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Design Research Using Game Design as an Instructional Strategy

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Abstract: Game design as an instructional tool can be expensive and time-consuming, as new software requires not only capital outlay but also training for teachers and students. Therefore, researchers have looked at low-tech design platforms to accomplish the same educational goals. One such way is to use Microsoft PowerPoint as a game design tool. In the second iteration of a design study, we have changed the way a homemade PowerPoint game project is implemented in an environmental chemistry classroom by providing more structure and more opportunities for instruction and feedback on the elements of the game design. We compared the performance of between groups who created games and groups who did not on tests for two separate units. Both test results showed statistically significant differences: in favor of the control group on the first unit and in favor of the group creating games for the second unit. Further research needs to examine which factors led to the significant findings in both instances.

The idea of using technology to allow students to create artifacts such as games has its roots in constructionist pedagogy, first championed by Seymour Papert (1991). Over the past few decades, computers have been used to create games using programming languages such as *Logo*, and later *Alice* and *Scratch*, to teach not only computer science but other content areas as well.

However, there are several obstacles to using game design to teach topics other than programming. First, time can be an issue; not only do teachers need to teach content, they need to teach the programming language as well have the proper infrastructure in place (Rice, 2006). Similarly, teachers may not have the technical acumen to appropriately teach the programming language and troubleshoot when difficulties arise on the part of the student (Kafai, Peppler, & Chiu, 2007). Finally, while some of the educational programming languages are open source and free of cost, a school's infrastructure and policies regarding software may prohibit their use (Barbour, Thomas, Rauscher, & Rieber, 2010).

As a result, some researchers have begun to look at "low-tech" ways to apply game-design pedagogy. One way is through the use of *Microsoft PowerPoint*. While *MS PowerPoint* is clearly not game-design software, it can be used to create simple games. However, much of the research using these homemade PowerPoint games has shown no statistical difference in performance, which has led researchers to question the philosophical justifications for their use (Barbour et al., 2009; Siko, Barbour, & Toker, 2011). It has also led researchers to examine whether or not the design and implementation of the game design project can influence student performance. In this study, we will review the justifications for the use of homemade PowerPoint games and review studies involving the use of the games in K-12 classrooms. We will then discuss changes made to the project based on the results of a previous study and detail any changes in performance based on those changes. Finally, we will look at the implications of those changes, and discuss what further research still needs to be conducted.

Literature Review

A homemade PowerPoint game can be created from a template (which can be found at http://it.coe.uga.edu/wwild/pptgames/PPTgame-template1.ppt) or from a blank *MS PowerPoint* presentation. The game elements include a narrative, objectives, and a means of going about meeting that objective. Like any good game, a narrative is in essence a short story providing context for the game. In a homemade PowerPoint game the narrative must fit on a single *MS PowerPoint* slide. Players are also given directions on how to play game, which usually involves answering multiple choice questions correctly in order to progress through the game to meet the primary objective. The game itself can be contained within the *MS PowerPoint* file, or the game can have external elements such as a game board, dice, or playing cards. Finally, students create multiple choice questions for the game, which utilizes the action button feature in *MS PowerPoint* (e.g., an action button, when pressed, sends you to a different slide in the presentation, not just the next slide).

There are three philosophical justifications for the use of homemade PowerPoint games. First, the games are a good example of constructionist pedagogy in practice. Seymour Papert (1991) first coined the term constructionism as an extension of constructivist pedagogy where the students learn by building some artifact, in this case a game. Thus, the students learn by building an educational game rather than by playing a game. Rieber, Luke, and Smith (1998) described game design as a rigorous process of problem-solving which requires creativity and collaboration which can have positive effects on learning and motivation. Sung, Shirley, and Rosenberg (2007) examined the use of game design to teach computer graphics in a college setting. The researchers found that the game design project required more time from the students than a traditional graphics course, yet student attitudes remained unchanged concerning the workload. The researchers also noted the increased richness in the graphical environments created in the student projects when given the context of designing a game. *Logo*, another programming language, was used to create games to teach astronomy content (Kafai, Ching, & Marshall, 1997) to fifth- and sixth-grade students. Students who created games showed statistically significant gains between their pretest and posttest in both astronomy content and knowledge of *Logo*.

The second justification for the use of homemade PowerPoint games is the writing of the narrative. Good educational games have a narrative intertwined with the content (Kenny & Gunter, 2011; Rieber, et al., 1998), unlike extraneous themes which simply provide a short story and present a task (e.g., "Defeat the wizard by answering 20 questions correctly!"). Students creating games need to provide the context for the game in a concise manner. This condensed style of writing is called a microtheme (Ambron, 1987). It allows for the student to take the content in the class and give it personal meaning, which helps to remove some of the apprehension around academic texts (Avraamidou & Osborne, 2009). Writing also allows students to be creative in subject areas such as science and allow them to grasp the social context of science (Gough, 1993). Understanding the social context is of particular importance, since the course used in this study covers several issues pertaining to science in society. Collins (2000) studied the effects of microtheme writing in a college biology course and found that when students completed more microtheme assignments, they scored better on assessments than those who completed fewer. In a meta-analysis of 48 studies using writing in other curricular areas, Bangert-Drowns, Hurley, and Wilkinson (2004) found that while the effects of writing strategies were small, the effects could be enhanced through the use of metacognitive prompts and reducing the overall length of the writing assignment. Both of these attributes can be found in homemade PowerPoint games, since the narrative is limited in size and the background of a game orients the purpose of the designer.

The final justification for the use of homemade PowerPoint games is the instructional strategy of students generating questions based on the content. Chin and Osborne (2008) gave four reasons why this strategy is beneficial: it helps direct their learning, foster discussion, monitor understanding, and increases motivation. Wong (1985) gave three theoretical justifications for the strategy. Question generation is a form of active processing, it is supported by metacognitive principles, and it incorporates facets of schema theory. Wong, whose literature review of 27 studies using the technique only provided mild support, did find several ways to enhance its effects. By increasing the amount of direct instruction on how to write questions and by having goals set which fostered the writing of more higher-order questions, student-generated questioning could be an effective tool. Studies by both Chin and Osborne (2008) and Herring (2010) supported the notion that increased structure led to increased effects on performance.

Harper, Etkina, and Lin (2003) examined the effects of student-generated questioning techniques in an introductory physics course. They found that while the number of questions written by students was not correlated with performance, the number of quality questions was correlated with performance. Lotherington and Ronda (2010) studied the use of student-generated questions in a fourth-grade geography class. They found that students wrote better questions over time when give feedback, the opportunity to revise, and the opportunity to see and edit the questions of classmates.

While the justifications for the use of homemade PowerPoint games in a classroom have empirical support, the research on the use of the games has shown little, if any, significant impact on learning and performance. The first published study involving homemade PowerPoint games centered on the teaching of grammar to middle school students (Parker, 2004). While the students who created games did increase their scores between the pretest and posttest, the students in the control group showed greater gains and scored higher on the posttest. In defense of the games, the author noted that the students who created games were generally lower performing students, and their scores on the posttest were higher than their class average would typically predict (i.e., the students who created games normally achieved failing grades on assessments and the class average for the test where they created games was average). Parker suggested that the games could be used as a motivational tool for low-performing students.

Clesson, Adams, and Barbour (2007) conducted a study using games as a review tool for a British Literature class. Students in the control group reviewed for the test in a traditional manner while students in the treatment group created homemade PowerPoint games to prepare for the test. The researchers found no statistically significant difference between the groups. They noted the sample size (i.e., 20 students in the treatment group and

15 students in the control group) as a potential methodological issue with the study. While the games did not statistically improve performance, the authors suggested that the games did not hinder performance, either. Barbour, Kinsella, and Rieber (2007) conducted a similar study in a U.S. History course in a blended environment (i.e., the course had elements of both online and face-to-face instruction) with approximately 50 students. Again, there was no statistical difference in performance when the games were used to review; however, scores were slightly higher when the students did create the games.

Siko et al. (2011) examined the use of games in a high school environmental chemistry class. Students created games for two separate units, one on resources and materials, and the other on air quality and gas laws. For both units, there was no statistical difference in performance. Furthermore, the researchers wanted to see if the students who created games for both units performed better on the second unit test than those who created games for the second unit only or not at all. In other words, they wanted to see if practicing the technique had an effect on performance. While the group who created games for both units scored higher than the other two groups listed, the difference was not statistically significant.

Due to the repeated lack of statistical differences in the research, researchers have begun to examine the games more closely. Barbour et al. (2009) tested the assumption that students wrote more higher-order questions by looking at the questions created for the games in the Barbour et al. (2007) study. In their analysis of over 1,900 questions, they found that almost all of the questions (i.e., 94%) were "Knowledge" level questions, the lowest level on Bloom's Taxonomy. None of the questions written were above the "Application" level on the taxonomy. Siko (forthcoming) had similar results when examining the questions written in the Siko et al. (2011) study. Students wrote fewer "Knowledge" level questions than in the Barbour et al. (2009) study (i.e., 61% and 67% for the first and second unit, respectively). Still, the majority of the questions were factual recall questions, and in the end the test data from both studies showed no statistical difference in performance. Author (under review) also analyzed the level of questions written by students on the second test based on their level of experience with writing questions (i.e., did students who created games on two occasions write more higher order questions than those who only did created games on one occasion). The students who created games twice did write more higher-order questions, but the difference was not statistically significant. Siko et al (2011) and Author (under review) also criticized a lack of opportunity for revision and feedback for student-generated questions, which Lotherington and Ronda (2010) noted as a crucial component of the strategy.

In this review, we have introduced the concept of a homemade PowerPoint game and provided empirical support for the three justifications for their use. In spite of these justifications, there is little empirical support for the use of the games in a classroom environment, and that has led researchers to question the three justifications. Thus, a new line of research involving homemade PowerPoint games should involve adding more structure to the game project. Elements of the structure include opportunities for feedback, games being created as a unit project rather than a review tool, requirements for question difficulty (i.e., guidelines for the level of Bloom's Taxonomy), and the interrelatedness of the game's narrative to the content.

Methodology

Since this was the second iteration of Siko et al. (2011) study, we had similar research questions for this study. However, since the Siko et al. study viewed the homemade PowerPoint games strictly as a review tool, the research questions have been slightly altered:

1. Do students who created homemade PowerPoint games as a unit project perform better on multiple-choice tests than students who did not create games?
2. Do students who have created homemade PowerPoint games on more than one occasion perform better than those who have only constructed games once or the control group?

For each of the two research questions, we have developed the following hypotheses:

H_0: No different in student performance.

H_1: A positive difference in performance for those creating homemade PowerPoint games.

For the first unit of this study, computer lab time was limited to three nonconsecutive days over two weeks preceding the unit test. The students were introduced to the project and given time to write questions and narratives in the classroom. The rationale for the change was based on the critique given by Siko et al. (2011), where the authors discussed time off-task in the lab as a practical issue for teachers who wished to use the game project. In addition, critiques of constructionist pedagogy (Kirschner, et al., 2006; Mayer, 2004) showed a lack of support for discovery learning in constructionist settings, with Mayer pointing out the more structured approaches yielded positive results. Another difference was a requirement for the number of questions that were from the first three levels of Bloom's Taxonomy (i.e., knowledge, comprehension, and application). Students could have no more than ten knowledge-level questions, and at least five comprehension and application questions.

For the second unit, which covered material on gas laws and the atmosphere, the project was introduced at the beginning of the unit. The teacher and students co-created a timeline for due dates for drafts of the narratives and questions. The rationale for this change was based on studies by Rosenshine, Meister, and Chapman (1996) and Lotherington and Ronda (Lotherington & Ronda, 2010), which found that feedback and revisions were important aspects of improving student learning through question-writing strategies. The students were given three days in the computer lab throughout the unit; one at about the midpoint of the unit, and two consecutive days preceding the unit test. The due dates for the questions were before the days in the lab in order to ensure that students were not using computer lab time to actually create questions. As with the first unit, students were shown examples of games and allowed to play games as a class while in the classroom and not the computer lab. However, for the second unit, a rubric detailing all of the requirements and guidelines (i.e., fill-in spots for due dates, question requirements, and requirements for the narratives) was handed out at the beginning of the unit. Finally, in order to answer the second research question, students could only work in homogenous groups. That is, both students in a group either made games for the first unit or both students were making games for the first time.

Results

To answer the first research question, an independent t-test compared the results of the students who created the games and students who did not. The students in the control group on average received a higher score (M = 30.26; SD = 5.52) on the instrument than the group who created games (M = 27.95; SD = 6.14). The difference was determined to be statistically significant, $t(137) = 2.306$; $p = .023$. On the second unit test, the group who created games (M = 26.53; SD = 5.16) scored higher than the treatment group (M = 23.92; SD = 4.86). The difference was also determined to be statistically significant, $t(142) = 2.936$, $p = .004$.

To answer the second question, a one-way ANOVA compared scores within the treatment group. Students who created games on both occasions in the study scored higher than students who only created games for the second unit, who in turn scored higher than the control. The difference was determined to be statistically significant, $F(2,143) = 4.29$, $p = .016$. However, post hoc comparisons showed that these differences were between the treatment groups and the control, not the subsets of the treatment group.

In summary, the control group performed statistically better than the treatment group on the first unit test, while the reverse was true for the second unit test. When we compared scores on the second unit test based on the number of times the students had created games, an ANOVA also showed a statistically significant difference between the control, the treatment group who only created games once, and the group who created games for both units.

Discussion

This study produced two novel results with respect to performance based on comparing the performance of students who created homemade PowerPoint games and those who did not. The prior studies (Barbour, et al., 2007; Clesson, et al., 2007; Parker, 2004; Siko, et al., 2011) have all shown no statistically significant results, which led researchers to suggest that the games are as good as traditional review techniques. In this study, we have a result showing that the control performed statistically better than the treatment, as well as a result which showed the students creating the games performed statistically better than the control.

Aside from the content, one major difference was the makeup of the treatment group. In the first unit, the entire treatment group had not been previously exposed to the game design strategy. In the second unit, about one-half of the group had participated in the first unit test; for the other half, it was their first experience. Collins (2000) found that more practice with microthemes led to improved performance, but this study found no statistical difference on the second unit between students who created games twice versus the group who only created games once. It would be difficult to analyze the number of higher order questions written by the students, as Barbour et al (2009) and Author (under review) did, since this iteration of the study had specific guidelines for the number of questions written based on difficulty. If students followed the guidelines from the teacher (i.e., where 50% of their questions were recall, 25% were comprehension, and 25% were application), they would have written more higher-order questions than either the Barbor et al and the Siko et al (2011) studies. While Harper et al. (2003) did find a correlation between the number of higher order questions and performance, we only see this result on the second unit test.

In the Siko et al. (2011) study, the authors noted an initial discomfort with the technique as a possible reason that the scores for the treatment group were lower (albeit not statistically different) than the control group. While one could make the same argument for the statistically significant difference on the first unit of this test, we see that is not the case for the second unit. If it were, the group who created games for the first time on the second unit would not have performed statistically significantly better than the control.

Thus, the main difference between the results of the first unit (where the control group scored statistically higher) and the second unit (where the treatment group scored statistically higher) is how the project was implemented. In the first unit there was much less structure. While the implementation in both units included the games as a unit project rather than a review, with fewer days spent in the computer lab, the second unit included deadlines, opportunities for feedback and revisions, and more instruction on how to write higher-order questions.

While the design change resulted from a call for a better alignment with one of the justifications for the use of the games (i.e., shifting from a review to a unit project), we found for the first time where the control performed statistically better than the treatment group. As a result, more structure was added to the protocol, and for the second unit, for the first time a group creating homemade PowerPoint games demonstrated a statistically significantly higher result than the control group. Studies examining the three justifications for the use of the games all have some support for increasing the amount of support. The results of the study provided some answers but also introduced areas for future research to support this notion of structure.

Conclusions and Implications

In this study, we have looked at the effects of a change to the design and implementation of a project using homemade PowerPoint games. While the change from a review tool to a unit project provided a stronger basis for stating that the games are a form of constructionist pedagogy, the scores from the first unit test showed that the control group performed statistically better than the group who created games. Previous research on PowerPoint games could at least make the claim that the games were as good as traditional review techniques; in this case, though not for a review, traditional instructional techniques were superior. However, with the addition of increased structure to the project, the second unit scores painted a different picture, with the group creating games showing a positive statistical difference. Similar to the findings from the Siko et al. (2011) study, there was no statistical difference on the second unit test between groups who created games twice versus those who only created games once.

Future research needs to validate the notion that the differences in the results of this study were due to changes in the protocol (i.e., an increase in structure). In addition, researchers could continue to test the assumptions made for each of the philosophical justifications for the use of homemade PowerPoint games. Comparisons in performance between students who create games with extraneous versus intertwined narratives could be studied. Research could continue to examine relationships between performance and the types of questions written. Using qualitative methods, student perceptions of the game design project could be collected and analyzed, paying particular attention to variations in perceptions based on the academic abilities of the student to test whether or not the games can be a motivating factor for low-achieving students. Finally, in addition to providing opportunities for feedback, researchers could test whether or not repetition of the project (i.e., consecutive units rather than once per semester) to see whether or not the writing ability, question quality, and test performance improves.

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