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ABSTRACT

A dilemma in designing computer simulations for instruction is how to provide a challenging exploratory environment and yet provide sufficient support so that students do not become lost. Directive support such as corrective feedback may detract from the exploratory quality of a simulation. Two methods of non-directive support are: (1) simplifying the initial presentation of the simulation by having the student manipulate only some of the variables; and (2) presenting the simulation problem to a small group rather than to individuals so that students may give each other feedback on their hypotheses and procedures. This paper examines the effect of both of these methods and their interaction upon undergraduate students solving a problem in a four variable computer simulation of the spread of an epidemic. Subjects were divided into four treatment groups working with varying complexity levels. In terms of instructional effectiveness, as measured by the percentage of students reaching a correct solution, a significantly greater proportion of subjects who worked individually reached the correct conclusion when the task was initially simplified. In contrast, a greater proportion of subjects who worked in groups reached the correct conclusion when presented with full initial complexity. Subjects performed significantly more simulation runs when they were presented fewer variables first and all of the variables later. This study suggests that when a complex, multi-variable simulation is presented, it may be preferable to present it to groups for solution rather than attempt to break it down into component parts. (Contains 17 references.) (Author/AEF)

Title:

The Effects of Group and Task Structure in an Instructional Simulation

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Abstract

Computer simulations allow students to explore learning environments by forming hypotheses and making and testing predictions. A dilemma in designing such simulations is how to provide a challenging exploratory environment and yet provide sufficient student support so that students do not become lost. Directive support such as corrective feedback may detract from the exploratory quality of a simulation. Two methods of non-directive support are 1) simplifying the initial presentation of the simulation by having the student manipulate only some of the variables and 2) presenting the simulation problem to a small group rather than to individuals so that students may give each other feedback on their hypotheses and procedures. This paper examines the effect of both of these methods and their interaction upon undergraduate students solving a problem in a four variable computer simulation of the spread of an epidemic.

Subjects were divided into four treatment groups: individuals working with reduced initial complexity, individuals working with full initial complexity, groups working with reduced initial complexity, and groups working with full initial complexity. In terms of the effectiveness of instruction as measured by the percentage of students reaching a correct solution, a significantly greater proportion of subjects who worked individually reached the correct conclusion when the task was initially simplified. In contrast, a greater proportion of subjects who worked in groups reached the correct conclusion when presented with full initial complexity.

Subjects performed significantly more simulation runs when they were first presented fewer variables and finally all of the variables. When a task is complex individuals may benefit from working with a group. In this study group work provided no benefit for the simplified task. The study suggests it may be preferable, in presenting a complex, multi-variable simulation, to present it to groups for solution rather than attempt to break it down into component parts.

With increasing emphasis on constructivist approaches to learning and greater availability of appropriate software, instructional computer-based simulations are increasingly being used to allow students to explore complex multi-variable phenomena by manipulating variables and observing changes. For example, Smithtown allows students to vary economic variables (wages and prices) and observe outcomes, such as shift in the demand function (Shute & Glaser, 1990). MIDAS, a simulation in the domain of decision-support theory, requires users to see the effects of specifying different weights on user preference scores (de Jong, de Hoog, de Vries, 1993). REFRACT allows students to see the effects of manipulating variables such as optical density, angle of refraction, and image distance on objects such as surfaces, lenses and rays (Reimann, 1991). Numerous such simulations now exist in both the physical and social sciences. Common to all of them is the process of experimentation, which includes forming hypotheses, making and testing predictions, and modifying the hypotheses. A dilemma is that this process, basic to scientific inquiry, is both a prerequisite for and an outcome of using such simulations. Some simulations have been used in an attempt to teach the methods of scientific inquiry, for example Discovery Lab (Minnesota Educational Computing Corporation, 1984). But more often, as in the examples above, the main purpose is to teach content, namely, the relationships of variables defining a physical or social phenomenon.

While it is widely believed that simulations can effectively teach about complex systems through this controlled method of discovery, studies have demonstrated that not all students meet with success (e.g. Shute & Glaser, 1990; Njoo & De Jong, 1991). Learning in such environments requires students to construct their own knowledge and is generally very demanding for students, even with some form of instructional support. However, the provision of such support needs to be considered in terms of its effects on the nature and level of learners' exploratory strategies. Ideally, such support should facilitate student learning while maintaining the exploratory nature of the learning experience. More precisely, what is needed are support strategies which solve the dilemma between a *low-support, low effectiveness, high involvement* and *high-support, high effectiveness, low involvement* situation.

Various authors have investigated the effects of varying levels of instructional support in experiential learning environments. De Jong, de Hoog, de Vries (1993) categorize such support as either directive (for example, hints, Socratic dialogue, corrective feedback) or non-directive (for example, hypothesis sketch pads, goal decomposition trees, overviews of output obtained or input history). Non-directive support is preferred as it maintains the exploratory nature of the learning environment. Shute and Glaser (1990) provided non-directive support in terms of tutoring in scientific skills. Reimann (1991) provided structure for subjects' hypothesis generation and testing through the use of window and notebook facilities to keep track of experiments and to organize and manipulate information, and through the use of graphic and verbal feedback. Njoo and de Jong (1991) studied the effects of providing different levels of support to college level students of engineering using a simulation in the domain of control theory. In addition to providing subjects with notetaking facilities, Quinn and Alessi (1994) showed some success for a strategy of breaking the overall task into subtasks of increasing complexity when used in conjunction with a strategy of generating and testing multiple hypotheses. Quinn & McCune (1995) showed a greater level of exploration on the part of subjects who were successful in completing a variable optimization task than those who were unsuccessful.

Our current focus is on optimizing student learning while promoting and maintaining exploratory behavior in the context of a complex multivariable simulation. The literature on scientific inquiry provides many guidelines to foster hypothesis generation and testing and subsequent exploratory behavior (Popper, 1978; Holland, Holyoak, Nisbett, and Thagard, 1986), with recent research identifying several relevant factors. These include task complexity (Mynatt, Doherty, & Tweney, 1978; Gorman, 1989), effects of working in groups (Gorman, 1989), structure of the phenomenon (Klayman & Ha, 1987), goals (Klayman & Ha, 1987), timing of tests of confirmation and falsification (Mynatt et al, 1978; Tweney, Doherty, Worner, Pliske, Mynatt, Gross, & Arkelin, 1980), familiarity of the context (Cheng & Holyoak, 1985), subjects' prior knowledge (Klahr & Dunbar, 1988), and the number of hypotheses generated (Mynatt et al, 1978; Tweney et al, 1980; Klahr & Dunbar, 1988).

This present study is concerned with the development of non-directive support strategies which take into account two of the factors mentioned above - structure of the phenomenon and the effects of working in groups, and is a follow-up to Quinn & Alessi (1994). In that study, the phenomenon being investigated depended on several variables and the overall task presented to subjects was to investigate the effects of modifying four of these variables. One of the variables behaved in a counterintuitive manner (the optimal value for the goal assigned to subjects was its maximum value, but it appeared to many subjects that the optimal value should be the minimum value) and this was the principal reason for subjects failing to obtain the optimal combination of the four variables. The purpose of this study was to increase the proportion of subjects who obtained the optimal combination of variables by requiring subjects to work in dyads. The rationale behind this approach was that requiring subjects to work in pairs would increase the probability of subjects perceiving the counterintuitive nature of the optimal combination of values, while maintaining the exploratory nature of the task. Thus, requiring subjects to work in pairs was seen as a form of non-directive support. In addition, some subjects were presented with the overall task initially and some subjects were presented with the task in stages. Such a design allowed investigation of task structure on performance. Therefore, the principal research questions in this study were: 1) what will be the effect of subjects working in pairs on performance on a task involving variables which behave in a counterintuitive manner?; and 2) what is the effect of task structure on such performance?

Methods

Subjects

Subjects were 66 students in a teacher education program. Twenty-one students were enrolled in a 1 semester hour course titled "Introduction to Microcomputing for Teachers", 30 students were enrolled in a three semester hour course titled "Educational Psychology and Measurement", and the remainder (15) were enrolled in a three semester hour course titled "A Survey of Computer Applications in Instruction". All were given bonus points for participation.

The Simulation

The computer simulation was a model of the spread of an influenza epidemic. There were two displays in the simulation (Figure 1 and 2) and it was very easy to operate. On the control display (Figure 1) the subject dragged sliders to choose values of the 4 variables. The subject then pressed the Run Simulation button to obtain the next display (Figure 2). This display shows both tabular and graphic representation of the number of people ill across time. The subject could then click the Simulation Control button (returning to the control display) to try new values and observe the output, or click the End of Phase 1 button to go on to the next phase of the experiment. Typically, subjects go back and forth between these two displays, changing variables and observing the result, until they believe they have solved the assigned problem. All subjects were presented with the following goal: to determine the combination of variable values that would keep the maximum number of people ill in any one week as low as possible. Subjects were told that they could consider the outbreak to be over as soon as the number of people ill fell below 150 as the outbreak receded.

Figure 1. Simulation control display.

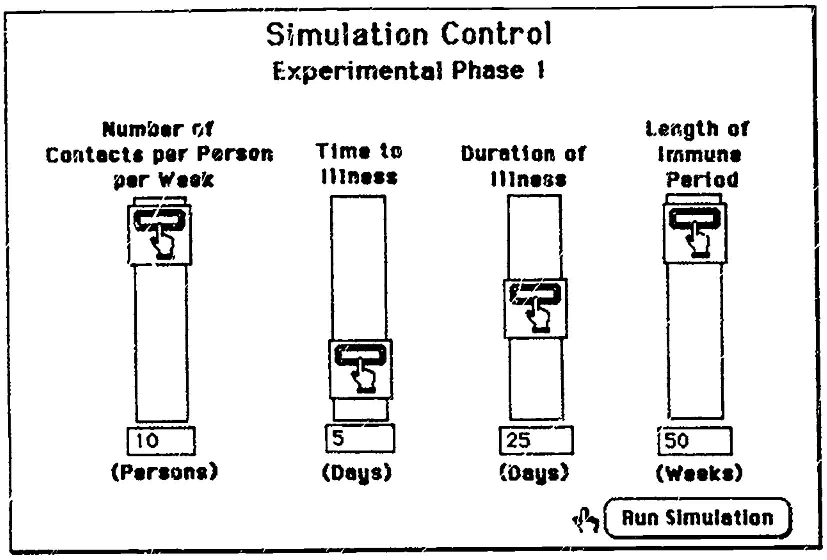
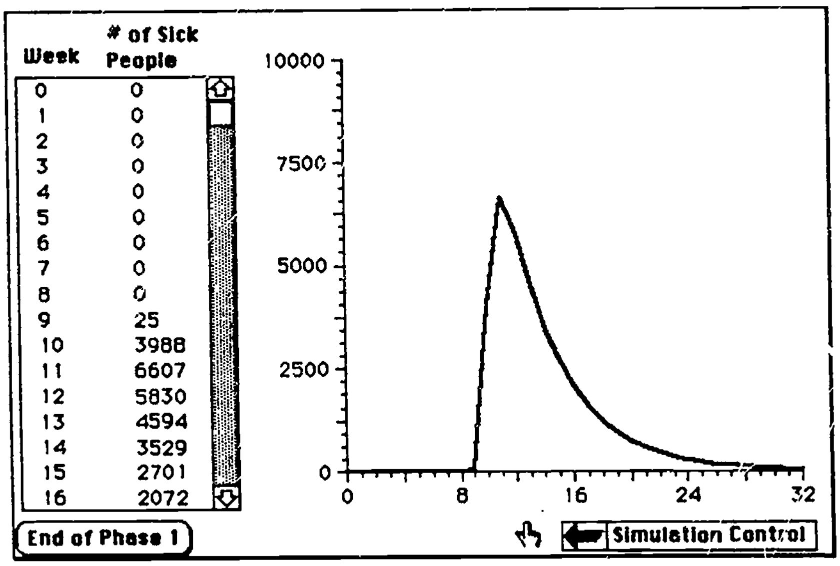


Figure 2. Graphical and tabular output from simulation.



In the simulation model, the number of people ill with influenza depended on four variables: the number of contacts per person per week, the time to illness, the duration of illness, and the length of the immune period. The output observed was the rise and decline of infection within a population of 10,000 people over 32 weeks. The range of these variables are presented in Table 1. Table 2 presents the optimal values of these variables for each of the goals presented to subjects. In Quinn & Alessi (1994), the proportion of subjects who reached the correct conclusion for Goal 1 was approximately 70%. In addition, the principal reason for an incorrect conclusion to Goal 1 was an incorrect specification for the optimal value of the variable "Time to Illness" - 50.6% of subjects who failed to complete the task successfully incorrectly specified the minimum value of the variable "Time to Illness" rather than the maximum value.

Table 1.

Ranges and of Variables Affecting Spread of Influenza in the Simulation Model.

Variable	Range
Number of Contacts per Person per Week	2 to 10 persons
Time to Illness	3 to 28 days
Duration of Illness	14 to 35 days
Length of Immune Period	13 to 27 weeks

Table 2.

Optimum Values of Variables Affecting Spread of Influenza in the Simulation Model.

Variable	Optimal values for minimizing maximum number ill in any week.	Optimal values for minimizing the number of weeks the outbreak lasts.
Number of Contacts per Person per Week	2 persons	2 persons
Time to Illness	28 days	2 days
Duration of Illness	14 days	14 days
Length of Immune Period	27 weeks	27 weeks

Design

Subjects were divided into four treatment groups. In each treatment the overall goal was the same and subjects were required to manipulate all four variables. In two groups (I234 and I4) subjects worked on their own and in two groups (G234 and G4) students worked in pairs. All subjects were randomly assigned. In groups I4 and G4, subjects were presented with all four variables initially. In groups I234 and G234, subjects were first presented with two variables and were required to specify the optimal value of these two variables (Phase 1). When subjects concluded they had specified the correct combination of variables, a third variable was introduced and the process was repeated for three variables (Phase 2). Finally, a fourth variable was presented and subjects determined the optimal set of values for all four variables (Phase 3). For each of the four groups, subjects were asked to complete a questionnaire about their interaction with the simulation. The dependent variables measured were the proportion of subjects who reached the correct solution (Correct) and the amount of investigation as measured by number of simulation runs performed by subjects (Simrun).

Procedures

Subjects in groups I4 and I234 (who worked individually) first proceeded through an orientation phase where they were introduced to the subject matter of the simulation and learned how to manipulate the simulation. In this phase, subjects were also given a brief description of the four variables. Subjects were then asked to generate and record an initial hypothesis as to what combination of variables would keep the number of weeks the outbreak lasts as small as possible, while at the same time keeping the maximum number ill in any one week less than 1500. Subjects could specify a range of values for any or all variables and were also given the option of indicating that they did not think that there was any combination of variables which would satisfy the goal. Then, subjects were instructed to begin investigation by manipulating the levels of the variables and running the simulation. Before each run of the simulation, subjects were required to record on an Experimentation Record Sheet the levels of each of the variables in the proposed simulation run. Then, subjects were instructed to begin investigation by manipulating the levels of the variables and running the simulation. After each simulation run, subjects were asked to record the maximum number ill in any one week period and the length of the outbreak. Subjects were not given feedback as to the correctness of the levels chosen. Only by manipulating variables and observing the output from the simulation could subjects increase their confidence that a particular set of values would generate data to fulfill the goals of the simulation.

Subjects in groups G4 and G234 proceeded through the task in a manner similar to subjects in groups I4 and I234 except that additional instructions were given about working together. In the orientation phase, subjects working in pairs were told that they would be working on the task together and were instructed to proceed through the orientation phase working together. At this point, subjects were also told that throughout the study, they could discuss as much as they wish and perform as many simulation runs as they wished. One Experimentation Record Sheet was available to each group. Subjects were told to decide which group member would record data on the record sheet and which member would interact with the simulation. Finally, it was emphasized to subjects that while they would work in groups, it was not necessary that they agree on the optimal combination of values for the specified goal. Each group member recorded their conclusions separately.

Results

Analysis of variance was first performed to determine the effectiveness and efficiency of the two treatments - Learning Context (individual versus group work), and Task Structure (presentation of variables all at once or in parts). This was done by analyzing the dependent variables Correct - proportion of subjects reaching the correct conclusion, and Simrun - the number of simulation runs performed by subjects.

Effectiveness

The dependent variable, Correct, measured the proportion of subjects who came to the correct conclusion. Subjects who came to the correct conclusion were given a score of 1; subjects who did not reach the correct conclusion were given a score of 0. Table 3 presents the mean proportion and standard deviation of students who reached the correct conclusion in the simulation in each group. Analysis of variance indicated a significant Learning Context by Task Structure interaction [$F(1,61) = 5.330$, MSerror = 1.224, $p = .024$]. The data are plotted for clarity in Figure 3. In view of the interaction, simple effects were examined at each level of Learning Context. The test for simple effects of Learning Context indicated a significant effect for Learning Context only in the case where all four variables influencing the outcome of the simulation were presented at once [$F(1,61) = 20.436$, MSerror = 4.694, $p = .000$]. When all four variables were presented at once, subjects performed better when they worked in a group than when they worked alone. The test for simple effects of Task Structure indicated a significant effect for Task Structure when subjects worked individually [$F(1,61) = 38.773$, MSerror = .230, $p = .000$] and in groups [$F(1,61) = 8.845$, MSerror = .230, $p = .004$. A significantly greater proportion of subjects who worked individually reached the correct conclusion when the task was presented in parts; in contrast a greater proportion of subjects who worked in groups reached the correct conclusion when the task was presented in its entirety.

Figure 3. Proportion of subjects reaching the correct conclusion by learning context and task structure.

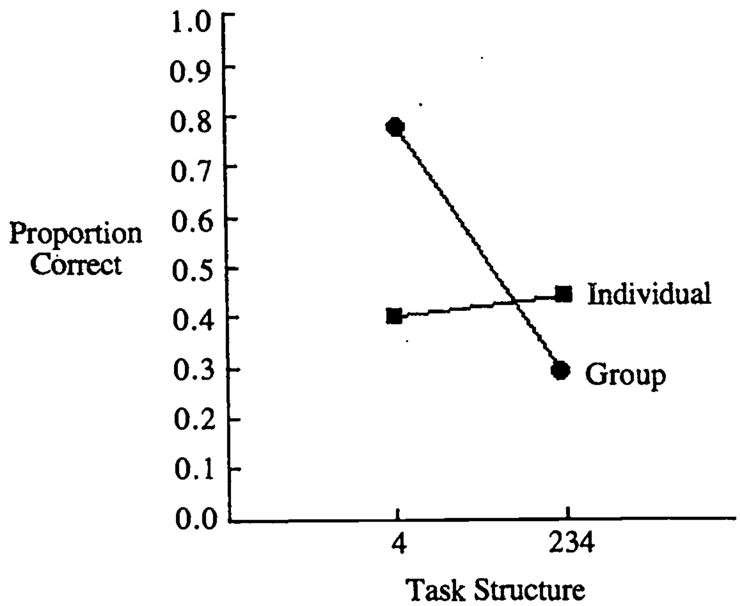


Table 3.

Proportion of Subjects Reaching the Correct Conclusion.

GROUP		Proportion of Subjects Reaching Correct Conclusion
Group I234	M	.444
	SD	.511
		(n=18)
Group G234	M	.278
	SD	.461
		(n=18)
Group I4	M	.400
	SD	.507
		(n=15)
Group G4	M	.786
	SD	.426
		(n=14)

Efficiency

The dependent variable Simrun measured the number of simulation runs performed by each subject. Table 4 presents the means and standard deviations for Simrun only for those subjects who successfully completed the simulation. Analysis of variance did not indicate any significant differences between groups in terms of efficiency.

Table 5 presents the means and standard deviations for Simrun for all groups. Analysis of variance indicated significant main effects for Task Structure [$F(1,61) = 12.644$, $MS_{error} = 221.880$, $p = .001$]. Subjects performed significantly fewer simulation runs when the task was presented all at once rather than in parts.

Table 4.

Number of Simulation Runs Performed by Subjects Reaching the Correct Conclusion.

GROUP		Number of Simulation Runs Performed by Subjects Reaching the Correct Conclusion
Group I234	M	31.835
	SD	12.722
		(n=8)
Group G234	M	36.800
	SD	21.241
		(n=5)
Group I4	M	30.107
	SD	20.203
		(n=6)
Group G4	M	18.091
	SD	11.077
		(n=11)

Table 5.

Number of Simulation Runs Performed by All Subjects.

GROUP		Number of Simulation Runs Performed by All Subjects
Group I234	M	30.111
	SD	13.248
		(n=18)
Group G234	M	35.444
	SD	16.343
		(n=18)
Group I4	M	20.400
	SD	16.008
		(n=15)
Group G4	M	18.714
	SD	13.652
		(n=14)

Discussion

With regard to learning effectiveness, the interaction effects indicated no clear advantage for either Learning Context or Group Structure alone. Thus, there was no clear advantage for presenting the task in parts or allowing subjects to work with a partner. Rather, the results indicated that the effectiveness of allowing subjects to work with a partner depended on whether all variables were presented at once or in parts. The findings suggest that subjects who worked with a partner performed better when the task was presented all at once than when it was presented in stages. This finding suggests that when a task is complex, individuals may benefit from working with a partner, but when a task is simple there may be no advantage to working with a partner. On the other hand, subjects who worked alone performed better when the task was presented in parts rather than all at once. Thus, our hypothesis that subjects in the group condition would outperform those working individually was not confirmed. In addition, there was no clear advantage for breaking the task into subtasks.

It was not surprising that groups performed better when all variables were presented at once. We might have concluded that the simple task didn't require the extra resources of a group if both the individuals and groups had done very well, but in fact both did rather poorly, especially the groups. This may be due to the fact that presenting the simulation in stages of increasing complexity made it logistically more complicated. Students may have expended a great deal of effort on the first sections and then may not have wanted to devote much of their time or attention to the final stage to reach a correct conclusion. Groups did not make significantly more runs but they may have taken a bit longer per run especially in the simplified presentation. Thus the groups who were presented with the task in parts may have become fatigued toward the end of the simulation.

Another major finding in this study was that subjects who worked individually performed significantly better when the task was presented in parts. One implication of this finding is that when subjects work alone they do not have access to the types of support provided in a group setting, thus they benefit from instructional support built into the instruction. Overall the findings indicate that there are two ways to provide instructional support. First, the task may be divided into more manageable parts or individuals may be allowed to work with a partner; however both of these strategies or types of nondirective support should not be combined. Also, although learning is improved by decomposing a task for individuals working alone, the far more effective strategy is to present the task all at once but to groups rather than to individuals.

In terms of learning efficiency, the results of this study indicated an advantage for presenting the task in its complexity. Subjects performed significantly fewer runs when they were presented with all four variables at once. This finding coupled with the finding regarding learning effectiveness suggests that learning is most effective and efficient when tasks are presented in all their complexity to groups as opposed to individuals. One implication of this result is that attempting to simplify a task by decomposing it into parts may make the task more logistically cumbersome. Another interpretation of this finding is that breaking a complex task into its component parts and making it more cognitively manageable for learners may increase their willingness to persevere on a task.

Conclusion

This study investigated the effects of group versus individual learning and task presentation format on learners' ability to understand and simultaneously consider the effects of more than one variable on a single dependent variable. There appears to be no clear advantage for individual versus group work. The effectiveness of either learning context depends on the complexity of the task at hand. When the task is simple, learning context does not make a difference in performance. However, when the task is complex there is a significant advantage to working in a group. Some of the benefits of working with other individuals on a task are that it encourages one to view phenomena from multiple perspectives, increases level of commitment to solving a task, and also increases the amount of cognitive effort invested in a task because of the subtle social pressure of working in a group (Rysavy & Sales, 1991). Thus, individuals are more likely to reap the benefits of working in groups on complex tasks than on simple tasks, since simple tasks do not require viewing ideas from multiple perspectives, or investing a great amount of cognitive effort, or an inordinate amount of perseverance. The findings of this study suggest that a more effective way of facilitating learning of complex tasks is to have individuals work in groups rather than simplify the task by decomposing it into more manageable pieces. This finding is encouraging in light of the practical concerns of most teachers. Rather than spend time watering down difficult concepts teachers would do better to simply have students work with a partner to solve a difficult task or understand a complex topic. This strategy does not require more time on the part of the teacher and also has numerous other benefits for the student apart from the cognitive advantages, such as the acquisition and practice of social skills, improved self esteem, and the increase in perceived status of low achieving students (Rysavy & Sales, 1991).

Given the increasing emphasis on constructivist software tools such as simulations, it is imperative that educators identify ways to help students manage the cognitive demands of computer-based simulations yet still preserve their exploratory nature. This study suggests that one way to facilitate learning from simulations which present complex tasks is to allow subjects to work in groups. However, this study did not assess comprehension of the material presented in the simulation, thus, one issue that needs to be addressed in future research is comprehension as opposed to simply arriving at the correct conclusion in a simulation or not. Thus, future research should assess comprehension through the use of a posttest given that it is entirely reasonable that subjects may have learned a great deal yet may still not have arrived at the correct conclusion.

A second issue that needs to be addressed in future research concerns the optimal size of groups. At what point do the logistics of additional group members outweigh the pedagogical benefits of collaborative learning in a simulation? Future research should investigate the effects of allowing subjects to work in groups consisting of more than two members.

A third issue for future research concerns the operational definition of task complexity. In this study, task complexity was defined in terms of logistics. That is, the task was simplified by decomposing it into parts as opposed to presenting a different task that was conceptually simpler. It would be of interest to investigate the interaction between task complexity when the task is made simpler conceptually as well as logistically.

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