in authentic contexts should be more successful in promoting transfer than computer-based instruction that does not.

Many researchers now use the term *simulation game* (Jacobs & Dempsey, 1993) to describe a new class of games that make use of high-fidelity simulated environments. Simulation games have been defined variously as a combination of simulations and games with competition (Heyman, 1982) and as a subset of games (McGrenere, 1996). One of the more complete definitions is proposed by Szczurek (1982, p. 27): "[An instructional simulation game is] an instructional method based on a simplified model or representation of a physical or social reality in which students compete for certain outcomes according to an established set of rules or constraints. The competition can be (1) among themselves as individual or groups, or (2) against some specified standard, working as individuals or cooperating as a group." For the purposes of this study, *simulation games* are defined as an interactive experience containing some representation of a world, real or imagined, that behaves according to a coherent (if not realistic) set of rules, in which the participant(s) often have a clear goal, the pursuit and attainment of which may result in an entertaining, rewarding experience.

In this study, competition is viewed as a separate variable, which may be present or absent in a simulation game. A great deal of research supports the positive effects of individual competition on performance (e.g., Fisher, 1976; Hurlock, 1927; Julian & Perry, 1967; Miller, 1981; Spalt, 1988; Wilkes, 1965), while others show no difference (Craig, 1967) or even negative effects (e.g., Cartmill, 1994; Keefer & Karabenick, 1998; Thompson, 1972).

There are several reasons why competition might be expected to promote learning. For learners who are extrinsically motivated by social standing and recognition, competition against other individuals may serve to increase their efforts and perseverance in the instructional game in order to gain standing among their peers. Learners who are intrinsically motivated may likewise compete against their own score to see how much better they can do. Competition is related to Malone and Lepper's (1987) concept of Challenge, which is one construct that may contribute to intrinsic motivation.

There are reasons why competition may not promote learning, however. For competition to promote performance and learning, students must perform at less than their maximum level of performance in noncompetitive conditions—otherwise, there is no room for improvement. Competition alone cannot make learners function beyond their unassisted maximum ability, or what Vygotsky (1978) would call their zone of proximal development, unless they have help, such as a teacher (in traditional instruction), or a coach, mentor, or advisor.

How then, do we begin to reconcile researchers' conflicting results regarding competition?

One explanation may lie in learners' level of expertise in and familiarity with the content to be learned. Miller and Heward (1992) identified two basic stages of knowledge acquisition, (a) the acquisition stage and (b) the practice stage. In the acquisition stage, the goal is for the learner to learn the skill. Instruction should therefore focus on teaching the student to demonstrate the skill correctly and accurately (error-free learning) without reference to speed or automaticity. Once the learner has begun to make more correct responses than erroneous responses, instruction should begin to shift into time trials (a form of competition). By extension, competition at the acquisition stage might then be expected to result in negative results in performance, while competition during the practice stage might be expected to increase performance. There are few studies that examine how competition interacts with advisement or help systems in problem-solving–transfer tasks. It was one of the purposes of this study to examine some of these issues.

Advisement may also have special relevance for promoting transfer. One means of promoting transfer of learning involves making the connection between the learning context and performance context explicit (Adams et al., 1988; Lockhart, Lamon, & Gick, 1987). Brown (1989) found that simply prompting learners to consider prior learning improved transfer, and Brown's finding has been replicated by other researchers as well (e.g., Gick & Holyoak, 1980; Hayes & Simon, 1977; Perfetto et al., 1983; Reed et al., 1974; Simon & Hayes, 1976; Weisberg et al., 1978).

When the context of the instruction shifts to real-world representations, as it does with simulations and simulation games, it may become important for the advisement also to be a part of that simulated world. Noncontextualized advisement in such a game might work against what Csikszentmihalyi (1990) termed "flow" by forcing the learner to shift out of the simulation context, thereby interrupting flow and interfering with the optimal learning experience.

If, as some researchers suggest (e.g., Black & Schell, 1995; Perkins & Salomon 1989), transfer is highly context dependent and specific, and requires guidance and cueing, then it seems reasonable to assume that a computer-based simulation game with some kind of simulated teacher or advisor could promote transfer. It was one of the purposes of this study to examine the role that such contextualized advisement plays in transfer learning.

The literature on transfer suggests that a simulation game might function similarly to anchored instruction by making use of authentic, situated learning. Competition, an integral part of all games, may interfere with elaboration and depth of processing during acquisition learning, and thus work against transfer learning. In addition, providing a means of making the connection between prior knowledge and the current situation via advisment should further promote transfer, and the extent to which that advisement is contextually relevant to the advisement should determine its efficacy in promoting transfer.

Based on the above literature review, the following four hypotheses were tested in this study:

1. Participants who select contextualized advisement more often than others will have higher transfer of mathematics scores.
2. Participants in the contextualized advisement conditions will have higher transfer of mathematics scores than those without access to contextualized advisement.
3. Participants in the noncompetitive simulation conditions will have higher transfer of mathematics scores than participants in the competitive simulation game conditions.
4. Participants in all intervention conditions as a group (i.e., those who experience an authentic learning environment) will have higher transfer of mathematics scores than participants in the control conditions (those who experience word problems only).

METHOD

Population & Sample

The target population for this study was middle-school children in grades 7 through 8, with a range in age from 12 to 15 years old. The sample for this population was selected from four middle schools in a American Gulf Coast city: School A (n = 50), School B (n = 75), School C (n = 123), and School D (n = 80). Schools A and B were used for pilot testing and field trials (respectively) of the game, and School D was ultimately unable to participate. Accordingly, the sample for this study included students at School C only. School C is a Catholic school serving grades K–9, and the students are primarily upper middle class and Caucasian. Participants ranged in age from 12 to 15, with a mean age of 12.8. Of the 112 participants for whom valid sex data were available, 54 were male and 58 were female. The school is fairly well funded, and participants had regular access to the computer lab and access to a game on math as well as other knowledge and entertainment games during free lab time as part of their normal studies. Accordingly, participant computer skills and familiarity with the computing environment in which the study took place enabled them to complete all computer tasks without difficulty. More than half (58%) of participants reported using a computer at home 1–5 hr per week, and 26% reported using a computer at home 6–10 hr per week.

Lesson Content

The content of the lesson was delivered via a computer-based simulation game and was developed using the National Council of Teachers of Mathematics (NCTM) 2000 mathematics curriculum standards. In particular, the content included portions of NCTM 2000 content strands 1 (number sense, properties, and operations), 2 (measurement), and 3 (geometry & spatial sense).

Problems based on these goals and standards were developed and integrated into an instructional simulation game (described fully in the Instruments section), in which participants played a peer-aged character working for their "aunt and uncle's" home remodeling business. Participants were to calculate how much paint was needed to paint a room in a house (area, addition, subtraction, multiplication, division, and number conversion) and how much wallpaper border was needed to put a border around the room at ceiling height (perimeter, addition, subtraction, multiplication, division, and number conversion).

Independent Variables

Contextualized advisement

In the beginning of the simulation game, one half of the participants are introduced to the interface through a video of their aunt and uncle. During this two-minute introduction, the aunt and uncle explain that they need help with this house, and that the participant's job will be to work in one room of the house while they are in another room. These participants had access to advice from their aunt and uncle by clicking on a walkie-talkie icon (presumably calling them in another part of the house), at which point a brief

(4 s) video of their aunt and uncle walking into the room through the doorway in the north wall played. This form of advisement is referred to as contextualized advisement, because it has a high contextual relevance to the storyline of the game itself. Most advisement in computer-based instruction or training (CBT) is text-based and accessed through a help menu or, at best, consists of a talking head which, although human, is only passingly related to the context of the instruction. The aunt and uncle asked the participants what they needed to know, at which point the participant was presented with a list of possible topics (Ask how to begin, Ask about paint problem, More help with paint problem, Ask about wallpaper border problem, Ask about tools). Clicking on a topic produced a discussion between the aunt and uncle about the problem and the solution process, addressed ostensibly to the participant. Thus, advisement was specifically and immediately available at the point at which the participants required it.

Some of these topics focused on ways to approach the problem, while others focused on making connections to prior knowledge (promoting transfer). For example, when the learner asked about the paint problem (How many gallons will be needed?), the following conversation was intitiated:

Bob: Ah, figuring out the paint problem; this one's always my favorite!

Ann: Mine too, Bob. The first thing you need to do is to figure out how much wall space you need to paint.

Bob: Right. But wait. We'll need to paint the ceiling too, right?

Ann: Right, Bob. But we don't need to paint the doors or windows either.

Bob: That's right, so you'll need to figure out how much wall space and ceiling space there is, and then subtract for the doors and windows. It's too bad they don't teach us anything about this in school; it was always about forumulas, shapes, lines, and numbers . . .

Ann: But wait, Bob. I think you're on to something. These walls look like rectangles to me, the ceiling looks like rectangles and triangles, and those windows look like . . . .

Bob: Squares and circles! That's it. Now all we have to do . . .

The other half of the participants did not have access to the aunt and uncle, and were unable to ask for help with the problems. They had identical access to all other aspects of the simulation game as described later.

Competition

In the competitive environment, participants were told to work quickly because they were competing against a computer character whose ability level, gender, and ethnicity they chose. This competitor (face icon) was continuously present in the lower right-hand corner of the screen. In the noncompetitive environment, participants had no opponent to compete against for time or accuracy, but they were encouraged to work quickly and accurately. The two competition conditions are referred to as competition and no competition. The four cells formed by crossing the two advisement conditions with the two competition conditions are referred to as contextualized advisement, no competition; contextualized advisement, with competition; no contextualized advisement, no competition; and no contextualized advisement, with competition.

Controls

Participants in the control group were given a computer-based tutorial containing word problems that were numerically and semantically identical to those in the program. Participants in the control group did not see the graphics as they appeared in the game, nor were they able to explore their environment, gather information, or use tools. They were given shapes that represented walls and ceilings with the same measurements and told to calculate how much paint and wallpaper border to use. Each problem (paint and wallpaper border) was represented on a separate screen. After entering an answer, learners clicked on a forward arrow button to go to the next problem. They had no access to advisement, nor was any element of competition involved.

Dependent Variable

Transfer of mathematics skills was assessed via a second computer-based instructional simulation identical to the simulation game in the treatment conditions in terms of structure and general content but differing in the setting (a theater instead of a house). Transfer was measured solely by the ability to solve the problem correctly. While transfer might theoretically be measured by the selection of the formula alone, or by the ability to solve the problem correctly *and* select the correct formula, such measures present difficulties. Participants were not *required* to select any formula at all; if they could solve the problem because they knew the correct formula already, they were able to do so. Accordingly, any measure of transfer that depends in whole or in part on the selection of a formula from the reference book would incorrectly identify such participants as having failed to transfer (Type II error). Likewise, participants who selected the incorrect formula, realized their mistake, but never went back to select the correct formula and instead solved the problem in their heads or on scratch paper would also be incorrectly identified.

Alternatively, if the research accepted as evidence of successful transfer participants who selected the correct formula *or* who solved the problem correctly, the analysis would then include as correct those who had selected the correct formula by chance, resulting in too liberal a test and an increased likelihood of a Type I error. It was unlikely that a participant would arrive at the correct solution to the problem using an incorrect formula, nor was it likely that participants could simply guess the right answer without using the correct formula. Therefore, transfer was measured solely on the ability to arrive at the correct solution. This measure may have been overly conservative, in that participants who recognized the correct formula but made calculation errors during the solution would be identified as examples of failure to transfer, but this was deemed the most valid measure of transfer.

Instruments

Demographic survey

In order to obtain data for possible use as covariates and for post hoc analyses, a 16-item demographic survey was developed to determine participants' age, sex, ethnic background, computer experience, mathematics experience, game playing behavior, hours spent on schoolwork and other activities. This scale had a Flesch-Kincaid Grade Level reading score of 3.1.

Pretest

A 23-item pretest was developed to assess incoming mathematics skills and to verify that students were capable of performing the mathematical computations required in the simulation game and simulation. This instrument was tied to the same NCTM standards and strands as were used to develop the simulation game. Questions were delivered via a computer-based module in which individual questions on area, perimeter, addition, multiplication, subtraction, and division were presented to the participant on screen in the form of text and, where appropriate, graphics. Examples of questions include text-response questions, such as "2,453 + 2,567 = _____," multiple-choice questions, such as "What is the perimeter of this square?" which accompanied a graphic of a square with measurements listed, and followed by a series of response choices, such as "(a) 144, (b) 48, (c) 24, (d) 72." In addition to these questions, a word problem was included at the end, in which the participant was instructed to calculate the number of square feet and the perimeter of a proposed school parking lot in order to determine how much asphalt and fencing would be needed. The shape of the parking lot was achieved by combining a 12 × 12 yd square with a 6 × 8 yd rectangle attached to the upper right quadrant of the square. This question was designed to test their ability to apply the prerequisite skills in a word problem context (which was the basis for the control group). Each question was scored as 1 point for correct, 0 points for incorrect, with a total of 23 possible points. Face validity for this instrument was verfied by the teachers at the participants' schools and by a professor who teaches mathematics instruction to K–12 teachers at an American Gulf Coast university. This instrument had a Flesch-Kincaid Grade Level reading score of 5.2.

Simulation game (intervention)

The computer-based instructional simulation game was developed using Macromedia Authorware 5.1 for Windows 95/98. This instruction was an exploratory learning environment consisting of a computer-generated room in a "house." There were four walls and four corresponding ceiling panels, making eight possible areas to examine and measure, only one of which could be viewed at a time (e.g., when looking at the north wall, one could not see the ceiling or other walls). The room was rectangular, measuring 12 × 15.5 ft × 8 ft high, resulting in rectangular walls that were either 12 × 8 or 15.5 × 8 respectively. The ceiling was peaked (i.e., not a flat ceiling), and comprised two rectangular panels measuring 6.92 × 15.5 ft and two triangular panels measuring 12 × 4.33 ft.

Participants were able to "navigate" from one wall or ceiling panel to any adjoining wall or ceiling panel by moving the mouse in the desired direction and clicking when the cursor changed to a hand pointing in the desired direction (e.g., to move from the north wall to the west wall, the participant would move the cursor to the left edge of the north wall and click; to move from the north wall to the north ceiling panel, the participant would move the cursor to the top edge of the north wall and click). The east wall had a round window in it and a rug on the wall. The south wall had a rectangular door (presumably to the outdoors) and a square window in it. The west wall had a rectangular picture on it. The north wall had a doorway in it and an oval mirror hanging on it. A hallway could be seen dimly through the doorway.

Participants were able to use a variety of "tools" in the program, including a tape measure to measure walls, doors, and windows (activated by clicking on the tape measure and then on the area to be measured), a workbook to record information used to solve the problem, a reference book to look up facts (e.g., how many square feet a gallon of paint covers) and formulas (area, perimeter, volume, etc.), and a calculator. Each time participants selected a formula from the reference book, corresponding formulas would appear in their workbook in which they could fill in blanks based on their measurements. For instance, selecting the formula for the area of a square would produce formula work spaces for each wall, such as "North Wall: L ____ × W _____ = ______." Participants were then able to click in each blank and enter the appropriate measurements for that wall to get its area.

It was assumed that the path to the correct solution to the gallons-of-paint problem (area) in the game involved measuring all walls, ceiling panels, doorways, and windows with the tape measure (12 actions), opening the reference book and selecting 4 formulas (area of a circle, square, rectangle, triangle,) and one fact (square feet covered per gallon of paint), entering the measurements of each wall and door and window in the appropriate length and width formula spaces for each (24 actions), calculating the area or perimeter for each (12 actions), totaling the areas to be painted and not to be painted (2 actions), subtracting the areas not to be painted from the areas to be painted, converting feet to inches, and dividing the total by the number of feet per gallon of paint, to arrive at the correct number of gallons of paint needed.

It was assumed that the path to the correct solution to the wallpaper border problem (perimeter) in the game involved participants selecting an additional formula (perimeter of a rectangle) and fact (number of feet per roll of wallpaper border), entering the length and width measurements (2 actions), calculating the perimeter, converting inches to feet, and dividing the total by the number of feet per wallpaper border roll to arrive at the correct number of wallpaper border rolls needed. In both problems, it should be noted that learners were not required to perform any of these actions beyond measuring the surfaces in the room and determining the coverage of a gallon of paint and roll of wallpaper border. Once they had those data, it was theoretically possible for them to solve the problems in their heads or on scratch paper and enter their answers into the simulation game.

A reference book containing a variety of facts and formulas was provided to all participants, since the goal was to measure the ability to *apply* prior knowledge, not to see if participants had memorized the relevant formulas. Participants were able to click on an icon of a book to call up a full-screen image of a reference book, which could be paged through to view facts and formulas.

In the contextualized advisement conditions, participants had a walkie-talkie to call their aunt and uncle for advice. When they did this, a video of their aunt and uncle (a man and woman dressed in jeans and work shirts) would appear in the doorway of the north wall as if they had just walked into the room. The video was shot in such a way that the background of the hallway could be seen through the video, and the aunt and uncle were presented to scale with the room so that they appeared to be a natural part of the game context. In the competitive conditions, participants competed against a self-selected computer character whose face would appear in the bottom right corner of the room. This character would occasionally make comments like "Ah-hah! I get it!" and other indications that he or she was hard at work solving the same problem as the participant. The participants were instructed to try to finish with the most accurate answer *and* before their competitor.

The simulation game went through three rounds of testing prior to implementation: once with 20 members of the target population, again with 10 members of the target population, and finally with 75 members of the target population. In each case the vast majority of changes addressed programming bugs and minor interface changes; all video, content, and navigation remained unchanged from the beginning. Changes to the interface included adding more instructions to each "page" of the workbook (participants were unsure how to get started with each page and how to move from page to page) and specific instructions for selecting formulas and facts from the reference book and filling in the corresponding formula blanks in the workbook. Participants also tended to move beyond the first page of the workbook prior to having collected all the measurement data needed for the problem, so the program was modified so they could not proceed beyond the first page until all the data were present.

The text present in the game (instructions and feedback during interface training) had a Flesch-Kincaid Grade Level reading score of 4.

Posttest (transfer)

Whereas the simulation game in the intervention consisted of a room in a house, the transfer posttest was assessed by a simulation game set in a movie theater. Content remained identical in all ways except for the setting (theater vs. a house), the measurements (different numbers were used to avoid any practice effect), and the tools used. Participants calculated the amount of material to buy to replace the movie curtain instead of the amount of paint needed to paint the walls. They also calculated the number of carpet rolls needed to replace the carpet aisle running around the outside of the theater seating area, rather than the number of wallpaper border rolls to put around the top of the room. While the number of problems (2) remained identical to the simulation game, the solution to the area problem represented a significantly simpler solution in that they had only to calculate the area of one rectangle (the curtain), and did not have to subtract for any irrelevant areas as they did with windows and doors in the simulation game. This difference in complexity was created to isolate transfer specifically from the computational and problem-solving skills as much as possible. Because transfer is essentially the ability to apply prior knowledge in a novel context, recognizing that the correct solution to the theater problem is achieved in similar fashion to the room problem is an indication that transfer has taken place. While this might have potentially resulted in a ceiling effect, this was not observed in the data; the mean transfer score was .88 out of 2.

No advisement was available, nor was there any element of competition present in this simulation game. While this might seem to give undue advantage to the treatment conditions over the control condition, it should be noted that the control condition reflected traditional methods of instruction in area and perimeter (i.e., word problems). Research indicates that traditional instruction often results in failure to transfer, a result the simulation game is designed to mitigate. It was deemed critical, therefore, that the amount of practice with the content and the mode (i.e., computer-based) be controlled in the study. It is important to note that each transfer problem required several computations and conversions to complete. Accordingly, it was possible to complete only two problems in the allotted time (50-min session). Although data were available regarding each of these computations, they constitute math skills and as such are a measure of performance, *not* transfer. Additionally, participants were not required to enter the results for each mathematical calculation required to solve the problem, perform all calculations on screen, or correct any errors they detected, so the computational data are not a good measure of performance either, since it was possible for them to account for errors or perform calculations in their heads.

Debriefing questionnaire

A 10-item debriefing questionnaire was developed to capture qualitative data regarding participant attitude toward elements of the game, such as the competitor, the method of seeking help or advisement, the use of the advisement itself, the likeability of the game, and the usefulness of the game for learning math. The questionnaire also asked learners for their learning modality preferences in mathematics (game, book, teacher, etc.) and additional comments. Each item was an open-ended question completed on paper by the participants. These data were collected for possible post hoc analysis.

Research Design

The experimental design was a randomized pretest-posttest design with two independent variables and one dependent variable, resulting in a 2 × 2 design with an outside control group. Participants were randomly assigned to conditions beforehand, but participated as a class during their normal class time. Independent variables included contextualized advisement (the presence or absence of the video-based discussion of the problem, process, and formulas) and competition (with or without). The dependent variable was transfer scores. Participants were unaware of the different conditions. Very few visual differences existed between the conditions, participants were seated by condition and observed during the intervention, and headphones were used by all participants.

Procedure

Pretest

During the first 50-min session (Day One), participants received orienting instructions explaining the purpose and process of the study, were given the opportunity to ask questions, and were then given the demographics survey and the pretest, all in computer form.

Simulation-simulation game

Participants returned two days later for the second 50-min session (Day Two) and completed a 5-min computer-based simulation game tutorial, which oriented them to the game interface, including all tools within the game and navigation. They were unable to proceed to the simulation or simulation game until they had demonstrated the use of each tool and element of the interface one time. Participants then began playing the simulation game (intervention) or worked the identical online word problems (controls). Data were collected during the game via the computer and stored as text files for later retrieval. The game debriefing questionnaire was given to the participants to be filled out and returned at the next class session (Day Three). The teachers were instructed not to discuss or teach the content of the game (i.e., area and perimeter) between these class sessions, and they reported to the researcher that they had not done so.

Posttest

The third 50-min session (Day Three) occurred one week after the second session, when the posttest (the transfer simulation) was administered. Participants were then debriefed about the actual nature of the study.

Data from the instruments and the game and computer-based word problems (controls) were input directly from the computer-generated files into SPSS statistical software. After data screening for outliers and normality, and after checking for appropriate statistical assumptions, ANOVA, bivariate correlation, and chi-square analyses were performed to test the hypotheses.

RESULTS

Outliers were examined using Mahalanobis's distance and the critical value from the chi-square table at the .001 level. Mahalanobis distance is a measure of how much each individual's score on one or more independent variables differs from the mean for all individuals. Thus, a large Mahalanobis distance score indicates extreme values and thus potential outliers. Worst cases in the data were compared to the critical value obtained from the chi-square table. No values exceeded the critical value for the variables examined in this study. Assumptions for the statistical measures used were checked. All fell within acceptable parameters for the inferential statistics used, with the exception of the significant Levene's test for equality of variances among groups (Hypotheses 2, 3, and 4), which indicates the error variance of the transfer score was not equal across groups. The violation of this assumption is usually only problematic when samples (i.e., cells) are unequal (Huck & Cormier, 1996, p. 375). Because the samples were all large and relatively equal (29–35), the violation of this assumption was not deemed critical and statistical analyses were interpreted.

To control for treatment time, only those participants who had completed the simulation game (i.e., had not been forced to quit the game because of a computer problem or had not accidentally exited the game prior to completing the problems) were included in analyses. Of the 99 noncontrol participants, 35 had exited the game prior to completing it. While this was in some cases due to equipment failure, the majority were the result of participants not having enough time to finish the game in the allotted 50-min period because of the complexity of the tasks. Of those 35, none had entered a final answer for either the area or perimeter problem. Only one had used advisement (once) prior to exiting the game, and participants excluded were evenly split between males and females. Seven of these participants were from Group 1 (contextualized advisement, no competition), 8 were from Group 2 (contextualized advisement, with competition), 12 were from Group 3 (no contextualized advisement, no competition), and 8 were from Group 4 (no contextualized advisement, with competition). Further analysis revealed that the higher number of participants in Group 3 was attributable to seating arrangements in the lab during one session in which power was inadvertently turned off to one row of computers during the game. This affected

Table 1 ☐ Number of participants, means, and standard deviations of advisement use, pretest, game, and posttest (transfer) scores by condition

	Advisor		*Pretest*			*Game*			*Posttest (transfer)*		
Condition	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Control	—	—	24	17.58	2.98	24	.20	.51	24	.41	.65
Contextualized Advisement, no Competition	.94	1.08	21	18.67	1.85	24	.29	.46	17	.82	.88
Contextualized Advisement with Competition	1.00	1.03	21	18.62	2.67	25	.08	.28	17	.47	.80
No Contextualized Advisement, no Competition	—	—	23	18.87	2.83	24	.08	.28	12	.25	.45
No Contextualized Advisement, with Competition	—	—	23	18.35	2.99	26	.11	.33	18	.78	.94
Total	.97	1.04	112	18.40	2.64	123	.15	.38	88	.61	.83

Note: Samples (*n*), means (*M*), and standard deviations (*SD*) reflect participants who submitted answers (i.e., completed) the simulation game and the posttest, and were used for analyses.

four participants from Group 3. Final group sizes were 17, 17, 12, and 18 respectively.

Pretest scores were examined to determine prior knowledge. The mean score on the pretest for 112 participants was 18.4 out of 22, with a standard deviation of 2.64, indicating the participants had basic mastery of the prerequisite mathematics skills for the simulation game and posttest. It is important to remember that this pretest measures prerequisite computational skills, *not* transfer. Advisement use, pretest, game, and posttest scores are presented in Table 1. The results are presented and discussed in the order of the hypotheses as outlined in the introduction.

Hypothesis 1

Hypothesis 1, that participants who select contextualized advisement more often than others will have higher transfer of mathematics scores, was not supported. Statistical analysis indicated no significant correlation between transfer scores and advisement use (Hypothesis 1, $r = -.079$, $p = .325$). Participants accessed advisement an average of .97 times, with a standard deviation of 1.04, indicating advisement was rarely used. Advisement was positively skewed and had a disproportionate number of zeros (16 out of 35 possible participants never selected advisement). Advisement scores ranged from 0 to 3, with 2 being the most common score after 0. No transformations or nonparametric tests are available for a variable with a high number of expected 0 scores. Excluding all 0 scores from analysis resulted in a more normally distributed advisement use variable ($M = 1.79$, $SD = .71$), but there was again no statistically significant relationship between advisor use and transfer ($r = .111$, $p = .325$).

Hypotheses 2 and 3

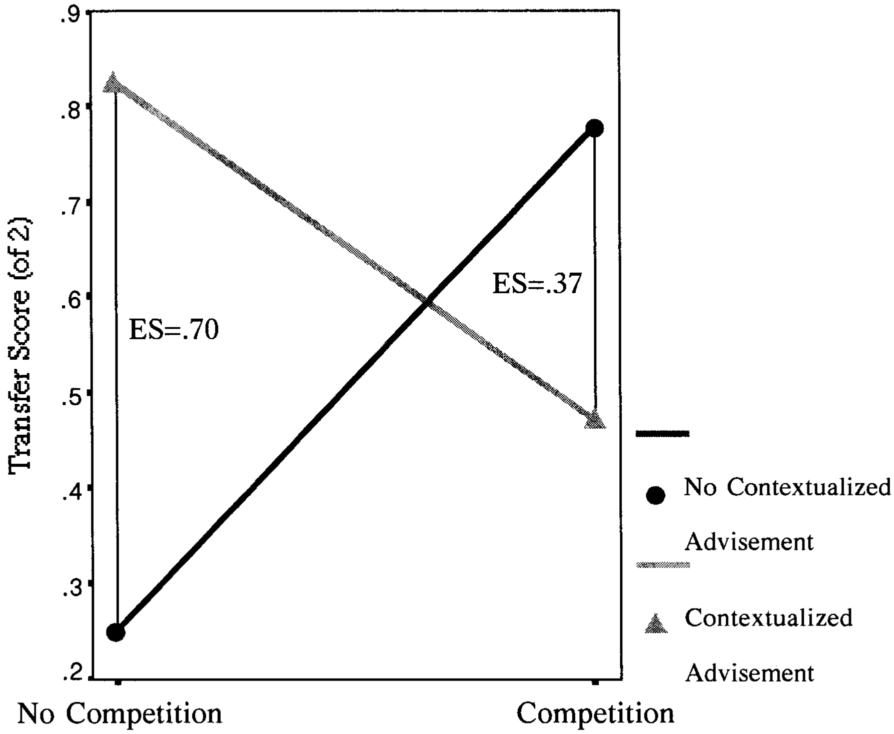
These hypotheses, that participants in the contextualized advisement conditions would have higher transfer of mathematics scores than those without access to contextualized advisement and that participants in the noncompetitive simulation conditions would have higher transfer of mathematics scores than participants in the competitive simulation game conditions, received partial support.

A 2 × 2 ANOVA was run on the four treatment groups (Competition × Contextualized Advisement) with transfer as the dependent variable. A significant interaction of competition and contextualized advisement was found, $F(1, 60) = 3.024$, $MSE = .668$, $p = .037$. No main effects were found. Table 1 presents the means and standard deviations for each group.

Following the significant interaction, the cell means were plotted and are shown in Figure 1. Simple main effects analyses were conducted to test for differences in the pairs of cell means. Neither F from these analyses was significant (for competition = 0, $F = 3.46$, $df = 1{,}60$; for competition = 1, $F = 1.235$, $df = 1{,}60$). Similar results were also found using Tukey's HSD. This appears to suggest contradictory results. However, the significant interaction only promises that *some* contrast among the cell means is significant, not necessarily the pairwise contrasts. Since the purpose of this study was to examine the pairwise comparison, effect sizes were calculated. For competition = 0, the effect size was .702, indicating that the two groups differed by about .7 standard deviations, whereas for competition = 1, the effect size of .376 indicated a difference of more than one third standard deviation. An effect size of .7 is a relatively large effect size, while one of .376 is a relatively moderate effect size according to Cohen's (1977) conventional definitions. The lack of significance in the simple main effects analyses is also in large part due to weak power. Power analysis indicates that to find an effect size of .75 to be significant at the .05 level with power = .80 would require 29 participants in each group; almost twice what was available. Therefore, we concentrate on the substantive importance reflected in the magnitude of the effect sizes for interpretation.

Participants in the contextualized advisement condition without competition had higher transfer scores (.82) than participants in the no contextualized advisement without competition (.25). Participants in the no contextualized advisement with competition condition had higher transfer of mathematics scores (.78) than those in the contextualized advisement with competition

Figure 1 □ Interaction of competition and contextualized advisement on transfer of mathematics score.



(.47). Because the analysis indicated a significant interaction and no significant main effects, main effect differences post hocs were not conducted.

A chi-square analysis was run using pretest and posttest scores on the area and perimeter problems (correct vs. incorrect) to ensure that transfer scores were the result of recognition and application of prior knowledge rather than simply a reflection of mathematics ability. This analysis indicated no statistically significant relationship between performance (correct or incorrect solution of the area and perimeter problems) on the pretest and posttest. Similarly, bivariate correlation analysis indicated no statistically significant relationships between overall pretest scores and overall transfer scores.

Hypothesis 4

This hypothesis, that participants in all intervention conditions as a group (i.e., those who experience an authentic learning environment) would have higher transfer of mathematics scores than participants in the control conditions (those who experience word problems only), was not supported. A one-way ANOVA of all five conditions using Dunnett's post hoc analysis indicated no statistically significant difference between the control group and any other condition. Simple contrasts likewise indicated no statistically significant differences. Means and standard deviations are presented in Table 1.

DISCUSSION

Transfer

There are several factors in this study that may have made it difficult to detect transfer learning in general. While some of these factors are specific to experimental condition and will be discussed in that context, others are applicable to all conditions and bear some mention here.

Restriction of range

The nature of the transfer variable itself may have made statistical differences difficult to detect. The transfer variable ranged from 0 to 2 (as there were two transfer problems), which may not have allowed for enough variability to detect differences. Standard deviations for the transfer score means were as high or higher than the means themselves, making any potential relationship between advisement and other variables of interest difficult to detect.

Although the correct solution of the transfer problems required participants to take measurements, select or know four appropriate facts and formulas, perform two calculations for area and perimeter, convert feet to yards twice, and divide by the number of yards per roll of carpet and square yards of curtain fabric, the actual transfer of mathematics scores ranged from 0 to 2, as they were based on the ability to select and apply the correct formulas for two problems. This was necessary because the intervention was limited by the schools to one 50-min session, and situated learning is complex and requires elaborate processing. Given this and the fact that the intervention itself (also limited to one session) required complex computations and required complex problem-solving skills, more than two problems could not have been finished by the learners in the allotted time.

The advisor use variable has a high, expected, number of zero scores, indicating that most participants did not select advisement (See Table 1). That this is reflective of advisment use overall in CBT is discussed in more detail elsewhere in this paper, but it is worth mentioning here that with most participants selecting advisement an average of one time during the intervention, any difference attributable to advisement use would have to be quite large. This is consistent with the effect size (.7) of the difference observed between transfer scores in the noncompetitive conditions.

Length of intervention and number of practice opportunities

Transfer is most likely to occur as the result of multiple practice opportunities over long periods of time, with systematically varied distances between the learning and practice contexts, and with support or scaffolding along the way. The intervention in this study was limited to one class period for practical reasons. Given that transfer (especially in the context of this study) is a form of problem solving, it is reasonable to expect that learners would need more exposure to the intervention. It undoubtedly takes more than 50 min to process the kind of learning and connections required for transfer to take place.

Transfer learning should also be distributed over time, with multiple practice opportunities. Increasing both the duration of the intervention and distributing that intervention over a longer period of time might provide students with the processing time needed to build the connections they need for transfer to occur. And finally, given the role of context (learning and demonstration) in transfer learning, it is probably necessary to systematically vary the “distance” or similarity between the learning and performance contexts, beginning with a high degree of context similarity and gradually increasing the distance with time and practice while providing the scaffolding needed for the learner to be continuously successful.

Knowledge versus skills transfer

It may be that knowledge and skills transfer differently. It may be easier for learners to transfer knowledge to multiple contexts because knowledge tends to be abstracted from the environment, which makes it less context dependent. Therefore, the learner is not required to make connections between apparently different contexts when determining whether to apply knowledge to the current context. Skills, on the other hand, are almost always context dependent, even when not consciously learned or taught in that way. When we learn a skill such as cutting a piece of wood, there are a whole host of environmental cues that are inevitably associated with the skill. These cues (smell, sound, touch, movement of the wood, etc.) become part of our schema for cutting wood; we don’t store a list of procedural steps by themselves. Transfer of skills then, requires the abstraction of knowledge from the contexts in which it was acquired.

In this study, for example, it might be much more likely to learners to abstract the concept of determining surface area of a wall (rectangle) to apply it to surface area of a door in the same room, because both share a context; abstracting from there to surface area of a curtain (as was the case in the transfer context) may be more difficult because the contexts differ more. This does not make transfer of skills impossible, of course, only more difficult and hence less likely to occur without lots of practice and support.

Hypothesis 1

Hypothesis 1, that participants who select contextualized advisement more often than others would have higher transfer of mathematics scores, was not supported. Bivariate correlation analysis of advisement use and transfer scores did not yield any statistically significant relationship.

Advisement in this question was measured by the number of times the participants selected contextualized advisement (the video of the aunt and uncle). Previous research on advisement and learner control has indicated that advisement is often not selected by learners (Dempsey & Van Eck, 1998; Tennyson, 1980a, 1980b, 1981, 1984; Tennyson & Buttrey, 1980). Thus the high number of zero scores (16, or 46%) for advisement use in this study is a reflection of advisement use in the population. Instruction that attempts to build in advisement for transfer or other learning goals should explore ways to promote its use; the mere presence of advisement is not enough. Redesigning advisement to prompt learners to use it may help produce a more normally distributed variable and improve statistical power.

Hypotheses 2 and 3

Hypothesis 2, that participants in the contextualized advisement conditions would have higher transfer of mathematics scores than those without access to contextualized advisement, and Hypothesis 3, that participants in the noncompetitive conditions would have higher transfer of mathematics scores than participants in the competitive conditions were partially supported. Statistical analysis indicated a significant interaction of competition and contextualized advisement (see Figure 1 and Table 1). Further analysis indicated that the nature of the interaction was complex, involving some combination of means differing from one or more other means. Effect size analysis revealed a relatively large effect size for the difference between the transfer scores for those in the contextualized advisement without competition versus those in the no contextualized advisement with competition. Similarly, a moderate effect size was found for the difference between those in no contextualized advisement with competition versus those in the contextualized advisement conditions with competition.

It seems that those in the contextualized advisement conditions did best when competition was not present, while those in the competition conditions did best when no contextualized advisement was present. Analysis of pretest scores and transfer scores indicated no significant relationship, which is as expected. It is important to remember that pretest scores reflect computational mathematics skills, while posttest scores reflect the ability to apply prior knowledge. While it is reasonable to expect that low pretest scores would result in low transfer scores as measured in this study (since transfer also required some computation), the mean pretest score was over 18 out of 22 questions, indicating that all participants had the prerequisite mathematics skills. Further, while most participants got the 6 questions relating to perimeter and area correct (perimeter and area of a square, 84%, 87%; rectangle, 86%, 90%; and triangle, 92%, 56%), most got the 2 word problems for area and perimeter incorrect (88% and 96%, respectively), indicating that while most could perform the calculations for area and perimeter correctly, they failed to transfer those skills even to word problem contexts. Since transfer is a different skill, the ability to transfer should be evenly distributed in the sample (across conditions), and thus no significant relationship between pretest and posttest scores was expected. This analysis indicates that any transfer score differences are more likely attributed to the intervention (different conditions) than to mathematics skills in general.

These results should be interpreted with caution given the restricted range of the transfer variable, the high number of zero scores (resulting in postive skew) in the advisor variable, and the high error variance in the transfer score (see Table 1). Given that advisor use in this study reflects advisor use in the population (e.g., people tend not to select advisement and help options in CBT) as was mentioned above, and that cell sizes were relatively large and equal, some interpretation is warranted.

It may be that the presence of competition creates an affective environment in which contextualized advisement cannot be fully attended to or processed because learners are concerned about the time they have taken (which is displayed on screen) and with beating the competitor. In other words, competition may inhibit metacognitive skills, attention, and elaboration. Transfer is also a form of problem solving, which is in this case a higher-order intellectual skill involving accurate problem space representation, recall of prior knowledge, and the formulation of rules about when and where to apply that knowledge. Accordingly, the cognitive load involved may be higher than for lower-level intellectual skills. Competition may create an affective state of anxiety and pressure that is detrimental to the processing necessary for transfer learning to occur. Likewise, attending to the advisement itself requires additional cognitive resources, resulting in higher cognitive load for those in the contextual advisement conditions. The increased cognitive load when combined with the competitive element may help account for the lower transfer scores.

This conclusion is consistent with Miller and Heward's knowledge acquisition model (1992). Although transfer rarely occurs, mathematics education often attempts to make use of real world scenarios (e.g., word problems and scenarios), perhaps providing some transfer learning in this domain. Accordingly, many students could be assumed to be somewhere between the knowledge acquisition stage and the practice stage in terms of transfer. Miller and Heward argue against time trials (a kind of competition) during the knowledge acquisition stage as it interferes with learning. If participants were still somewhere in the acquisition stage of learning, competition may have interfered with the cognitive processing necessary for transfer learning to take place.

In the noncompetitive conditions where the contextualized advisement was present, the students may have had more resources to devote to the learning and the contextualized advisement because they were not monitoring their progress in terms of time and performance (they were not under pressure to finish before a competitor, nor were they possibly distracted by the time clock advancing on the screen). This may have promoted a different goal state for learners, in which learning and being accurate were the most important goals, which is more compatible with acquisition stage learning. Alternatively, it could be hypothesized that competitive conditions work against selecting contextualized advisement, which adds time to the game every time it is selected. Although this was not borne out by advisement use in this study, (participants in both the competitive and noncompetitive conditions selected advisement equally), advisement use was so low overall that differences may not have been detectable (see Table 1).

It is interesting to note that competition alone (i.e., without contextual advisement) produced transfer scores nearly identical to contextual advisement without competition, which would seem to argue against the previous interpretation regarding acquisition and practice stages of learning. Previous studies that have found positive overall effects for competition (e.g., Fisher, 1976; Hurlock, 1927; Julian & Perry, 1967; Miller, 1981; Spalt, 1988; Wilkes, 1965). It is important to remember, however, that competition does not function identically in all situations, and to reduce the argument to the level of "competition is good" or "competition is bad" is an oversimplification that ignores some very important considerations. For instance, for competition to promote motivation, performance, and learning, students must perform at less than their maximum level of performance in noncompetitive conditions.

While this may often be true, it also follows that if students are already at a maximum for other reasons (such as extrinsic or intrinsic motivation, reward, or punishment), then competition is *less* likely to produce large improvement (Thompson, 1972). It may be that competition can improve performance, but that the means and extent to which it does so are at least partially determined by the content, the complexity of the learning, familiarity with the content, the nature of who is competing against whom, and other situational characteristics. It was not the purpose of this study to examine the relation of competition to these kinds of situational characteristics, so it is not possible to fully interpret these results. Future research should examine the relationship of competition to these other variables in more detail.

In any event, it appears that advisement should be modified according to whether competition is present or not. Games that make use of competitive elements may be incompatible with contextualized advisement, while contextualized advisement may be best suited for learning during the acquisition stage.

Hypothesis 4

Hypothesis 4, that participants in all intervention conditions as a group (i.e., those who experience an authentic learning environment) would have higher transfer of mathematics scores than participants in the control conditions (those who experience word problems only), was not supported. No significant differences in transfer were found between the control conditions and the treatment conditions.

It is surprising that controls did not differ from the other conditions, although controls did have transfer scores in the same range as the lower scores in the other conditions (see Table 1). One explanation for these results may lie in the nature of the word problems themselves. In an effort to keep content identical, participants in the control conditions were given semantically identical word problems in which they were told to calculate the amount of paint and wallpaper border needed for a room in a house. These participants were provided with graphics similar to those found in standard geometry problems such as squares, rectangles, circles, and triangles. Prior research has indicated that transfer can be promoted by making the connection between the current transfer context and prior knowledge (e.g., Adams et al., 1988; Lockhart et al., 1987). Thus, it may be that the act of providing the context (fixing up a room) in conjunction with the shapes and diagrams most common to the learner from earlier contexts (prior knowledge) was sufficient to produce some effect on the transfer measure later, although not enough to bring learners into the same range as participants in the contextual advisement, no competition or no contextual advisement, with competition conditions (see Table 1).

FUTURE RESEARCH

Future research should be conducted to replicate these findings over a much longer period of time while incorporating ways to promote advisement selection overall, and with more participants (at least 120). This would increase power in the analyses by increasing the variance in both the transfer and advisement use variables and by increasing the number of participants per cell. That transfer effects were found in this study at all, based on a 50-min intervention, is perhaps the most surprising result, and may indicate that these interventions have a high practical significance.

The intervention should be conducted over the course of a normal school year, if possible, so that the intervention is an integral part of the participants' experience and curriculum. In addition to the duration of the intervention, multiple opportunities in a variety of different contexts should be undertaken, as prior research on transfer learning indicates is needed (e.g., Dempsey, Tucker, & Jacobs, 1990; Gagné, Briggs, & Wager, 1992; Larkin, 1989; Perkins & Salomon, 1989; Quinones, Sego, Ford, & Smith, 1995).

To promote transfer use, it may be possible to build a kind of adaptive advisement system similar to that developed by Tennyson (1980a, 1980b), but which sends contextual prompts to the learner (e.g., after three errors or long periods of inactivity, voices come over the walkie-talkie asking if they need any help).

Finally, further research is also needed to explore the nature of the advisement mechanism itself. Similar video clips of people who are generic advisors unconnected to the context of the simulation or game might help determine how much of the effect is due to the content of the advisement versus the context of the advisement. Future research should also examine the role competition plays in elaborative processing and cognitive load to determine under which conditions competition may be most beneficial. These analyses should probably be undertaken as separate studies in order to isolate the specific contributions each makes to transfer learning as well as its individual relation to other situational variables and characteristics. ☐

Richard Van Eck is Assistant Professor University of Memphis.

Jack Dempsey is Professor at the University of South Alabama.

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