Using an Educational Computer Game as a Motivational Tool for Supplemental Instruction Delivery for Novice Programmers in Learning Computer Programming

Kuo-Chuan Yeh
The Pennsylvania State University

Abstract: This study uses an educational computer game as a supplemental instruction delivery method and investigates its effect on students' motivation toward computer programming, which is measured by Intrinsic Motivation Inventory. Twenty undergraduate students who enrolled in a basic computer programming course for non computer science major students volunteered to participate in this research study and were assigned to use one of two different supplemental instruction delivery methods for a three-week period. One group used an electronic quiz program and the other group used an educational computer game. Both methods used the same quiz bank and all quizzes were selected randomly. More quizzes were added every week after students learned more computer programming knowledge. After the treatment, students' intrinsic motivation was compared for the effect of using different delivery methods. Although the results did not show a significant difference statistically, the participants in the computer game group demonstrated higher intrinsic motivation, and the mean difference scores were approaching statistical significance as compared to subjects in the control group. We suggest that the study should be administrated using more participants and the game should be polished to make it more appealing to undergraduate students.

INTRODUCTION

Creating a motivational learning environment is one of the major objectives for educators and instructional designers. Researchers have proposed different strategies to facilitate greater learner engagement and interactions with instructional materials in a variety of disciplines, especially in those areas which students tend to view as boring, daunting, and difficult. Using educational video games, educational computer games in particular, is among the uprising strategies being used as a motivational tool because it provides an environment of enjoyment and challenge, among others. Many instructional materials were designed and delivered using educational computer games in areas, such as the military, medical education, and corporation training. Educational computer games were also deployed for learners of different ages, such as preschoolers, teenagers, and adults. With more and more people learning through non-traditional channels–distant education and online education–educational computer games seem to be an instructional strategy that can have tremendous influence in social and cultural perceptions of the information age.

Computer programming is one of the courses that students often view as boring and difficult. Computer science education is a relatively new discipline as compared to others. Before researchers started to realize the importance of computer science education, much effort was put into the improvement of speed and technique and computer programming was regarded as a solely professional job. As personal computers became more affordable and prevalent, most major colleges and universities began to offer computer programming courses, from basic to advanced levels, to meet the industry demand. Many researchers argued that we should view the process of learning to program as a method of developing intellectual and thinking skills. (Bork, 1981; Nickerson, 1982; Papert, 1980) However, computer programming is not a simple task that can be mastered in a short period (Feldgen & Clua, 2004; Jenkins, 2001); it is a cognitive task that has high complexity (Letovsky, 1986). Previous research studies found that students lost interest after taking a basic computer programming course (McKinney & Denton, 2004). One of the reasons is that, when she first learns to program computer software, the novice programmer does not have the required cognitive skills on which the basic computer programming schemas are built. (Hoc, 1988; Kahney, 1988; Perkins & Martin, 1986)

One solution is to provide a more motivational and enjoyable learning environment so the learners will remain in the course longer and, therefore, have a better chance to engage with the content. Previous research studies (Chang, Yang, Chan, & Yu, 2003; Schwabe & Goth, 2005) found that educational computer games were great motivational tools in teaching learners in different areas. Another study (Martens, Gulikers, & Bastiaens, 2004) found that students with higher intrinsic motivation outperformed those with lower intrinsic motivation. Because computer games have attributes such as providing challenges, fulfilling fantasies, and eliciting curiosity (Malone, 1980), it makes learning fun if the computer games are designed with specific instructional goals and immediate feedback.

The purpose of this research was to compare two supplemental instruction delivery methods' influence on learners' intrinsic motivation. One method was using a quiz program, which randomly selected quizzes from a quiz bank and presented them to learners as a way of practicing what they had learned in the classroom. The other method was using an educational computer game to present the same set of quizzes. The research study was designed to compare their effect on subjects' intrinsic motivation.

Methods

Subjects

The participants in this research study were twenty undergraduate students enrolled in an introduction to algorithmic processes in C++ course. Although fifty three students volunteered during the recruitment, only twenty students finished both the assigned supplemental instruction delivery method and the subsequent online survey. Participation in this research study was not mandatory for the course they were taking.

Material

Materials used in this research study were an educational game, a quiz program, the Intrinsic Motivation Inventory (IMI), and the Computer Game Attitude Scale (the above mentioned online survey).

An educational computer game, Capital Tycoon, was developed by us to facilitate practicing newly acquired knowledge. In this game, participants competed with computer-controlled players to gain control of state capitals of the United States by arriving and purchasing the city before someone else. It starts with a randomly selected state capital (a target city) with a certain amount of reward associated with it. Whoever arrives at the target city first will receive the reward, and the player who is the farthest from the target city will receive a penalty. If a player stops at a capital that is not owned by anyone else, he can purchase the city after answering a quiz correctly. The quizzes are randomly selected from a quiz bank. If a player stops at a capital that is owned by other players, the player has to pay the owner a certain amount of money. For every five quizzes that a participant answers correctly, he will receive one item, such as a one step card, two step card, insurance card, double card, … etc, randomly picked by the program to help him gain advantages in the game.

A quiz program was developed as a control treatment as well. The quiz program also randomly selects a quiz from the same quiz bank as the Capital Tycoon and students answered it and received immediate feedback, correct or incorrect. The process of presenting a quiz and giving feedback would continue until participant closed the program.

The functionality of the quiz part of both Capital Tycoon and the quiz program were the same. Since there was no limitation on how long the participants could use them, the same question might appear several times and some might not appear at all. All quizzes were multiple-choice items. All possible options were shuffled every time to ensure that learners did not just remember the position of the answer and, hence, to increase the opportunities for information processing. All quizzes were created based on the course material, mid-term exams, and lab activities, by subject matter experts, course instructors and the researcher.

The IMI was used to measure participants' perceptions of intrinsic motivation on computer programming. IMI is a multi-dimensional measurement instrument which contains several subscales. In this study, a total of thirty six items derived from the subscales included in the post treatment survey: interest/enjoyment, perceived competence, effort/importance, pressure/tension, and value/usefulness. Its reliability and validity had been established by previous studies (McAuley, Duncan, & Tammen, 1989; Tsigilis & Theodosiou, 2003), although they had some variances in the context and languages compared with this study.

Computer Game Attribute Scale (CGAS) is also being used in the post treatment survey by the experimental group to measure participants' attitude toward the computer game. There are two subscales: Liking and Comfort. The alpha reliability coefficients for the scores on the Liking, Comfort, and the total CGAS were .84, .86, and .88 respectively. (Chappell & Taylor, 1997)

Procedure

The participants were randomly assigned to one of the two groups-control and treatment group. The control group used a quiz program and the treatment used the Capital Tycoon for three weeks. There were fifty questions in the quiz bank in the beginning of the study, and additional questions were added each week when more content knowledge was taught. Logging in for either quiz program or the Capital Tycoon was required for both groups in order to collect data for each participant. Each participant received a pseudo ID and password prior to the first day of the study through an email, in which instructions about downloading and starting either program were also included. Another email was sent to the participants each week notifying them when the quiz bank was updated and more questions were added. Both programs were distributed using Java WebStart™ technology to ensure that the new questions would be included automatically each time the participants started the program through the links included in the email.

During the treatment period, the participants could use the applications any time they preferred as long as they had a computer with Internet connection. The experiment was not in a control environment in the sense that the participants could use the programs at home, in library, and other places. Authentication and log data were sent back and forth between client and server machines through Internet for data collection. Both programs were designed to be used remotely and individually. All IDs and passwords were unique in order to identify which log data belonged to whom. The participants were also told not to share ID, password, and the link to the program they were assigned with others.

After three weeks of treatment, the programs were taken off from online so the participants had no access to them anymore. An email was sent to all participants to inform them the treatment period was over and to ask them to finish an online survey. Data collection ended after they finished the online survey that included the CGAS to measure the likeness of the game.

Results

The hypothesis of this research study is that the participants in the treatment group which used a more motivational supplemental instruction delivery method will benefit from the educational computer game and demonstrate higher intrinsic motivation compare to those in control group after the treatment.

After the survey data was collected, IMI overall score was calculated by adding all categories except pressure/tension score which was reverted and then added to overall score because it is a negative predictor of a person's intrinsic motivation toward computer programming.

The result (table 1) suggests that participants in the treatment group have positive attitude toward this educational computer game. Comparing with the mean of its score range (36 and 44 in liking and comfort respectively), they believe they like ($42 > 36$) this game and also feel comfortable ($73.56 > 44$) about it.

Table 1.
Computer Game Attitude Scale Score by Treatment Group (N=9)

Score	Mean	SD
Liking	42.00	10.45
Comfort	73.56	16.00
Overall	115.56	24.68

Note: Liking scores range from 9 to 63. Comfort scores range from 11 to 77. Overall scores range from 20 to 140.

The dependent variable of this research study is participants' intrinsic motivation score measured after the treatment. The mean differences table (table 2) showed that there are differences between control and treatment groups in five different categories and IMI overall score.

Table 2.
Descriptive Statistics for Each Category by Group

Category	Condition	N	Mean	SD
Interest / Enjoyment	Nongaming	11	25.09	3.06
	Gaming	9	33.22	2.74
Perceived Competence	Nongaming	11	23.91	3.11
	Gaming	9	28.11	3.55
Effort / Importance	Nongaming	11	25.55	1.72
	Gaming	9	26.44	2.16
Pressure / Tension	Nongaming	11	17.00	2.39
	Gaming	9	15.89	2.97
Value / Usefulness	Nongaming	11	23.36	2.67
	Gaming	9	29.78	2.65
IMI Overall	Nongaming	11	120.91	8.45
	Gaming	9	141.67	8.30

Note: Pressure/tension score is negative predictor of intrinsic motivation and is reversed when compute IMI overall score.

We set the alpha level at .05 for the follow-up independent t-test analysis (table 3) and it showed no significant differences in all five categories and overall scores. However in interest/enjoyment, value/usefulness, and overall scores, it was approaching statistical significant difference, especially in interest/enjoyment (p=0.069).

Table 3.
Independent Sample Test for Each Category

Category	t	df	Sig. (2-tailed)	*r* (effect size)
Interest / Enjoyment	-1.93	18	.069	.81
Perceived Competence	-.89	18	.384	.53
Effort / Importance	-.33	18	.745	.22
Pressure / Tension	-.30	18	.771	.20
Value / Usefulness	-1.68	18	.109	.77
IMI Overall	-1.73	18	.101	.78

Discussion

The participants were informed that they could use the treatment as frequent as they want, and most participants (both groups) spent more than 30 minutes with their assigned methods. In the end of the study, two participants in treatment group expressed interests to play the game more because they thought it was useful and fun. The participants who spent less than 30 minutes did not finish the IMI survey either; therefore their data was excluded from this analysis. Although none of the results shows significant difference, the mean score of interest/enjoyment, perceive competence, and IMI overall are much higher in the treatment group than in the control group. This suggests that there is a positive relationship between the supplemental instruction delivery method and the participants' perception about whether they enjoy programming or not. It also indicates that the participants in treatment have more confidence in their programming ability.

Similar results (Klein & Freitag, 1991) can be found in using gaming as a instructional strategy to increase motivation. Although their study used an instructional card game instead of educational computer game, their result suggests that playing games do increase participants' motivation toward the content area. In their study, however, there was no significant difference in terms of using games to improve performances, which is not measured in this study. Giving same allotted time for control and treatment groups, the participants in treatment group were being exposed to the instructional materials much less than those in control group. The participants in gaming group spent time on both learning and playing. As a result, using educational game as an instructional strategy deprives time from learning content if the participants did not spend more time than their counterpart. We do not know how much the efficiency of using game playing compensate the time used in game playing. In other words, we do not know the threshold of using game playing (treatment group) or simply drill-and-practice (control group).

Although the sample sizes for control and treatment groups, eleven and nine respectively, are small, the effect size in some of the categories were very promising. According to Cohen (1988), with the effect size of .81 in interest/enjoyment, the mean of gaming group is at the 79th percentile of the nongaming group; and for IMI overall, the mean of gaming group is at the 77th percentile of the nongaming group. Therefore using the gaming as a tool for instructional strategy may have some promising practical values to instructional designers and educators. The reason of low effective size in effort/importance and pressure/tension (0.22 and 0.20 respectively) might be because most of the participants were information science technology major students, regardless their interests, computer programming is indeed an important skill for them to be successful in this field. Therefore, the educational computer game does not change how they view computer programming in terms of these two categories.

We are aware the gender imbalance in the area of computer programming. The proportion of female programmer is much less than the proportion of male programmer in the industry. Many research studies (Haliburton, Thweatt, & Wahl, 2003; Jagacinski, LeBold, & Salvendy, 1988; Sackrowitz & Parelius, 1996) investigated gender difference in the area of computer programming. Unfortunately same situation reflect on the computer programming classrooms and we cannot recruit enough female students to conduct further analysis on the effect of educational computer game on gender. The interaction between type of games, gender, and intrinsic motivation is one area that can be investigate in the future.

Another possibility for further study is to compare the retention rate of both groups because there were some students who switch to non-computer-programming major after taking one semester of computer programming course. It requires a larger number of participants and maybe longer time but it will provide great insights for computer programming educators.

Reference

Bork, A. (1981). *Learning with computers*. Bedford, Mass: Digital Press.

Chang, L.-J., Yang, J.-C., Chan, T.-W., & Yu, F.-Y. (2003). Development and evaluation of multiple competitive activities in a synchronous quiz game system. *Innovations in Education and Teaching International, 40*(1), 16-27.

Chappell, K. K., & Taylor, C. S. (1997). Evidence for the reliability and factorial validity of the computer game attitude scale. *Journal of Educational Computing Research, 17*(1), 67-77.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, N.J.: L. Erlbaum Associates.

Feldgen, M., & Clua, O. (2004). *Games as a motivation for freshman students to learn programming.* Paper presented at the 34th ASEE/IEEE frontiers in education conference, Savannah, GA.

Haliburton, W., Thweatt, M., & Wahl, N. J. (2003). *Gender differences in personality components of computer science students: a test of Holland's congruence hypothesis.* Paper presented at the Proceedings of the twenty-ninth SIGCSE technical symposium on Computer science education, Atlanta, Georgia.

Hoc, J.-M. (1988). Do we really have conditional statements in our brains? In E. Soloway & J. C. Spohrer (Eds.), *Studying the novice programmer* (pp. 179-190). New Jersey: Lawrence Erlbaum Associates, Inc.

Jagacinski, C. M., LeBold, W. K., & Salvendy, G. (1988). Gender differences in persistence in computer-related fields. *Journal of Educational Computing Research, 4*(2), 185-202.

Jenkins, T. (2001). The motivation of students of programming. *ACM SIGCSE Bulletin, 33*(3), 53-56.

Kahney, H. (1988). What do novice programmers know about recursion? In E. Soloway & J. C. Spohrer (Eds.), *Studying the novice programmer* (pp. 209-228). New Jersey: Lawrence Erlbaum Associates, Inc.

Klein, J. D., & Freitag, E. (1991). Effects of using an instructional game on motivation and performance. *Journal of Educational Research, 84*(5), 303-308.

Letovsky, S. (1986). *Cognitive processes in program comprehension.* Paper presented at the Empirical studies of programmers, New Jersey.

Malone, T. W. (1980). *What makes things fun to learn? heuristics for designing instructional computer games.* Paper presented at the Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems, Palo Alto, CA, United States.

Martens, L. R., Gulikers, J., & Bastiaens, T. (2004). The impact of intrinsic motivation on e-learning in authentic computer tasks. *Journal of Computer Assisted Learning, 20*(5), 368.

McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the intrinsic motivation inventory in a competitive sport setting: A confirmatory factor analysis. *Research Quarterly, 60*(1), 48-58.

McKinney, D., & Denton, L. F. (2004). *Houston, we have a problem: there's a leak in the CS1 affective oxygen tank.* Paper presented at the Proceedings of the 35th SIGCSE technical symposium on Computer science education, Norfolk, Virginia, USA.

Nickerson, R. S. (1982). Computer programming as a vehicle for teaching of thinking skills. *Thinking, 4*, 42-48.

Papert, S. (1980). *Mindstorms : children, computers, and powerful ideas*. New York: Basic Books.

Perkins, D. N., & Martin, F. (1986). *Fragile knowledge and neglected strategies in novice programmers.* Paper presented at the first workshop on empirical studies of programmers, Washington, DC.

Sackrowitz, M. G., & Parelius, A. P. (1996). *An unlevel playing field: women in the introductory computer science courses.* Paper presented at the Proceedings of the twenty-seventh SIGCSE technical symposium on Computer science education.

Schwabe, G., & Goth, C. (2005). Mobile learning with a mobile game: design and motivation effects. *Journal of Computer Assisted Learning, 21*(3), 204.

Tsigilis, N., & Theodosiou, A. (2003). Temporal stability of the intrinsic motivation inventory. *Perceptual and Motor Skills, 97*, 271-280.