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Abstract

This exploratory multiple case study attempted to examine whether game- based learning activities had any impacts on students' academic performances and behaviors, and what perceptions the teachers had toward implementing games into their classrooms. Data used in this study included 101 students' pre and post-test scores, and four structured written reflection papers by four STEM classroom teachers. The results indicated that students' academic performances improved during the week GBL was implemented. In addition, their behaviors were noticed to change positively. Finally, teachers' perceptions about GBL changed before and after they integrated the games into their classroom. The study was concluded with discussions, implementation of using GBL in STEM classrooms and suggestions for future studies.

Introduction

Game-based learning (GBL) is not a foreign concept to most American P-12 teachers. Actually, there are a great number of studies conducted in the 60's and 70's addressing the use of instructional games in the classroom. This concept has, however, attracted more attention of educators in recent years when GBL received "significant investment" from prestigious foundations such as the Bill & Melinda Gates Foundation and the MacArthur Foundation (Epper, Derryberry, & Jackson, 2012; Garris, Ahlers, & Driskell, 2002; Vu, Fredrickson, Hoehner, & Ziebarth, 2016). Nonetheless, as indicated by many researchers and educators (Cross-Bystrom, 2010; Epper, Derryberry, & Jackson, 2012; Fudin, 2012; Gershenfeld, 2011; Miller, 2014), teachers' attitudes toward applying this approach into their classroom and their competences to design GBL activities are some of the hurdles to implementing GBL into the classroom because most of game- creating platforms and/or programs require users a certain amount of coding skills and/or knowledge to be able to create a game applicable to classroom use.

In the field of STEM education, while there is an increasing demands for STEM-related jobs because STEM careers are driving our economy and generating a disproportionate number of other jobs (National Research Council, 2011), students at all levels are not interested in STEM subjects (Bowman & Bastedo, 2009). By the time elementary students reached 3rd and 4th grades, one third of them lost interest in math and science. This is not gender specific since both boys and girls showed the same pattern. By 8th grade 50% were either uninterested or believed it extraneous to their life. The lack of students' interest in STEM may be one of the reasons for the low academic performances of U.S students compared to their peers from other industrialized countries. Specifically, according to a report by the Trends in International Mathematics and Science Study (2015), U.S students continually ranked below other industrialized countries in both math and science in the seminal international exam particularly at the 8th grade level. Similar to that report, National Assessment of Educational Progress (2015) found that roughly 75 percent of U.S. 8th graders are not proficient in mathematics. To that end, this explorative case study attempted to examine whether using GBL in STEM courses had any positive impacts on students' STEM performances and the teachers' perspectives on implementing games into their STEM classrooms.

Literature Review

Game-based learning and Gamification

Innovative teachers always search for new and effective approaches for the delivery of instruction. A key

question facing them is how best to provide instruction that matches the digital savvy backgrounds of their Generation Z or "digital native" students. It seems that including games into classrooms is probably one of the answers to that burning question because from an early age, that generation has honed their digital skills and has taken multitasking to a new level. Concurrently, they can text, listen to music, and browse the Internet (Sardone & Devlin-Scherer, 2010). In addition, kids like video games and a simple logic is that "by applying Evidence-Centered Design (ECD), the game-based formative assessments address the needs of both students and teachers for reliable and valid real-time actionable data within a motivating learning environment" (Shapiro, 2014). In addition, it is commonly agreed that the digital native do not always need more time in the classroom to learn how to think and perform in the face of real-world challenges. What they need is effective, interactive experiences that can motivate and actively engage them in the learning process. This is where game-based learning comes in.

Before this topic is discussed, it is also critical that the terms "Game-based learning" and "gamification" should be defined to avoid possible confusion. According to Shapiro (2014), game-based learning is a practice or approach of using actual digital video games as a classroom tool while gamification is the use of game design elements in non-game contexts. In other words, gamification is the idea of adding game elements to a nongame situation in which students are rewarded for their good performances or behaviors such as producing exemplary work and/or helping their peers. Likewise, they may receive consequences for bad behaviors that are inconsistent with the class or school's expectations.

Finally, throughout this paper, the term "game" is referred to any form of digital or online games that can be played on common devices or platforms such as computers, tablets and/or social media games.

Impact of GBL on Students' Performances and Teachers' Perceptions of GBL

There may be debates about the different aspects of impact of using games in classrooms, especially in term of students' academic performances. However, there seem to be a consensus that using games in classrooms are not only simply "fun" because it involves many things such as collaborating, exploring, and naturally winning along with other qualities, but because they are also motivational, relevant, provide timely feedback, and students are able to repeat aspects of the game as often as they want to.

Shapiro (2014) observed that published research on the use of games in classrooms or game-based learning in educational settings in general has been scarce. Still, on the flip side, the results of studies about the impact of game-based learning have been promising. A study done in Ireland, by Killian Forde and Catherine Kenny in 2013, indicated that kids who played multi-player games online were more likely to have a positive attitude toward people from another country. Taking a broader perspective by summarizing the research on the benefits of playing video games, Granic, Lobel and Engels (2014) identified four types of positive impact that video games had on game players including:

Cognitive benefit: Games have been shown to improve attention, focus, and reaction time.
Motivational benefit: Games encourage an incremental, rather than an entity theory of intelligence.
Emotional benefit: Games induce positive mood states; and there is speculative evidence that games may help kids develop adaptive emotion regulation.
Social benefit: Gamers are able to translate the pro-social skills that they learn from co-playing or multi-player gameplay to "peer and family relations outside the gaming environment."

In summary, there was a limited body of literature about the impact of GBL on students' performances, especially in term of academic performances. This is one of the most concerns that stakeholders such as educational administrators and legislators have when discussing the use of GBL in classroom because different from other learning approaches, GLB requires intensive and extensive investments in both software and hardware. Any incorrect justification or judgment in adopting GBL in classrooms can possibly lead to a huge waste of financial and human resources. Using games into classroom seems promising but unless it can prove that learners' performances, particularly academic performances in term of standardized test scores, are improved, it will be a challenge to get administrators and teachers to buy in. In addition, teachers' perceptions about GBL are also another barrier to overcome. According to researchers (Huizenga, ten Dam, Voogt, & Admiraal, 2017; Watson, & Yang, 2016), teachers' perceptions of the usefulness of GBL might be a reason for the limited application of digital games in education. In their study with 43 secondary teachers, Huizenga, ten Dam, Voogt and Admiraal (2017) found that most teachers who actually used games in class perceived student engagement with a game and cognitive learning outcomes as effects of the use of games in formal teaching

settings. This explorative case study with four STEM courses at different levels was built to gain a further understanding of GBL impacts on students' performances and teachers' perceptions of GBL in authentic STEM learning settings. The expectation is that the exploratory case study of multiple cases would provide practitioners with test-based practices that can be applied into their own teaching setting. In addition, based on this exploratory case study, researchers can conduct further and more rigorous testing on this innovative practice of integrating games into STEM classrooms.

Research Method

This exploratory case study was a multiple case design project with four cases over a course period of one and a half year. We used an exploratory case study approach for this study because it enabled us to answer not only "what" but also "how" and "why" type questions, while taking into consideration how a phenomenon was affected by the context within which it was situated (Baxter & Jack, 2008). In addition, the data collected in this type of case study was normally a lot richer and of greater depth than could be found through other types of case study or experimental designs.

Case Description

Data used in this study included 101 students' pre and post-test scores, and four structured written reflection papers by four STEM classroom teachers who voluntarily joined the project by implementing the games they selected into their classrooms in a week. The four STEM teachers, selected via a convenience sample, were one fifth grade math teacher, one eight grade math teacher, one science teacher at an alternative education (continuation) high school for the students who failed to excel in the traditional school settings and were credit deficient, and one high school science teacher. Their technology competences were rated three out of five, using a technology competence self-rating metric. All of the participants identified themselves as Caucasus teachers whose teaching experience ranged from one to five years. Before starting the project, the teachers were told to search for an online game available on the Internet to implement into the classroom, using two criteria.

1. The selected game had to be relevant to the content or topic that the teacher planned to teach in his classroom.

2. The game should be either free or at an affordable price.

The rationale behind this was we understood that teachers often do not have sufficient time to design online or digital games, not to mention that creating a brand new online game requires many digital skills that most teachers were not familiar with. In addition, it was our belief that there were many online free game resources on the Internet and that teachers needed to take advantages of those resources to adapt and/or modify them into their teaching instead of re-inventing a new wheel. None of the participating teachers had received any formal training on how to implement GBL activities in their classrooms before. Upon finding the game and making any changes to the game content to fit their teaching needs, the participants had one week to implement the game into their classroom. A pre-test and post-test were administered to students before and after the GBL implementation to measure students' academic growth. The content of the pre and post-tests were designed by the teachers with the consultation of the researchers to ensure the content validity of the measurement. In addition, four of the participants were required to keep track of students' behaviors and performances by using a writing log. At the end of the project, they transferred the writing log into their reflection papers and shared them with the researchers.

Data Analysis

Data used in this study included 101 students' pre and post-test scores, and four structured written reflection papers by four STEM classroom teachers who joined the project by implementing the game they selected into their classrooms in a week. Reflective practice is a method and technique that helps individuals and groups reflect on their experiences and actions in order to engage in a process of continuous learning. According to Fook and Gardner (2007), reflective practice allows recognition of the paradigms – assumptions, frameworks and patterns of thought and behavior – that can shape our thinking and action. Dhoore, Van Houtte and Roose (2016) argued that reflective writing use within qualitative research as a method in its own right and/or as a data source and within the analytical processes is increasingly becoming visible and recognized as an essential part

of their methodology.

The structured reflection papers were required to all of the participants because we wanted to establish the consistency among the four cases. Below are the required information presented in the structured reflection papers.

1. *An overview of your students' behaviors and performances before you implement the game.*
2. *Your reflection and lesson learned from that GBL process.*
3. *An overview of your students' behaviors and performances after a week of GBL implementation.*
4. *Anything (if any) you would like to share.*

The constant comparative method (Olson et al., 2016) was used throughout this multiple case study to obtain a better understanding of the experiences of the teacher participants in the process of implementing the GBL. As categories emerged from the reflections, they were compared to one another and among the research participants' reflections. The reflections were read and initial impressions that seemed relevant to the research questions were noted in the margins. Common themes were then noted in the margins and became the codes.

Findings

Question 1: Does GBL activities have any positive impact on students' STEM learning performances?

To find the answer to this question, we examined 101 students' scores of the pre-tests and posts tests provided by the participating teachers. Since our data sample was not consistent among cases, we did not run a t-test to identify the significant difference between the pre and post- tests, but used the descriptive analysis.
The fifth grade math teacher chose the game "Order Ops", an interactive game on the website www.mrnussbaum.com, to help 19 students focus on the math skill of using Order of Operations. The eight-grade math teacher identified "Solving Equations" as his teaching topic in preparation for the state standardized test. He examined several online games available on the Internet and selected one game called "Rags to Riches" for his class that had seven students. The game idea and design were loosely based on the popular game show "Who wants to be a millionaire?". The science teacher at an alternative education high school selected a game "Pandemic 2" found at the website www.crazymonkeygames.com to use in three of his biology classes to help 65 students gain a greater understanding of the different types of pathogens and how disease spreads and could be prevented. The high school teacher picked a physics simulation game called Electric Field Hockey, created by the University of Colorado Boulder, to help his students understand how the electric force between two charged particles is proportional to the product of the two charges divided by the square of the distance between the two particles. This AP physics 2 course had ten students.
The result indicated that GBL activities had positive impacts on students' STEM performances across grade levels except for those in a high school AP physics course. Specifically, in the fifth grade math class where the game "Order Ops" was integrated, the mean score in the pre-test was 4.0 (N=19) while the mean score in the post-test was 5.0 (N=19). In the eighth grade math class, the result of the post-test showed that all students' test scores improved except for one student who was absent for two days during the week that they had the game activity. The student who could not even finish one problem on the pre-test ended up getting ¾ correct on the post-test. In three Biology classes at an alternative education high school where the game "Pandemic 2" was played, the mean score for the pre-assessment was 52 (N = 65) while the mean score for the post assessment was 82% (N= 65). In the high school physics class where a physics simulation game, Electric Field Hockey, was implemented, the mean scores of both the pre and post-test were the same (83%, N=10).

Question 2: Does GBL activities have any positive impact on students' learning behaviors?

Data for this research question were based on the teachers' reflection papers. The reflections were read carefully and initial impressions that seemed relevant to the research questions were noted in the margins. Common themes were then noted in the margins and became the codes. As categories emerged from the reflections, they were compared to one another and among the research participants' reflections. The two most common themes emerging from the four reflection papers were "*Engagement*" and "*Having fun*". The fifth grade math teacher reflected,

The enthusiasm my kids showed during the game was great as an attitude toward the game, and was something I wouldn't regularly see when doing practice type problems.

Similarly, the eighth grade math teacher wrote,

Students were focused beyond my belief. Our students are very well behaved but they are extremely close and like to talk. However, during the game, it was pure focus. There was still talking, but it was about who could make more money. I am not even sure they realized it was a math game.

The engagement and enjoying the learning activity were not only captured at the lower levels but also at the higher level. The high school biology teacher observed,

My students were completely engaged and loved the opportunity to play a game, little did they know how much they were actually learning :)

In the same vein, the high school physics teacher noted,

My students seemed interested. They were quite competitive in trying to finish the levels as fast as they could.

Question 3: What were the teacher's perspectives on implementing games into the classroom?

The answer to this question was constructed on the participating teacher's written reflection provided to the researchers after administering the post-test. Before this exploratory case study started, we debated whether an in-depth interview or written reflection was more productive since each of those data type has its own strengths and weaknesses. The written reflection was our choice because writing a self-reflective paper can facilitate reflexivity, whereby individuals involved in the research project can examine "personal assumptions and goals" and clarify "individual belief systems and subjectivities" during the whole process of self-reflecting. In addition, as pointed out by Mruck & Breuer (2003), reflective practice can also make "*visible to the reader the constructed nature of research outcomes, a construction that "originates in the various choices and decisions researchers undertake during the process of researching."*

All of the four reflection papers shared the same theme about how they recognized the power of using games in their classrooms. In his written reflection, the eighth grade math teacher indicated that his initial thoughts about playing a game in class were poor. In other words, he felt negative and even insecure because

It would be hard to control, it would look poorly if an administrator was to come in, and above all, I did not feel like I was actually doing something. All I did was put a link on the board and observe.

However, the positive results of students' behaviors and scores were beyond his expectation. The teacher also mentioned that he was not even sure they realized it was purely a math game, and he used it as a bell ringer activity. At the end of his reflection, the teacher discussed how the unexpected impact of implementing a simple online game he found on the Internet on his students' behaviors and performances. He wrote,
Combine this [students good behavior] with the fact that they improved their scores on the post-test and I am on my way to becoming a believer. I plan to repeat this experiment again in the near future with a different topic and see how the results turn out.
Similar to that thought, the fifth grade math teacher indicated,

I'm glad I chose to use this game during a Math lesson. Sometimes in Math, I feel I stick as a teacher to much to what I think I should be doing, as opposed to what I feel is best for my students. I genuinely feel that using games in Math is something I could/should do every day.

In summary, our findings revealed that implementing GBL activities had positive impacts on students' STEM performances across grade levels except for those in a high school AP physics course. The use of GBL activities helped improve not only students' academic performances but also their learning behaviors. Finally, the positive results of students' performances helped participating teachers recognize the power of using GBL in their classroom.

Discussion and Implementation

The finding in the first question makes it clear that using GBL in the classroom made positive impact on

students' academic performances in term of their test scores across grade levels except for those in a high school AP physics course. While this finding echoes what previous studies (Granic, Lobel, & Engels, 2014) found about the effect of GBL on students' cognitive performances, it left an unanswered question about the impact of GBL on students in AP physics course. In his reflection paper, the participating teacher of that class offered an explanation to this issue. According to him, the game would be better used as a way to introduce the concept of electric forces, as opposed to a means of practicing the concepts. He did not think this game could help them learn those concepts any better. However, if he had let the students play the game before teaching the concept, they would have been able to come to the conclusion that electric force is proportional to the product of the charges divided by the square of the distance between them all on their own.

Different from the previous studies that focused mainly on students' cognitive aspects of academic performances such as learning attention, focus, and reaction time, this study examined specifically the cognitive aspect of test scores. Although the result indicated students' learning growth after taking the GBL activities, we are also quite skeptical with it because we were aware of the novelty effect that students may have. This effect is the tendency for students' performances to initially improve when the GBL activity was instituted, not because of any actual improvement in their learning or achievement, but in response to increased interest in the GBL activity itself.

Another aspect of positive impact of the GBL activities on students' performances was their good behaviors. According to the participating teacher, they did not expect this result because it had not been in their original plan when implementing the game in their classrooms. As indicated in the reflection, their students were focused during the whole week when the game was implemented. This impact may surprise the teacher but what we found was actually in line with what previous studies found about the impact of GBL on students' motivational and emotional behaviors. Nonetheless, we were also cautious about the novelty effect that the students may have during the GBL was implemented and it was that effect that resulted in students' behaviors not the game. We believed that further studies about this interesting topic are needed to help educators better understand the mechanism of GBL and its impacts on students' emotional and motivational outcomes.

What we found in the third research question about the teacher's perspectives on GBL was intriguing. In his written reflection, the participating teacher addressed that his initial thoughts about playing a game in class were poor. He felt negative and even insecure because he was not totally convinced that adding a simple online game as a bell ringer could work in his class. This teacher's negative attitude toward the use of games in classrooms was actually uncommon as we already discussed in the literature review. However, the positive result of students' performances on the test scores and good behaviors changed the teacher's perspective about the use of game in his classroom. At the end of four reflection papers, all four teachers mentioned that they would continue using more games in their future teaching. Since we could not find anywhere in the literature about teachers' attitude shift after implementing GBL in classrooms, we could not make any connection between what we found in this study with what other researchers found. In addition, as the nature of the explorative case study, we were more interested in understanding the natural phenomena which occurred within the data in question and providing new research ideas for future studies to explore. However, the result of the research question three echoed the previous findings about teachers' positive perceptions of GBL when they used it in their classrooms (Huizenga, ten Dam, Voogt, & Admiraal, 2017; Watson, & Yang, 2016).

In summary, the results of this explorative case study suggested that implementing GBL activities, even though a simple online game into a classroom, could result in students' academic performances in term of students' test scores and behaviors. One of the implementations from this study was that teachers did not need to spend time re-inventing the wheel but they could find simple online games and implement them into their teaching. The positive impact of the GBL may need more research to validate it but at least GBL is not a complicated learning concept and/or approach. A basic design of a learning activity with the use of a simple online game can lead to unexpected positive results. Finally, standing a new learning concept like GBL, teachers may have mixed attitudes and perceptions. However, giving it a try to see how and/or whether it works in a small scale is a better approach than trying to avoid it. School administrators may encourage their teachers to try new things and recognize their efforts instead of either ignoring them or putting pressures on the teachers.

Limitations

Like any typical exploratory case study, this study has some limitations that can impact or influence the interpretation of the findings from the research. Since this case study involved a small sample of participants, the generalizability and application to practice may not be possible to other settings. Future studies with a larger

sample of participants in different learning settings and from different countries would be recommended. In addition, more rigorous studies with experimental design to examine the impact of GBL on students' performances are also necessary to validate what we found in this study and provide teachers and educational administrators with more research-based evidences about GBL impact.

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