

Game-Based Learning in Mathematics: An Annotated Bibliography

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Alagic, M. (2003). Technology in the mathematics classroom: Conceptual orientation. *Journal of Computers in Mathematics and Science Teaching*, 22(4), 381–400.

Summary

This article provides information on how technology can be used to develop conceptual understanding in students. The article is not based on a study. It is a review and synthesis of the literature on this topic.

The article states the goal in mathematics is to move students beyond memorizing equations and towards being able to explain, generalize, and represent math in new ways. This is called conceptual understanding. Technology can be used to allow students to explore math in new ways and make connections. Many of these connections are not possible without the use of technology.

Research shows students need to be able to switch between modes of representation in math. This means they need to be able to switch between symbolic, verbal, manipulatives, real-world examples, and pictures. As students develop their ability to switch between these modes of representation, they are making connections and developing conceptual understanding. Again, technology can aid in this process by helping students make connections between these different modes with diagrams, charts, and simulations. Specific examples mentioned in the article were using spreadsheets for tabulating data and graphing it.

Relevance

Although the article isn't based on a specific study, it helps make the case for using technology to enhance the teaching of mathematics. It also provides valuable information on conceptual understanding which is a very important topic right now in math education.

Burns, M. K., Kanive, R., & DeGrande, M. (2012). Effect of a computer-delivered math fact intervention as a supplemental intervention for math in third and fourth grades. *Remedial and Special Education, 33*(3), 184–191. <http://doi.org/10.1177/0741932510381652>

Summary

This article is based on a study that looked at improving math fact fluency using a computer-based program. The importance of having a solid understanding of math facts was highlighted in the article. It is important for students to develop these foundational skills in order to be successful in higher-level math courses. This study looked specifically at elementary students at risk for math difficulties.

Research Methods

There were 231 3rd and 4th grade students in the study. The students used a computer-based program to practice their math facts. Students used the program at least three times per week for 8 to 15 weeks. A control group (CG) of 240 3rd and 4th graders used the same computer program, but for a limited amount of time. Students in the CG used the program one time per week for 8 weeks. Pretests and posttests were used to measure achievement.

Results

Students in the experiment group showed larger gains in fact fluency when compared to the control group. The use of the computer-based program to practice math facts was identified

as successful. However, it was noted that it is unknown whether having a solid foundation in math facts translates to advanced math skills for this particular students.

Strengths and Weaknesses

This study involved a large sample of students which appears to be a strength. A weakness of the study is the limited demographic data on the students involved in the study. The article suggested further studies should look closely at the implementation of the computer program and how it integrates with classroom instruction.

Relevance

This is a solid study on the impact of computer-based programs on math achievement at the elementary level.

Carr, J. M. (2012). Does math achievement h'app'en when ipads and game-based learning are incorporated into fifth-grade mathematics instruction? *Journal of Information Technology Education, 11*, 269–286.

Summary

This article was based on a study that looked at the impact of 1:1 mobile devices on math achievement in students at the elementary grades. If students develop a solid foundation in math skills at the elementary level they tend to do better in upper level math classes. The literature review indicates elementary math scores have only improved marginally from 2002 to 2012. In the past few years 1:1 initiatives specifically with mobile devices have increased. This article was looking to fill a void in the research on the impact of GBL applications used on mobile devices (iPads) on student achievement at the elementary level.

Research Methods

The study utilized 105 5th graders from Virginia. There were 48 students from one school in the control group (CG). These students did not have access to iPads. There were 56 students from a nearby school district with 1:1 iPads in the experiment group (EG). All students were given a pretest to determine their math skills. The EG students used the iPads for at least one math activity every day for one quarter. The apps on the iPads that were used included GBL applications, videos, and virtual manipulatives. At the end of the quarter all students were given a posttest.

Results

Both groups improved their performance on math scores. The EG students had a slightly larger gain in their performance, but it wasn't enough to be considered significant. The study found that 1:1 mobile learning devices like iPads were not show to be influential on student achievement.

Strengths and Weaknesses

The length of time (approximately 9 weeks) was a strength of the study. This was a considerably length of time to measure changes in performance. There were several weaknesses in this study. The EG and CG were not found to have equal abilities on the initial pretest. The quality of the teacher for each group could potentially have a significant impact on the outcomes. And, the EG group used a variety of applications on the iPads. It does not indicate what characteristics were used to identify which application should be used.

Relevance

This article is a very good fit for my area of research. It deals with math and game-based learning. For this particular study, GBL did not have a significant impact on math achievement, but it didn't measure motivation and engagement.

Chen, Z. H., Liao, C. C. Y., Cheng, H. N. H., Yeh, C. Y. C., & Chan, T. W. (2012). Influence of game quests on pupils' enjoyment and goal-pursuing in math learning. *Educational Technology and Society*, 15(2), 317–327.

Summary

This article is based on a study that sought to look at the impact of GBL on enjoyment and goal pursuing with students from Taiwan in elementary math classes. The authors noted students in Taiwan tend to have negative attitudes towards math. There is much research on the positive benefits of GBL in this area.

This study looked closely at how games are designed and who is involved in designing them. A three tiered approach to designing games is described in the article. The first tier involves content experts designing learning activities within the game world. The second tier is a “coupling mechanism” which involves creating the goal orientation for the game. The third tier involves game designers creating the game world. For this particular study a pet nurturing game was created in which students go on quests in a virtual world.

Research Methods

There were 53 4th graders from two classes involved in the study. It was assumed the students from both classes were similar in their math abilities. The students played two versions of the My-Pet-My-Quest game. One version of the game had quests as the goal orientation. The

other version didn't use quests. A questionnaire to measure student perceptions was used to collect data.

Results

Enjoyment, goal orientation, and goal intensity was higher for students when playing the quest version of the game. In addition students completed more problems in the quest version. Both of these items indicate using quests as the goal orientation has a positive impact on student perception and motivation.

Strengths and Weaknesses

This was a short-term study which is a limitation. The long-term effects are unclear. Another limitation noted was the questionnaire used to measure perception. It was developed by the authors and the validity and reliability could be in question. The authors made note of this in the article.

Relevance

The article supports my area of GBL and elementary math. This article provided a unique look at the individuals involved in designing games and provided information on their role in the process.

Eseryel, D., Law, V., Ifenthaler, D., Ge, X., & Miller, R. (2013). An investigation of the interrelationships between motivation, engagement, and complex problem solving in game-based learning. *Educational Technology and Society*, 17(1), 42–53.

Summary

This article is based on a study that looks at the relationship between motivation, engagement, and complex problem-solving during digital game-based learning (DGBL). The literature reviewed indicates game-based situated learning environments may promote

motivation and engagement. Because games often times provide opportunities for complex, ill-structured problem solving, they can be beneficial for learners. The goal with this study was to acquire information that might be helpful for designers to build better DGBL environments.

Research Methods

This study had 88 9th grade students play a massively multiplayer online game (MMOG) for one year. The game was an immersive experience in which students took on the role of a researcher tasked with creating a settlement on a newly found planet. Pre and posttest instruments were used to analyze problem solving skills. In additionally a motivation inventory was used to determine motivation and engagement of students.

Results

Motivation and engagement in the DGBL environment had an impact on problem solving outcomes. The design of the game can have an impact on engagement and self-efficacy.

Strengths and Weaknesses

The length of time in which this study was conducted appears to be a strength. Some of the weaknesses identified include other variables that were not tested may have influenced results. As well as the design of the game may have had an impact on the outcomes. Another area of consideration was the amount of involvement of the teacher. For this particular study the teacher was only a facilitator. If the teacher provided more guidance, the results may have been different.

Relevance

Although this article does not specifically address math, it does provide valuable information on the impact of DGBL on motivation, engagement and problem solving. Problem

solving in the math classroom continues to be a point of emphasis in mathematics education. This article could serve to provide evidence of the effectiveness of DGBL in that area.

Haydon, T., Hawkins, R., Denune, H., Kimener, L., McCoy, D., & Basham, J. (2010). A comparison of iPads and worksheets on math skills of high school students with emotional disturbance. *Behavioral Disorders*, 37(4), 232–243.

Summary

This article is based on study that compares GBL using iPads to the use of worksheets for practicing basic math facts. This study was done in an alternative school setting. The students were identified as struggling learners in math.

The research reviewed for this article mentions classroom management and the positive impact that student engagement can have on it. The research reviewed for this article specifically looked at students with emotional disturbance (ED). The goal was to look at the iPad as a possible way to increase student engagement and improve achievement.

Research Methods

Three students participated in the study. The students were 17 or 18 years old with ED and low math scores. Students alternated between using worksheets and various math apps on the iPad. Visual observations were the primary source for gathering data on student engagement.

Results

Both student engagement and number of problems increased with iPads compared to worksheets. Immediate feedback within the iPad apps was identified as the most likely cause for the increased level of engagement and increase productivity.

Strengths and Weaknesses

This study looked at a unique population which could be considered a strength. The weaknesses include very small sample size. In addition the GBL characteristics of the apps chosen was not taken into consideration which could have a significant impact on engagement and motivation.

Relevance

This fits my research area in terms of GBL and math. The strength of the study may not be great, but the unique population might be valuable as I continue my research.

Howard-Jones, P. a., & Demetriou, S. (2009). Uncertainty and engagement with learning games.

Instructional Science, 37(6), 519–536. <http://doi.org/10.1007/s11251-008-9073-6>

Summary

This article looked at the element of uncertainty in GBL and the impact it has on motivation and engagement. The authors noted the area of “uncertainty” hasn’t been researched as much as other areas of GBL.

The research reviewed for this article states the level of predictability of outcomes can increase dopamine. Dopamine levels have been linked to motivation. Research allows shows students often times have negative perceptions about uncertainty when presented in educational contexts. However, when uncertainty is presented in the context of games, interest goes up. In addition, acquisition of declarative knowledge can be enhanced when emotion is evoked. Uncertainty can be used to trigger emotional responses.

Research Methods

Three different students were used with children ages 10-14 and young adults for this article.

Study 1.

The first study involved 50 students with an average age of approximately 11 years. Students played a computer game with math fact questions. The element of uncertainty and choice was embedded in the game. Upon completion of the game ten students were randomly selected and interviewed. Based on the interviews, 80% of the students selected the uncertain option within the game more often than the certain option. The interviews suggested they made that selection because it was more exciting and engaging.

Study 2.

The second study involved 20 students with an average age of 14. Students played a different computer game with uncertainty embedded. Students played in a head-to-head environment and the conversations and reactions were recorded on video tape. Based on the analysis of the video footage, the game appeared to provide high levels of motivation for students. Students said it was both fun and annoying because of the uncertainty.

Study 3.

The third study involved 16 adults with an average age of 28. Participants played a computer game with uncertainty embedded. As they played the game electrodes attached to their fingers measured electrodermal activity (EDA). Their EDA went up with uncertainty.

Results

Overall the results from the three studies indicate uncertainty adds value to GBL by increasing engagement and motivation.

Strengths and Weaknesses

A strength of this study was looking at multiple factors to measure uncertainty. The small sample size for each study is a weakness.

Relevance

As I look at the impact of GBL, the component of uncertainty has value. Understanding how this component can impact motivation and engagement will be important for my research paper.

Hwang, G.-J., Sung, H.-Y., Hung, C.-M., Huang, I., & Tsai, C.-C. (2012). Development of a personalized educational computer game based on students' learning styles. *Educational Technology Research and Development*, 60(4), 623–638. <http://doi.org/10.1007/s11423-012-9241-x>

Summary

This article looked at the impact that learning styles has in an adaptive GBL environment. Research shows that learning styles have an impact on learning performance. Additionally GBL has been shown to improve motivation and performance. Moreover personalized or adaptive learning systems have also been shown to improve performance. This study combined those three elements -- learning style, GBL, and adaptive learning systems -- to measure the impact on elementary students.

Research Methods

An adaptive role play game (RPG) was used with 46 5th graders in Taiwan. There were 24 students in the EG and 22 students in the CG. All students were given an initial pretest to measure skills, learning styles questionnaire to determine their learning style, a motivation questionnaire, and a questionnaire to determine their comfort level with technology. The students in the EG were directed to the RPG based on their learning style. There were two options, sequential or global. The sequential option provided a very linear approach to working through the RPG. The global option gave students more freedom and choice.

Results

Students in the EG showed significant benefits in all areas. Their motivation was high, their perceived ease of use was high, and their achievement improved significantly compared to the CG.

Strengths and Weaknesses

The strength of this study was looking at the multiple areas that could potentially impact performance. Those areas include learning style, comfort level with technology, and motivation. This study was done with a small group which is a weakness.

Relevance

This article provides information on learning styles which should broaden my understanding of the impact of GBL. It also relates to elementary grade students which is the age group I'm the most interested in for my research project.

Ke, F. (2008). Alternative goal structures for computer game-based learning. *International Journal of Computer-Supported Collaborative Learning*, 3(4), 429–445.

<http://doi.org/10.1007/s11412-008-9048-2>

Summary

This article is based on a field study that looked at the impact of various goal structures embedded within GBL math programs. The three goal structures that were looked at were cooperative, competitive, and individualistic. Researchers sought to determine how the three goal structures impacted attitudes and achievement in the context of GBL.

The literature reviewed indicates computer games have the potential to have a positive impact on attitudes and achievement when used in the math classroom. It was noted that not all games are created equal. The characteristics of the game and the way in which games are

integrated into classroom instruction has an impact. The motivation to look at various goal structures stems from the trend of providing social interactions within GBL.

Research Methods

There were 160 5th grade students from 8 schools involved in the study. Students completed pretests and posttests based on state standardized assessments. Students were randomly assigned to one of three groups: cooperative, competitive, or individualistic. Students played a series of drill and practice programs to reinforce math skills. The games were played as a part of class over a 4-week period.

Results

Students showed significant growth in math achievement across all three goal structures compared to a control group that used paper and pencil. There was no significant difference in math achievement between the goals. The cooperative goal structure did show the greatest impact on attitude towards math.

Strengths and Weaknesses

A strength of this study was looking at various goal structures and the relation to social learning theory. The small sample size was a weakness. In addition the motivational effect was not solely based on the game, but on the environment in which it was implemented. The study also only looked at drill and practice programs which may have an impact on motivation and attitude.

Relevance

This article supports my research in terms of looking at the impact of GBL on elementary math.

Ku, O., Chen, S. Y., Wu, D. H., Lao, A. C. C., & Chan, T. (2014). The effects of game-based learning on mathematical confidence and performance: High ability vs. low ability.

Educational Technology and Society, 17(3), 65–78.

Summary

This article was based on a research project that looked at the impact of game-based learning (GBL) on math achievement and confidence. If students have low confidence in their math abilities this leads to difficulty in learning math concepts. Past studies have shown that GBL has a positive impact on achievement and motivation, but the articles review of the literature didn't include information that specifically dealt with confidence. That was part of the motivation for this study. In addition, the authors also wanted to look at the impact GBL has on high-ability and low-ability students.

Research Methods

The study used an experimental group (EG) with 26 4th graders and a control group with 25 4th graders (CG). Within the EG and CG the students were identified as high-ability or low-ability. The EG completed math tasks using digital mini-games. The CG completed math tasks using paper and pencil. The specific math skills students worked on was mental calculations using multiplication. Each group worked on their math skills in 10 20 minute sessions over the course of 5 weeks. All students were given a pretest and posttest on their math abilities and a pre-survey and post-survey on their confidence towards math.

Results

GBL had a significant impact on confidence in both high- and low-ability groups. In terms of performance, GBL had a greater impact on the low-ability students. Students in both the

EG and CG improved their performance, but GBL had the greatest impact on the low-ability students. Immediate feedback of performance was indicated as a key contributor to these results.

Strengths and Weaknesses

The study looked at confidence which is a key element in learning math. It also looked at the impact GBL has on high- and low-ability students. However, this was a small study (51 students) and it did not take into account gender or cognitive styles.

Relevance

This article supports my research because it provides evidence of the impact of GBL on performance and confidence specifically in the area of mathematics..

Li, Q., & Ma, X. (2010). A meta-analysis of the effects of computer technology on school students' mathematics learning. *Educational Psychology Review*, 22(3), 215–243.

<http://doi.org/10.1007/s10648-010-9125-8>

Summary

This article was a meta-analysis of 46 studies on the impact of computer technology (CT) on math achievement at the K-12 level. Although there have been many studies on various aspects of CT on math achievement, the goal with this article was to bring clarity to this issue by analyzing a large group of studies.

Research Methods

The study took a systemic approach to looking at 46 studies involving CT applications. There were a total of 36,793 involved in these 46 studies. The CT applications were categorized into the following categories: communication media, tutorial device, or exploratory environment. In addition teaching methods were analyzed to determine how the CT applications were implemented.

Results

The meta-analysis found that CT applications have a positive impact on math achievement. In addition the method of teaching and how the CT is integrated into the curriculum has an impact as well. CT applications had a bigger impact on math achievement for students with special needs, for students at the K-5 level, and when a constructivist teaching approaches were used.

Strengths and Weaknesses

Looking at a large number of studies and analyzing the data is a strength of this article. The individual weaknesses of each study could have an impact on the overall analysis.

Relevance

Although the terminology used is CT as opposed to GBL, there are many GBL components within this analysis. The results of this analysis will be valuable as I research the effectiveness of GBL in math at the K-5 level.

Sedig, K. (2008). From play to thoughtful learning: A design strategy to engage children with mathematical representations. *The Journal of Computers in Mathematics and Science Teaching*, 27(1), 65–101.

Summary

This study looked at how GBL can be used to engage and motivate students in mathematics. Often times math is viewed by K-12 students as something that is not very engaging or enjoyable. This study sought to analyze whether or not GBL could have an impact on student perception as well as learning specific math skills.

The literature reviewed for this article identified the importance that motivation plays on learning math. Research shows that components of GBL such as goals, points, and challenges have all been shown to increase motivation. Because of this there are many games available. Unfortunately many of the games available focus on drill and practice activities. Designing effective games is not an easy task.

This study used the program, Super Tangrams, with students. Super Tangrams was specifically designed to engage students in deep thinking activities as they learn geometry concepts.

Research Methods

There were 58 6th graders in the experiment group and 20 6th graders in the control group. A pretest and posttest were used to measure math skills. A design questionnaire was used to measure student perceptions.

Results

Significant improvements in math knowledge were found. Student perceived the game as fun and enjoyable. The outcomes of the study indicate design of games matters.

Strengths and Weaknesses

The study only looked at one implementation of Super Tangrams which was a limitation. It also only focused on one math skill. A strength of the study is the in-depth analysis of the Super Tangrams game and how it fosters deep thinking as opposed to drill and practice.

Relevance

This is a great article for my research topic. I really want to be able to identify the characteristics of what makes GBL effective in mathematics. The details provided on the Super Tangrams game is very helpful.

Valdez, A., Trujillo, K., & Wiburg, K. (2013). Math snacks: using animations and games to fill the gaps in mathematics. *Journal of Curriculum and Teaching*, 2(2), 154–161.

<http://doi.org/10.5430/jct.v2n2p154>

Summary

This article looked at study of a GBL math program called Math Snacks. The literature reviewed for the article indicates that technology continues to play an increased role in education. Constructivist technology applications have been shown to have a great impact on learning compared to traditional drill and practice approaches. The Math Snacks program was developed specifically to target gaps in mathematical knowledge for middle school students. The Math Snacks program employs GBL methods with constructivist instructional approaches.

The goals for this study were to determine if the Math Snacks program has an impact on improving math skills on specific target areas, and to evaluate the effectiveness of the Teacher Guides that accompany the program.

Research Methods

There were 460 6th and 7th grade students and 9 teachers involved in the study. The Math Snacks program was used for 8 weeks. A control group used the program without the accompanying Teacher Guide. The experiment group used the program with the Teacher Guide. Data was gathered on math skills using pretests and posttests. Researchers conducted observations to evaluate the effectiveness of the Teacher Guide.

Results

The 6th grade students showed significant improvements in math skills in both the CG and EG. The 7th grade students showed significant improvements in the EG, but not the CG.

Strengths and Weaknesses

Weaknesses of the study include random selection of CG and EG which could lead to varying level of math aptitude across the groups. The study does appear to do a nice job of collecting data based on observations which looked for fidelity of instruction.

Relevance

This article is a good fit for my research because it looks at the impact of GBL on acquiring math knowledge. It could potentially be used to draw attention to the impact of teacher effectiveness on implementing GBL solutions.

Woo, J.-C. (2014). Digital game-based learning supports student motivation, cognitive success, and performance outcomes. *Educational Technology and Society*, 17(3), 291–307.

Summary

This article was based on a study done with university students to look at how digital game-based learning (DGBL) techniques can be employed to impact germane cognitive load and motivation. Germane cognitive load is the load dedicated to the creation of schemas. The literature review indicates DGBL has the potential to increase motivation and performance. However, cognitive load can be too high in DGBL environments and this may lead to decreased motivation and performance.

Research Methods

The study used a computer-aided manufacturing game in which students operated a small factory. There were 63 university students that participated as a part of a college course. They played the game for 3 hours per week for 8 weeks. A likert scale was used to measure motivation. The game was designed using Keller's ARCs motivation model and information on germane cognitive load.

Results

The game had a positive impact on motivation and had an increase on german cognitive load. German cognitive load is something we should work to develop in learners so this was positive. The authors concluded that following the ARCs model when designing DGBL helped lead to the positive outcomes.

Strengths and Weaknesses

This article does a nice job of aligning game characteristics to their design strategies. This study had a small sample size which is a limitation.

Relevance

This article provides information for me on DGBL game characteristics which is beneficial. In addition, it specifically targets germane cognitive load which is helpful.

Zhang, B. M., Trussell, R. P., Gallegos, B., & Asam, R. R. (2015). Using math apps for improving student learning : An exploratory study in an inclusive fourth grade classroom. *TechTrends: Linking Research & Practice to Improve Learning*, 59(2), 32–39.

Summary

There are a lot of apps able for mobile devices such as the iPad and research on the effectiveness of these apps is limited. This article is based on an exploratory study done with 4th graders to determine if apps on the iPad would improve math skills. The literature reviewed indicates educational technology has been shown to have a positive effect on math learning. As mobile devices gain popularity because of features such as the number of apps available, size, battery life, and ease of use, the authors sought to identify the impact on learning.

Research Methods

There were 18 4th grade students involved in the study. The students were from a public elementary school in an urban area of the southwest United States. All of the students were either Hispanic or African American and 68% received free or reduced lunch. This study was the students first experience using iPads in the classroom.

The students used two apps on the iPad that taught or reinforced decimals and multiplication. The study took place over the course of one month during during four math classes which lasted 80-90 minutes each. Three assessments were given each one contained a pretest and posttest. In addition to pretest and posttest data, researchers observed students as they worked on the apps looking for level of engagement.

Results

Students showed significant improvements from pretest to posttest for all three assessments. The struggling learners improved more than the non-struggling learners. Immediate feedback provided by the apps and self-pacing options were identified as the reasons for helping the struggling learners. Observations indicated that the apps were generally engaging although additional features were identified that could possibly improve engagement levels.

Weaknesses

The sample size was small and the duration was short. The study did not contain a control group.

Relevance

The article specifically looks at GBL and math at the elementary level. Although it does not specifically mention game-based learning, the features of the apps described in the article have game-based learning elements.