Effects of Thinking Style and Problem Difficulty on Students’ Decision-Making Behavior in a Real Time Strategy Game

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Abstract—The purpose of this study is to explore the problem-solving processes, decision-making behaviors and tendencies of students facing different problem difficulty levels in strategy games. The problem difficulty in the strategy game as manipulated by two situational factors—information availability and resource advantages. Forty-five college and graduate student participated in the experiment. Quantitative data was measured to represent student’s gaming performance, and qualitative data was collected to reveal the problem-solving process of students. Students’ thinking style (liberal and conservative style), another variable related to students’ problem solving tendencies and habits, served as a classification variable for students. Results indicated that, liberal style students have an “active-oriented” problem-solving style, whereas conservative students have a ‘passive-oriented’ problem-solving style. The two situational factors can be applied to construct a personalized game-based educational instrument to develop students’ problem-solving skills by adjusting their difficulty level. Also, research findings on the two thinking styles in problem-solving processes will help support the development of a personalized and game based learning environment for strategic planning tanning. The results and implementation of this study are also discussed.

Keywords— Personalized learning, Problem-solving, Thinking styles, Strategic planning, Strategy games

I. INTRODUCTION

Educational researchers [1-7] have already shed light on the importance of computer game on students’ learning, but there is quite important to explore the process when students are interacting with game-based learning instruments. Regarding to the research on exploring the process while students interact with game-based learning instruments, Hong & Liu [8] attempt to apply a computer-based puzzle game to compare the problem-solving process between expert and novice students. They found that expert students tend to solve the puzzle problems by using analogical thinking process, whereas novice students tend to solve the puzzle problems by using trial and error thinking process. Their result implied that different students may have different thinking tendency and requirements of learning. Therefore, understanding the roles that computer game play in student learning processes can help practitioners (teachers and designers) to development personalized learning instruments to meet different students’ requirement and then enhance their learning performance.

The purpose of this study is to explore the problem-solving processes, decision-making behaviors, and tendencies of students faced with problems of varying difficulty in strategy games. This is because playing strategy game is highly similar to a problem-solving process [8]. Also, strategy games create high-fidelity problem-solving situations where players must exert their cognitive abilities during game play [9]. Therefore, exploring the problem-solving process which players face in gaming situations might help transform the design of educational game into train students’ problem-solving abilities, such as exploration, inference, and decision-making. Additionally, the study applied Sternberg’s mental self-government theory [10] to model different students’ thinking style. The thinking style (liberal style and conservative style) describes students’ problem-solving tendencies and habits that served as a variable to classify students in this study. The strategy game problem difficulty was manipulated by two situational factors—information availability and resource advantage.

II. METHODS

A. Experimental design

This experiment employs a 3 (information availability) × 3 (resource advantage) between-subjects factorial design. The independent variables were the two decision-task factors—‘information availability’ and ‘resource advantage’, and each variable involves three levels. Two types of thinking style leanings, the critical descriptors of decision-makers, were also considered as another independent factor. The measurement variables contain both quantitative and qualitative data. The quantitative data includes students’ gaming performance (win/lose) and time spent completing in-game tasks. Qualitative data was collect verbally from subject to represent their strategies when performing in-game tasks.

B. Participants

Forty-five male college and graduate students (mean age, 23.3; SD, 4.5 years) participated in the experiment. Subjects were randomly assigned to one of nine experimental conditions, with five subjects in each experiment condition. Students’ thinking style leanings were judged by Sternberg’s [11] thinking style inventory. They were asked to complete a
self-assessment form containing sixteen items. Eight items measured the liberal style and eight items measured the conservative style. Each item was measured with a seven-point scale from not at all well to extremely well. Calculating the liberal conservative scores showed that the forty-five students can be classified into three categories: liberal style (23 students), balanced style (10 students), and conservative style (12 students), according to the score interpreting standard proposed by Sternberg [13]. This study only discusses the liberal and conservative styles; two significantly different categories of thinking style leanings.

C. Instruments
This study used Microsoft’s Age of Empires II: The Conquerors (AOE), a popular strategy game.

D. Independent variables
The levels of information availability and resource advantage during gameplay were defined as follows. High level of information availability provides real-time updated information regarding the location of castles, the number of soldiers, and the location of enemy troops. A medium level of information availability provides only the starting location of castles, number of soldiers, and location of enemy troops, and this information is not updated throughout the game. Lastly, a low level of information availability provides no information about the opponent. The level of resource advantage was modeled in three states of competitive advantage: superior, equal, and inferior. In superior state, the student has ten more soldiers than the opponent. The equal state denotes that the student has the same number of soldiers as the opponent. In the inferior state, the student has ten fewer soldiers than the opponent.

E. Measurement and Data collection
The quantitative measurements in this study contain two main parts: task performance (win/lose) and time spent completing the task. The task performance criterion is defined as follows: a subject wins a game as soon as all his opponents’ castles or all his opponent’s soldiers have been destroyed. The second criterion—time spent—is defined as the amount of time a student required to complete in-game tasks. The study employed the GOMS model [12] as the coding schema to model student’s problem-solving behavior in the strategy game. This model has been well applied to analyze the interactions between human and computer. The study then decomposed students’ problem-solving process into three main stages (operators)—Stage 1: pre-war strategy; Stage 2: search & move actions; Stage 3: attack tactics.

F. Procedure
In the prepare stage, the game was demonstrated to each subject in the preparation stage. Each subject was then requested to practice the game for 10 minutes to develop basic skills for manipulating soldiers; for example, selecting soldiers, moving soldiers, and attacking enemy soldiers. In the experimental stage, gaming performance, time spent, and student’s verbal protocols were collected.

III. RESULTS

A. Effects of students’ thinking styles on problem solving performance
An one-way ANOVA was performed to study the effects of students’ thinking style leanings (liberal, balanced, & conservative) on the students’ problem-solving performance (win/lose) and time spent completing in-game tasks. Results indicate that students’ thinking style leanings significantly affect the time spent completing in-game tasks (F (2, 42) = 6.792, p < .01), whereas the effects on problem-solving performance were not significant (F (2, 42) = 0.316, p > .05). A post hoc Tukey-HSD test reveals that the time spent completing in-game tasks for ‘liberal style students’ (mean time spent = 552.3 sec) was significantly longer than ‘balanced style students’ (mean time spent = 400.4 sec; p < .01). Although the difference between liberal and conservative students was not significant, the liberal style students spend more about 100 sec of different based on their mean score difference (conservative = 452 sec).

B. Strategies used by liberal and conservative style students at different levels of information availability
With regard to the strategies used in the pre-war stage in the high information availability scenario, liberal style students tend to use offensive warfare (57.40%) and frontal assaults (42.86%). Conservative style students prefer to perform defensive warfare (75.00%). Similar results were found in the low information availability situation. Here, liberal style students still prefer offensive warfare (66.67%) and frontal assaults (50.00%) whereas conservative style students prefer defensive warfare (50.00%).

In the search and move stage, liberal style students were inclined to search for the enemy and move their soldiers to the target using ‘covering search and move’ actions (42.83%). Conservative style students used various strategies in this stage. When the level of information availability decreases, liberal style students prefer to use one-way (50.00%) and multi-way search and move actions (50.00%); conservative style students concentrate on one-way search and move actions (83.33%).

Concerning the use of attack tactics in a high information availability setting, most liberal style students tend to attack enemies with guerrilla warfare (57.14%) or shock tactics (42.86%). Conservative style students use a variety of tactics in this situation. In the low information availability scenario, liberal style students attacked their armies using shock tactics (50.00%), and both liberal and conservative style students tend to use the pit ten against one tactic (50.00%; 50.00%) in this situation.

C. Strategies used by liberal and conservative style students in different state of resource advantage
With regard to the strategies used in the pre-war stage of the superior resource advantage scenario, liberal style students tend to use balanced warfare (50.00%), but only two shared their thoughts—the others were silent. Additionally, most conservative style students tend to use defensive
warfare (66.67%) in this situation. As the resource advantage decreases, liberal style students prefer to use offensive warfare (66.67%) and balanced warfare (44.44%); whereas conservative style students concentrate on defensive warfare (66.67%). In the search and move stage of the superior resource advantage scenario, liberal style students tend to move their armies with a multi-way strategy (50.00%). Similar to the information availability scenario, conservative style students prefer to search and move with a one-way track (83.33%). In the inferior state, although both strategies reported by students were relative weak, one-way and multi-way search are the most commonly selected strategies for both styles of students.

Concerning the use of attack tactics in the superior resource advantage scenario, liberal students were more likely to use diversion tactics (75.00%) and shock tactics (50.00%). Conservative style students in this situation tend to attack their enemies with lure tactics (50.00%). In the inferior resource advantage scenario, the military strength of students was relatively weak compared to the enemy. As a result, both liberal and conservative style students performed various kinds of tactics in this stage.

IV. DISCUSSION

With regard to the effects of liberal and conservative styles on problem-solving performance, this study finds no significant effects. That is, students’ thinking style leanings may not be a key factor in determining their problem-solving performance. This finding supports the viewpoint proposed by Sternberg [11]. That is, thinking styles are the habits and tendencies people experience when facing a problem-solving situation. Therefore, people’s thinking styles cannot be equated to their personal capability [11]. Also, it cannot be equated to their problem-solving skills.

This study also finds that liberal style students spend more time completing in-game tasks than conservative style students. Most of the conservative style students tend to use the ‘on-way’ searching and moving strategy. Liberal style students tend to move their soldiers and search for their enemies using a ‘multi-way’ strategy. Here, the time cost of performing a ‘multi-way’ strategy is higher than the ‘one-way’ search and move strategy.

Again, the attack tactics performed by liberal students varied from those used by conservative style students. This evidence might explain why liberal style students take longer to solve problems. These results support the definition of liberal/conservative style students developed by Sternberg [11]. That is, liberal style students like to try new ways of doing things and change routines to improve the task. Conservative style students follow the fixed rules and solve problems in a traditional way [11].

In the pre-war stage, this study finds that liberal style students tend to use an ‘active-oriented strategy’ such as offensive warfare and frontal assaults in almost the level of information availability. On the contrary, conservative style students use a ‘passive-oriented strategy’ in all situations of information availability and resource advantage. This finding implies that even when conservative style students possess numerical superiority, they still adopt a ‘passive-oriented strategy.’ To the contrary, liberal style students vary their strategies from ‘active-oriented’ to ‘passive-oriented’ as they experience resource shortages.

Concerning the use of tactics in the attacking stage, again, liberal style students execute shock tactics to attack their enemies in almost all situations of information availability and resource advantage. Shock tactics can be classified as a type of ‘active-oriented strategy.’ Conservative style students also performed shock tactics, but only when placed in a high information situation. Both styles of students perform ‘pit ten against one’ tactics to attack their enemies when they have little information, which supports the quantitative results reported in this study. That is, information plays an important role in both students’ problem-solving performance and the time spent completing a task.

The lure tactic, a kind of ‘passive-oriented strategy’ was performed by liberal style students with inferior resources and by conservative style students with superior resources. This finding implies that even when conservative style students possess numerical superiority, they still adopt a ‘passive-oriented strategy.’

V. ACKNOWLEDGMENTS

We thank all the volunteers and students who helped with this study. We also thank the National Science Council (NSC) in Taiwan for providing financial support under grant NSC 102-2218-E-163-002.

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