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Digital Game-Based Learning Activities in Primary Grade Mathematics Achievement

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Abstract

The research paper has gathered and analyzed research from online databases to find how digital game-based learning activities were used in mathematics and how it influences the affective domains of academic engagement, motivation, and academic self-perception. The paper aims to inform primary educators of the benefits and limitations of digital game-based activities in primary mathematics. Digital game-based learning has positively influenced students' academic engagement through interaction, play, and effort, which had a positive effect on their mathematical achievement. Increased motivation felt by students when doing digital game-based activities resulted in higher mathematical achievement and an increase in learning more mathematics based on intrinsic and extrinsic factors. Digital game-based learning activities have also promoted students' academic self-perception such as confidence and judgment of their ability. Drawbacks include the below-average percentage of high mathematical improvement as educators may want an activity with full confidence. Another drawback is that the rise in mathematical achievement may not be immediate. Some studies have acknowledged that students would eventually exceed their paper assessment scores if given more time to play. In conclusion, digital game-based learning activities in mathematics may increase student learning factors but remain inconsistent in learning gains. The research found in this paper will provide educators with the benefits and drawbacks of digital game-based activities in primary mathematics and allow educators to decide if this approach is right for their classroom.

Keywords: Digital Game-Based Learning (DGBL), mathematical achievement, motivation, academic engagement, academic self-perception

Chapter One: Introduction

Education is a field that is constantly changing and adapting to technology. With the changing landscape in education, student-centered methods are being favored over traditional or teacher-centered methods. With every level of cognitive development, students should be actively engaged in the learning process (Woolfolk, 2020). A method that is quickly rising in popularity that embodies this student-centered engagement is Digital game-based learning (DGBL).

Digital games and activities are a form of media that has captured the attention of children. The cultural acceptance of digital games as a leisure activity has led to an increase in digital game-based activities or educational video games in the classroom (Greipl et al., 2020). Because of their cultural relevance and the ability to consume hours of attention, video games are being looked at as an engaging learning experience (Tokac et al., 2019).

An area that is growing from the increased use of DGBL activities is the subject of mathematics. Despite its popularity, empirical research on the effects of mathematical video games remains inconsistent (Tokac et al., 2019). Do children learn from DGBL activities from a combination of factors such as behavior, cognitive learning processes, or the environment it creates? This begs the question of how to use DGBL and its activities to best teach mathematics to primary grades.

Scope of Research

There are four core arguments in favor of game-based learning and its effects on student learning: 1. Games motivate learners intrinsically or extrinsically to generate interest, 2. Games engage by physical movement or interactions as part of the experience force learners to become more active, 3. Some games can adapt to any learning style with personalized feedback and

scaffolding according to the learner's achievements and interactions, and 4. Games can be used to create an environment that is safe to make errors-alleviating the negative consequences of failing, which promotes attitudes and perceptions towards mathematics (Greipl et al., 2020).

These four arguments are useful for teaching any subject with DGBL along with how it influences the affective factors of learners are the basis for the research question: In light of what is known about how primary grades (K-6) learn mathematics, how shall educators best teach using digital game-based activities? This paper focused on the affective factors of academic engagement, motivation, and academic self-perception based on the four arguments listed earlier. Games: motivate learners intrinsically and extrinsically, engage learners by physical movement or interactions, adapt to any learning style, and create safe learning environments to promote attitudes and perceptions towards mathematics. These strands along with their effect on mathematical achievement were also the focus of this paper.

Research for this review was gathered from studies, journal articles, case studies, and other research published within the last seven years. The population researched was primary-grade students. Primary grades range from kindergarten to grade seven depending on state and school district policy (International Affairs, U.S Department of Education., n.d,). This review was focused on the grades of kindergarten to grade six as the research participants from the studies were from these and all varied in age. There are two appendices that each contain a matrix for visual representation. Appendix A contains the Article Tracking Matrix and Appendix B contains the Article Limitation Matrix.

Importance of Topic

Mathematics is a discipline in which components such as numbers, shapes, and algebraic relationships are used to study their properties and develop connections between them. The

logical reasoning developed can be used to analyze and comprehend a vast array of challenges and situations in science, engineering, and everyday life (Minnesota Department of Education., n.d.). The reputation of this subject is that it is equally as difficult for students to learn and for teachers to find the right tools and methods that promote learning. DGBL activities are seen as a solution to both issues, however, while DGBL does promote achievement in various domains such as problem-solving and algebraic skills, affective factors such as motivation, beliefs, and attitudes towards mathematics and its teaching, have remained in question (Vankus., 2021). With the current push for more student-centered methods, there is a need for a literature review to assess DGBL's influence on a student's affective domain. When teachers of primary grades are aware of what DGBL activities do and how they influence affective factors, their students will become more receptive to the challenges of mathematics and thrive.

Research Question

This paper asks the research question, in light of what is known about how primary grades (K-6) learn mathematics, how shall educators best teach using digital game-based activities? This question ties into the Concordia University Master of Teaching Program essential question; in light of what is known about how people learn, how shall we best teach? Both questions address how to teach students of different ages, a variety of approaches or methods that cater to every unique mindset or learning threshold. The research question expands on the essential question by focusing on K-6 students and the subject material of mathematics while also approaching students' learning with DGBL activities.

Definitions of Terms

The terms listed are found throughout this paper and are important to define to have a better understanding of the research. Each term is grounded in texts written by established authors, professionals, or organizations and therefore accompanied by citations.

Academic Engagement. A quality of a student's participation, investment, commitment, and identification with school-related activities to enhance a student's performance, academic engagement is relatively diverse as it encompasses different aspects (behavior, cognitive, emotional) to operate together to reflect students' approach to learning (Alrashidi et al., 2016). Academic engagement in the school setting is the interaction between students and curricula and in DGBL, the interaction between students and game.

Academic self-perception. The awareness and perceptions about oneself, and academic self-perception can affect academic achievement positively or negatively. Positive self-perception about one's capabilities forms a significant part of adolescent life and adjustment in school (Mathew., 2017). Academic self-perception is the feelings of confidence, determination, and resolve felt by students and may allow them to be more receptive to math curricula and decrease math anxiety.

Digital Game-Based Learning (DGBL). A form of student-centered learning using digital games for educational purposes, DGBL is a form of student-centered learning that uses digital games on electronic devices for educational purposes (Hussain et al., 2016). A few studies have found that DGBL application of video games can enhance learning and learning attitudes. DGBL in mathematics are varied in forms but all are presented on a digital device in a game setting.

Mathematical Achievement. Competency is shown by the student in the subject of mathematics (Pandey., 2017). Mathematics achievement is the quality and quantity of learning attained in mathematics after a period of instruction, activity, or study that presents the ability of the student. Mathematics achievement is the performance of the student's ability in mathematics and may be assessed using games, discussions, or paper tests.

Mathematics. A discipline whose basic ingredients are numbers, shapes, and algebraic relationships, mathematics uses logical reasoning to study the properties of objects and develop connections between them with results that can be used in everyday life (Minnesota Department of Education., n.d.). The mathematics presented in primary school relies on the curricula and state standards of the district's location.

Motivation. Internal processes that initiate, direct, and sustain behavior. Motivated students put out more effort, persist longer, learn more, and score higher on assessments. To be motivated is not to be thrilled by the task but to move energetically towards a goal or to work hard (Woolfolk.,2019). Motivation in mathematics is important to primary school educators as students who are motivated are more likely to participate, engage, challenge themselves, and seek out knowledge.

Chapter Summary

The delivery of mathematics content has changed dramatically since the beginning of the decade. The COVID-19 pandemic has challenged teaching methods around the world. With the closure of schools and the rise of distance learning, many teachers have searched for different methods to draw the engagement of students based on technology that can be used independently or at home. Of these methods, the integration of digital learning devices with DGBL activities in mathematics has not only been embraced, but it continues to grow and spread in popularity.

While DGBL activities are known, there is a need for further research on how DGBL affects mathematical achievement. The paper has stated an introduction to DGBL activities along with the scope of the research based on the four arguments that encourage DGBL's effect on the factors of academic engagement, motivation, and academic self-perception. The importance of the topic being DGBL's ability to raise mathematical achievement compared to traditional methods ties into the research question. The definition of terms that are used throughout the paper is listed for the reader to have a better understanding. In the next chapter, fifteen sources about DGBL activities in the primary mathematics classroom will be examined and analyzed as part of the literature review.

Chapter Two: Literature Review

Mathematics is a broad and deep subject that can be approached with a variety of instructional methods. Educators are in a constant state of researching the best practices for content delivery, learning retention, and efficiency of time. DGBL activities such as tablet games, computer games, and other educational video games are rising to the forefront. DGBL activities that started as a learning station or side activity are being used as the main method of content delivery. DGBL provides a student-centered approach where learners are less intimidated by the subject, they feel motivated and encouraged to play, and their time spent in the activity correlates to the amount they learned. Research for this review focused on three affective domains that DGBL has an impact on that directly influence student mathematical achievement: academic engagement, motivation, and academic perception.

Academic Engagement

Academic engagement is a complex term that is applied to many different patterns of behavior. It involves various patterns in motivation, cognition, and behavior (Alrashidi et al., 2016). Students engaging in the classroom by participating, interacting, or investing in the activity of the subject correlates to their achievement in the subject. DGBL activities are seen as the most engaging tool that educators have but do the effects of this engagement have a significant impact on their mathematical achievement?

There are specific DGBL activities that measure engagement and mathematical learning for the teacher. One such activity is the My Math Academy application as studied in *Accelerating Early Math Learning with Research-Based Personalized Learning Games: A Cluster Randomized Controlled Trial* researched by Thai et al. (2021). The application's purpose is to engage and accelerate early mathematics learning with games that cater to early number

sense and operations. This quantitative study used the blocked cluster random assignment design that used a 3-level hierarchical linear model to account for differences in students' pre-and post-test scores after adjustment from baseline scores. Descriptive analyses were conducted to measure the interest of students' engagement. A survey was conducted as well to describe the impact of teachers' perceptions of the activity. Participants of this study were 20 kindergarten and transition kindergarten classrooms with 453 students who came from four Title I elementary schools in urban Southern California.

Before the start of the study, classrooms were randomly assigned to the treatment group or control group. A pre-test was issued called the Test of Early Mathematics Ability, 3rd edition (TEMA-3). This test measured the mathematics performance of children between the ages of three and eight years. The data for the pre-test was then gathered and analyzed. Each treatment classroom received six tablets with access to My Math Academy and the activity was implemented in small groups. For 15 minutes per day, students took turns with the tablets in groups of six while the rest of the class worked with the teacher. Control groups did not receive access to the activity and did normal instruction. After the period, students undertook the TEMA-3, and post-test data was again gathered and analyzed. Teacher surveys were also given out at the end of the study (Thai et al., 2021).

Another DGBL activity that encourages academic engagement to have a positive impact on mathematical achievement in a different age group is the study titled *Game-Based Training to Promote Arithmetic Fluency* by Jay et al. (2019). Both high and low ability students engaged in the activity to the same extent and all students improved in their scores. This quantitative study was administered to a different age group of seven- to eight-year-old children.

Participants were separated into two classes with the groups being randomly selected to be the treatment class (group A) and the control class (group B). Group A would receive the game intervention for two weeks followed by a return to normal interventions. Group B would have normal interventions for two weeks followed by the two-week game intervention. Before the start of the intervention, each class was given a pre-test which required the children to complete as many single-digit addition problems as possible in one minute. After the pre-test, the game was installed on tablets and group A began playing the game with each session lasting twenty minutes every academic day. At the end of the final session, the test was repeated and given to both groups. After the mid-test, the roles were switched with group B being introduced to the game and playing for the next two weeks. After the final gameplay session, a final post-test was given using the same testing materials (Jay et al., 2019).

Neither study had shown any qualitative data as to why and how academic engagement influences mathematical achievement. The study, *Sixth-grade students' experiences of a digital game-based learning environment: A didactic analysis* researched by Gok & Inan (2021), is a qualitative study that found similar results from the previous two studies with an older age group. The study incorporated a math game on a tablet called "Race with Numbers" to prove that digital game-based learning activities build mathematical knowledge through the interactions and feedback between the student, teacher, and the game itself. This was done in the observation of 16 volunteer students from the sixth grade of a public school in the Eastern Anatolia region in Turkey. Observations of the students and teacher lasted 75 minutes (Gok & Inan., 2021).

Not all studies had positive effects. Some studies have had mixed or negative results as well. A follow-up to research by Thai et al. (2021) was conducted by Bang et al. (2022). *Efficacy of an Adaptive Game-Based Math Learning App to Support Personalized Learning and Improve*

Early Elementary School Students' Learning focused again on the My Math Academy app and increased the participant sample from kindergarten to second grade. This mixed-method study used a two-level Hierarchical linear model in its analysis of student math assessments as well as observations, surveys, and interview transcripts to identify major themes and patterns in the classrooms. This qualitative data was a limitation of the previous study and was addressed in this one.

Other researchers have had similar mathematical achievement results to Bang et al. (2022). The quantitative study *From here to there! Elementary: A game-based approach to developing number sense and early algebraic understanding* by Hulse et al. (2019), claims that while academic engagement did raise mathematical achievement, it did not make any statistical difference with those who did and who did not partake in the gamified version of the activity. One hundred eighty-five second-grade students from ten classrooms in three schools from Massachusetts participated in the study, which differed compared to the population of K-2 students from California as in the studies of Bang et al. (2022) and Thai et al. (2021).

A bigger difference between Bang and Thai's studies with this study is the method, as students interacted with either one of two versions of the activity, the gamified or non-gamified version. Students took the pre-test and played both the gamified and non-gamified versions during these four sessions. A week after the sessions were completed, students completed the post-test assessment. An independent-sample t-test was applied by the researchers to test for any difference in pre-test scores for the gamified and non-gamified. There were no significant differences. The study was not clear if the students were separated into two groups based on the version they took.

The previous study had given results that showed that DGBL activities can positively influence academic engagement but can have a mixed effect on mathematical achievement. *Effects of a Mathematics Game-Based Learning Environment on Primary School Students' Adaptive Number Knowledge* by Brezovszky et al. (2019) is another study that came to another set of mixed conclusions. The quantitative study researched the effectiveness of a DGBL activity called the Number Navigation Game (NNG) and the effect it had on adaptive number knowledge. The results that were shown were of mixed engagement levels with equally mixed achievement levels.

As with the earlier study by Hulse et al. (2019), different gains of knowledge varied with each grade level. Tools used in previous studies such as the two-level hierarchal design with covariates were used in the analysis and planning of the study. The participants of the study were 1,168 fourth to sixth-grade primary school students which had the most participants in this paper's academic engagement section. Another noteworthy difference was that this study took place in Finland.

The results of the studies in this section began with Thai et al. (2021). Their study conducted descriptive analyses and revealed that the more games started by students, the greater their learning. There was a correlating relationship between the number of games mastered and learning gains (Thai et al., 2021). To measure the comparison to the control groups, results show that My Math Academy had produced significantly higher gains in children's mathematical achievement when compared to normal instruction as the treatment group outperformed the control group by 5.71 points with the difference being statistically significant (Thai et al., 2021). Specifically, the activity had made the most impact on students with some prior knowledge. Students who scored in the middle third and top third on the pre-test showed greater gains than

their peers from the control group. My Math Academy had made an impact on those with some prior knowledge and/or those who were engaged with the app.

The research done by Jay et al. (2019), showed that the game was designed to be academically engaging among students with an already high level of mathematical knowledge and students with a low level of knowledge. The results confirmed the design function as it showed a very small correlation coefficient which indicated that children engaged with the game to the same extent, regardless of levels of ability (Jay et al., 2019). When tested in mathematical achievement both groups improved by 10.1 points on average (Jay et al., 2019). These results confirm that DGBL activities, when engaged with, do lead to better mathematical achievement as the result from the study of Thai et al. (2021) also concluded.

Gok & Inan's (2021) qualitative data showed a bit more as to why there was an effect from the observations that the researchers made. They noticed that students interacted with each other by providing feedback on strategies and revisiting those strategies in later situations**.** This data was collected with video and recording devices. The results explain that feedback from digital games plays an important role in accessing hidden mathematical knowledge through a reasoning filter (Gok & Inan., 2021). The study shows that the activity when combined with interaction and feedback can be used to introduce mathematical concepts and cause student achievement as the game provides opportunities for students to work on social skills. These skills positively influenced students' critical thinking and problem-solving skills.

However, not all results came to the same conclusion. The study of Bang et al. (2022) built off the study of Thai et al. (2021) had mixed conclusions. By analyzing qualitative data, academic engagement was measured based on feedback, and researcher observations. Teachers praised the activity for going at the student's own pace which led to high engagement. The high

engagement factor of the activity enabled students to progress steadily through more difficult material without showing any negative behaviors or fatigue (Bang et al., 2022). This was reinforced with further responses such as the activity's flexible approach to math content strengthened foundational knowledge that kept students engaged.

Data analyzing mathematical achievement noted that while all grades improved, some grades benefited more than others. Using the same hierarchical linear models from Thai et al. (2021), data shows that there were small and large impacts. Starting with kindergarten, the treatment group scored about one point higher than the control group, and the difference was statistically significant. For first grade, the difference decreased to about 0.6 points and was not statistically significant. Researchers conclude that the activity benefited the students at kindergarten the most because they had more room to grow (Bang et al., 2022). When connecting academic engagement and mathematical achievement, the correlation between post-test and use per week was weak with a score of 0.18, but the connection between post-test scores and the number of skills mastered was strong at 0.73 (Bang et al., 2022).

The study by Hulse et al. (2019) reinforced the same conclusion that mathematical achievement will not always be influenced by the academic engagement used by DGBL activities. The differences in post-tests between gamified and non-gamified students in terms of mathematical achievement had a surprising result as the researchers discovered as researchers suggested there were no differences in post-test performance between the two groups (Hulse et al., 2019). However, as engagement was measured with the post-test scores, students in the gamified condition performed 6.58 points higher on the post-test than students in the other condition (Hulse et al., 2019). Like with other studies in this section, students with the lowest pre-test scores benefited from higher learning gains compared to those who engaged with the

activity less. Hulse et al. (2019) supported the idea that digital-based learning did not result in enough differences in mathematical achievement even though the gamified participants engaged more with the activity.

The study by Brezovsky et al. (2019) was the most different compared to the others as results for engagement and mathematical achievement were both mixed. NNG had shown positive interaction and engagement within all grades, but many were varied depending on the domain as with students in grade four who showed significant interactions for finding the correct solutions for arithmetic fluency, but no interactions were found for multi-operational solutions or pre-algebra knowledge. In grade five, interactions for finding correct solutions for multi-operational solutions were found, but no interactions were found for math fluency and pre-algebra knowledge. In grade six, results had shown significant interactions for pre-algebra knowledge (Brezovszky et al., 2019). It seems that with more advanced content, grades four through five did not engage with the activity as much.

When assessing mathematical achievement or learning gains, the researchers concluded that the gameplay's impact on grade four's adaptive number knowledge was supported by the game's effect on development. Fifth graders who had more calculation fluency were impacted positively by the gameplay and by the more complex problems the game would provide. Sixth graders, while knowing some pre-algebra, did not benefit much from the game because the challenge may have been too low (Brezovszky et al., 2019). NNG is an example that while digital games engaged students, it did not lead to further mathematical achievement or even academic engagement. DGBL activities must be chosen based on the level of appropriateness and challenge. When comparing Brezovszky et al.'s (2019) study with Gok and Inan's (2021) study, Brezovszky et al. (2019) had mixed results with the older students whereas Gok and Inan

(2021) had more positive results with the older students. DGBL activities, cultural differences, or limitations of the research could explain the differing results. When compared to the U.S. studies, the results reflect each other. DGBL activities have a high academic engagement level with positive to mixed results on mathematical achievement.

When applying the research question, it seems that academic engagement is an effective influencer of mathematical achievement that teachers need to be aware of when selecting their DGBL activity for mathematics in primary grades. Despite some studies showing mixed reactions to mathematical achievement based on the challenge or grade level of the game, DGBL activities have proven to be mostly engaging and useful for the primary teacher.

Motivation

As previously mentioned, motivation is a pattern in academic engagement. Learners use these processes to initiate, direct, and sustain their behavior toward a goal or to work hard. If academic engagement initiates students, then motivation propels them forward. There are two types of motivation: intrinsic and extrinsic. Intrinsic motivation seeks to conquer challenges, interests, and exercise capabilities, whereas extrinsic motivation is based on external factors outside the task itself, such as getting a good grade or pleasing the teacher. DGBL activities are both intrinsically and extrinsically motivated. (Woolfolk.,2019).

A quantitative study that presents play as intrinsic motivation is *Acceptance of Game-Based Learning and Intrinsic Motivation as Predictors for Learning Success and Flow Experience* by Ninaus et al (2017). The purpose of the study was to use an activity on iPad called the Semideus School game and see its impacts on rational number knowledge and if there was any connection to intrinsic motivation.

Thirty-two sixth graders from a Finnish public primary school participated in the study. The study took place over one week with four playing sessions of thirty minutes each. Using self-reported measures and the Technology Acceptance Model (TAM), researchers measured the intrinsic motivation of the participants while also using a paired t-test to measure the game's effect on mathematical achievement through rational number knowledge.

The pre and post-tests did not come in the form of questions but on the game itself. Students were told to complete at least thirty levels as that would act as the post-test. Researchers also observed and discussed the game with students during the study (Ninaus et al., 2017).

Another study on intrinsic motivation, *JEUTICE: An Arabic Serious Game to Enhance Mathematics Skills of Young Children* by Tazouti et al. (2019), is a quantitative study that focuses on fourth-grade and fifth-grade regarding how intrinsic motivation establishes a positive effect on mathematical achievement. Not much is known about the participants other than that their first language was Arabic and they lived outside the U.S., which is similar to the study by Ninaus et al. (2017). Students would participate in a pre and post-test at the beginning and end of the study to identify the learning impact of the game. After game sessions, students would fill out a survey that depicted their perceptions of the game by answering simple questions on a scale of one to seven (Tazouti et al., 2019).

As the previous studies focused on intrinsic motivation, *the Effects of Game-Based Learning in an OpenSim-supported virtual environment on mathematical performance* by Kim & Ke (2016) resulted in extrinsic factors that motivated students to higher mathematical achievement. This quantitative study brings the activity to virtual reality (VR) and shows how game mechanics motivated students extrinsically to achieve higher. This study focused on fourth

graders similar to the participants by Tazouti et al. (2019) but the location of the study was located in Florida.

The entire study took place on one day with a pre-test given seven to ten days prior. Participants were randomly assigned into two groups: an experimental group that received the activity with game characteristics and a control group that did not. Seven to ten days prior, students underwent a pre-test in CCSM practice items. On the day of the study, students were seated in front of computers and participated in preliminary instruction for approximately 10-15 minutes. Students were then given four tasks to solve that lasted 30-40 minutes (Kim & Ke., 2016).

The games presented in the study have been on computers and small devices but for the mixed-method study of *Commercially available Digital Game Technology in the Classroom: Improving Automaticity in Mental-maths in Primary-aged Students* by O'Rourke et al (2017), the activity was played on a handheld gaming console. Using a quasi-experimental design with semi-structured interviews and observations, the study's purpose was to research whether the digital game was more effective at students' speed and accuracy in mental math than traditional instruction. Just as it was discovered in other studies, both the intrinsic and extrinsic forms of motivation were positively influenced, thus leading to better mathematical achievement.

Like previous studies, this one took place outside of the U.S., with the research set in four public schools and three Catholic education schools in Perth, Australia. The same grades of fourth- and fifth-year students aged between nine and eleven years from previous study demographics were listed. The study lasted over a 10-week school term with each gaming session set at twenty minutes. The name of the game was *Dr. Kawashima's Brain Training* and was played on the handheld gaming console of the Nintendo DS Lite. Classes in the control

group followed their regular math curriculum while the experimental group received the consoles and game. Students in both groups were given a basic number facts test called the Westwood One Minute Test of Basic Number Facts. The experimental group then played the game over a twenty-minute session for ten school weeks. All participating students then took the same test at the end of the study (O'Rourke et al., 2017).

Another quantitative study, *Motivation Outcomes in Math-Related Video Games* by Hoffman et al. (2020), measured levels of motivation in students with different perceptions of mathematics with the game *Dance Dance Revolution*. A quasi-experimental design was set up with an independent sample t-test to show a positive influence on motivation but unlike in the previous studies in this section, there was no difference in mathematical achievement.

Moving the focus back to sixth grade, it is not known how many game days there were except that each session lasted over fifty minutes. Before the study, students were surveyed with the Self and Task Perception Questionnaire to assess their perception of math as being highly motivated (HM) or lowly motivated (LM). 30 of the 49 fell into these two experimental groups with the extra 19 students recruited to serve as a control group. Information was not given on where the study took place.

When the studies were analyzed, Ninaus et al. (2017) measured the effect of intrinsic motivation and its effects on mathematical achievement, The correlation analysis indicated that perceived usefulness, intention to use, and perceived ease of use correlated positively with mathematical achievement and were associated with students' improvement in rational number knowledge (Ninaus et al., 2017). When calculating mathematical achievement, researchers found that students improved significantly between the pre and post-tests, an indication that the game was effective (Ninaus et al., 2017). The evaluation of these results indicated that intrinsic

motivation and acceptance of game-based learning as predictors of learning success have medium to large-sized positive effects.

Similar to Ninaus et al. (2017) study, the results from Tazouti et al. (2019) showed that mathematical achievement was positively influenced by the activity in terms of averages. The pre-test found that knowledge of surfaces had an average of 7.05, measurements of 6.20, and numbers of 6.21. In the post-test, surface knowledge was 7.82, measurements were 7.13 and numbers were 7.29 (Tazouti et al., 2019). Researchers attributed intrinsic motivation as being the factor of the rising scores as the activity stimulates intrinsic factors such as student interest and engagement to solve mathematics problems. Because of the increased motivation, students tried many new behaviors learned in the game and different methods of playing (Tazouti et al., 2019).

With the evaluations and results of intrinsic motivation shown, results from Kim & Ke's (2016) research with the ANCOVA analyses revealed that extrinsic factors can also positively influence mathematical achievement as based on the partial eta squared value (0.14), the effect size is considered large. The significance of the result indicated the post-test mean of the experimental group on math learning achievement was higher by 1.72. More than the control group with the difference being significant (Kim & Ke., 2016).

When discussing why, researchers hypothesized that combining learning integration with extrinsic motivation could have driven the experimental group to achieve higher. Instant rewards combined with learning could have enhanced motivation and contributed to mathematical achievement. (Kim & Ke., 2016). Extrinsic factors such as instant rewards played a large role in developing students' mathematical achievement. However, activities should have both forms of motivation as later studies show.

A DGBL activity can also combine intrinsic and extrinsic motivation to have a positive impact on mathematical achievement. O'Rourke et al. (2017) used quantitative and qualitative data. The activity's results for mathematical achievement were positive. When comparing the pre-and post-tests of both groups, researchers concluded that the significant gain made by the intervention group (20.41) compared to the other group (3.78) was confirmed by the results of the parametric and non-parametric tests (O'Rourke et al., 2017). Every class in the experimental group made more learning gains than the classes in the other group.

Researchers then gathered qualitative data to answer why. Student interviews were conducted, and common themes of the students were that they felt motivated and encouraged to practice based on the enjoyment of the game (intrinsic), and how they wanted to improve their speed (extrinsic) (O'Rourke et al., 2017). Unlike in other studies, parent feedback was also received. Parents reported that children were motivated by the activity and that their attitude toward math had become more positive (O'Rourke et al., 2017). When compared with all studies outside the U.S., results were unanimous. The motivation was positively affected, and it had an equally positive effect on mathematical achievement. When compared to the study of Kim and Ke (2016) located in the U.S., the results were reflected. Motivation is a key affective domain to target when selecting DGBL activities in primary mathematics learning.

Interestingly, Hoffman et al. (2020) came up with a different result. After analyzing the scores with the independent t-test, researchers concluded that there was no significant difference found between the teacher-assigned course grades in mathematics. This suggested that the two experimental groups were functionally equivalent in terms of mathematical achievement (Hoffman et al., 2020). This puts it at odds with other studies that result in higher motivation leading to higher achievement. The results in the game leading to higher motivation were as

expected. With an Independent Samples t-test, a significant difference was confirmed as the high-motivation group had a significantly higher math motivation score (M = 3.96, SD = 0.22) compared to the low-motivation group (M= 3.30, SD = 0.34) (Hoffman et al., 2020). Both experimental groups had higher motivation scores than the control group but did not record significant mathematical achievement. The type of motivation observed was not listed in the study, however.

Despite the previous study's results on mathematical achievement, DGBL activities that motivate students intrinsically or extrinsically have a positive influence on mathematical achievement. When applying the research question, DGBL activities encouraging enjoyment, practice, rewards, or skill improvement were accepted by the students in all studies and is a key affective domain that DGBL targets to improve mathematics learning.

Academic Self-Perception

Academic self-perception or academic self-concept encompasses the worth or value of the academic capabilities of the student. Self-efficacy or the ability to be aware of one's thinking allows the student to develop concepts about the internal workings of the system and can be intrinsically motivated and is an important factor to show the relationship between self-perception and student achievement. "Self-perception and academic achievement are positively correlated to each other. It has been observed that students who have scored higher and have greater self-perception reflect confidence." (Mathew., 2017, p. 3). Mathematics can be intimidating for students and positive self-perception can lead to higher mathematical achievement. DGBL activities claim to cause higher academic self-perception through their student-friendly characteristics such as engaging environments, enjoyable problem-solving, and constructive feedback (Garneli et al., 2017).

Using another quasi-experimental design, *Role-Playing Game Based Assessment to Fractional Concept in Second grade Mathematics* researched by Chiu & Hsieh (2017) uses quantitative data gathered from paired sample t-tests and assessments based on the satisfaction of the students to show progress in mathematical achievement based on academic self-perceptions through learning attitudes.

The purpose of the study was to determine if assessments based on role-playing games (RPGs) were more effective than traditional methods. An ANCOVA analysis was also conducted to analyze the differences between different mathematical achievements. The RPG assessment was given on computers and presented the concepts of fractions in a story-told objective-based game where students played as virtual characters on a mission. Textbook contents were implemented into ten game levels and the completion of a level was seen as the mastering of a concept of the fraction unit (Chiu & Hsieh., 2017).

One hundred students from the second grade participated in the study and were from the same school. Fifty students were each assigned to the experimental group and the control group. Researchers then administered a pre-test to twenty-seven second-grade students to assess discrimination. The experimental group then played the game for three days for a total of 120 minutes as the control group underwent traditional methods. After the last game session, a satisfaction assessment was given to the students with researchers analyzing the data afterward. It is not known how long the total study lasted (Chiu & Hsieh., 2017).

While Chiu and Hsieh's (2017) study attributed that DGBL activities promote academic self-perception's correlation with mathematical achievement, the following studies gave different results in both attributes. The qualitative study, *Enhancing Math-class Experience throughout Digital Game-based Learning, the case of Moroccan Elementary Public Schools* by Bouzid et

al., (2021) focused on how the attitude toward a subject and attention to mathematics anxiety (MA) can affect academic self-perception toward mathematics. Through DGBL activities, researchers concluded that levels of MA are lowered but mathematical achievement was higher in written performance rather than DGBL activities. The researchers concluded that by using the Analysis, Design, Development, Implementation, and Evaluation instructional model (ADDIE) with the Mathematics Anxiety Rating Scales (MARS) along with classroom observations, discussions, and interviews, the study would not lead to better mathematical achievement, but the lower amount of MA in students could lead them to better performance eventually.

Participants were 164 students from fifth to sixth grades in six elementary schools from across different regions across southern Morocco could be a factor in the differing results compared to the study done by Chiu and Hsieh (2017). While a great deal of research about MA has been done in developed countries, few comprehensive studies have been done in Morocco where the environment and culture of the classrooms are different and unfamiliar (Bouzid et al., 2021). Students underwent a game session followed by a paper assignment that lasted an hour each. Teachers tutored, observed, and ranked students' levels of concentration, motivation, and connection to the game. The game was set on computers on a Moodle-based platform and was made by the teachers. (Bouzid et al., 2021).

Another study that also researches math anxiety's relation to self-perception is the quantitative study, *Evaluation of math anxiety and its remediation through a digital training program in mathematics for first and second graders researched* by Ng et al. (2022). The study was set in Taipei, Taiwan. While the research was not prevalent in the Moroccan study, East Asian countries are aware of reports of high levels of worrying about failure in math from students. The researchers expect that math anxiety would start in Taiwanese first and second-

graders and that it should be negatively correlated with math school attainments (Ng et al., 2022). By using a DGBL activity as a training program to work on core math skills and mathematical achievement, researchers hypothesized that prolonged exposure to DGBL would alleviate high math anxiety in children.

This quasi-experimental design used questionnaires, assessments, and data analyses to collect and process data. The activity, *Igo Invasion*, was played on computers or Android devices for six weeks as students were instructed to play the game at home in a self-initiated and self-guided manner. The study included a total of 111 first and second-graders from multiple school districts in Taipei, Taiwan. However, this study did their method differently by sorting students into how much time they played the game with children being sorted into high- and low-intensity groups depending on the time they were exposed to the game (Ng et al., 2022). This would result in mixed reactions to academic self-perception that correlated to mixed results of mathematical achievement.

Digital educational games and mathematics. Results of a case study in primary school settings by Fokides (2018) is a quantitative study that uses questionnaires and evaluation sheets to indicate that DGBL activities were not only viewed as highly positive by students, but game groups outperformed students in some other groups.

Unlike other studies in this section, the participants were an unknown amount of first, fourth, and sixth-grade primary students from Athens, Greece. The activity was also developed by teachers like in the study of Bouzid et al. (2021). The teachers used Microsoft's Kodu Game Lab as their platform because of the interesting game levels and scenarios designed to practice a certain mathematical state standard of that grade. The activity had play sessions of two hours, but it was not known how long of a timeframe the study lasted. (Fokides., 2018).

Also, unlike other studies in this section, students of the same age were divided into one experimental group and two control groups. One control group used a conventional teaching method and the other used a contemporary method while the experimental group used the game method. The conventional method used textbooks without any other additional learning material while the contemporary method was based on constructivist frameworks of collaboration and building off prior knowledge. All groups of students were given a pre-test to assess cognitive process and a post-test to assess the sustainability of knowledge (Fokides., 2018).

Students worked in pairs and collaborated on the math presented in the gameplay such as discussing ideas and guiding each other through the game. For first grade, the content was number counting as well as the numbering system. Fourth grade content was decimal number memorization with sixth grade's content of decimal to fraction conversion and multiplication and subtraction of decimals. After the post-test, students immediately filled out an evaluation form. All tests included mainly mathematical operations of right-wrong, multiple choice, and fill-in-the-blank questions.

The studies in this section were analyzed to find that Chiu & Hsieh's (2017) research was the only study to show a positive influence on both academic self-perception and mathematical achievement. Results from the paired samples t-test showed significant differences in both mathematical achievement and self-perception between the two groups. With scores of progress of 28.80 for performance and 0.88 for attitude in the control group compared to 41.12 for performance and 17.35 for the experimental group, the experimental group showed significant progress in mathematical performance and learning attitude compared with the control group which showed no differences in learning attitude between the pre-test and post-test. This indicated that the application of RPG-based assessment was effective in mathematical

performance and learning attitude (Chiu & Hsieh., 2017). The research conducted by these researchers reinforced the reciprocal relationship between mathematical achievement and student self-perception and how DGBL activities can utilize this.

As with most studies in this section, academic self-perception was positive. The research by Bouzid et al. (2021), observed that teachers noting motivation, concentration, and connection were ranked higher during the game session compared to the paper assignment. Math anxiety levels also dropped in both sessions as students reported positive shifts in self-perception towards mathematics. After the paper assignment, students shared their positive perceptions of the game and expressed their negative perceptions of the paper assignment. Students were averse to the difficulty of the paper assignment because it did not use drafts and resulted in the anxiety of putting down the wrong answers. They were also confused if their mistakes were going to be checked. All preferred the game session much more (Bouzid et al., 2021).

However, most pupils scored better on the paper assignment than in the game session. Researchers explain that MA and mathematical performance can influence one another and if the students were allowed to play more, they would have exceeded their paper scores. It was suggested that students learn more efficiently through game-based activities than traditional paper methods based on their willingness to make mistakes and repetition. (Bouzid et al., 2021). While this study showed no increase in mathematical performance, the results did show that there was a decrease in MA, an influencer on mathematical performance. Students may have also been marked lower on the activity due to their willingness to make mistakes or the time constraint placed on them during the activity (Bouzid et al., 2021). Researchers concluded that while mathematical achievement was not better in DGBL activities, researchers noted the

potential of it and how participants of the DGBL activity could have better mathematical achievement than participants who did the paper assignment.

There were similar results in the study of Ng et al. (2022). By using the main effect analysis, an unexpected result from the data was discovered as interactions were driven by math anxiety. There was a significant reduction of math anxiety in the high-intensity group after the training, whereas math anxiety slightly increased in the low-intensity group (Ng et al., 2022). This was a slight contrast to Bouzid et al. (2021) as math anxiety decreased in some students but not in others.

When analyzing the effect the activity had on math achievement, researchers discovered a near-equal result. Parallel analyses were conducted on children's math achievement with the interaction effect between group and time being significant (ATS $F = 9.23$, $df = 1$, $p = .002$;). Results suggested that the high-intensity group had increased mathematical achievement after training (ATS $F = 16.54$, $df = 1$, $p < .001$), whereas the low-intensity group showed no difference between the initial and post-assessment (Ng et al., 2022). DGBL's effects on self-perception are correlated to engagement when resulting in mathematical achievement, if a student is not engaged with the activity, the self-perception towards mathematics may worsen with no change to mathematical achievement.

The study by Fokides (2018) focused on three grades of varied content that had more positive results but were mixed on mathematical achievement. The researcher used post hoc comparisons and the Tuckey HSD test showed that the group that played the DGBL activity outperformed the group that used conventional teaching in all fifteen cases. However, students in the games group outperformed the group that used contemporary teaching in only four cases, with the contemporary group learning more in two cases. In the remaining nine cases, the

achievement levels in the games group and the contemporary group were not statistically different (Fokides., 2018). While DGBL concepts were better compared to conventional teaching, there was no significant variation compared to contemporary teaching.

From the questionnaire, academic self-perception had a more positive effect as students had a strong positive attitude toward the games and the lack of notable problems. Students also stated that they learned a lot from these games. (Fokides., 2018). While DGBL activities may not outperform other teaching methods, the positive self-perception that the students had towards mathematics was a better factor compared to the traditional teaching method.

These studies except for Chiu and Hsieh (2017) being of unknown location, all took place outside of the U.S. It is not known if there were many other factors affecting the self-perception of students such as cultural and educational differences, limitations of the research, and the acceptance of DGBL activities as a learning tool. Further current research is needed in the U.S. school system.

When applying the research question, DGBL activities show that they can positively influence a student's academic self-perception by increasing positive learning attitudes or decreasing mathematical anxiety. While the results on mathematical achievement have been mixed to negative, the correlating relationship between academic self-perception and mathematical achievement is linked. This linkage can be utilized in DGBL activities that can contribute to an eventual rise in mathematical achievement over time or when combined with another contemporary method.

Chapter Summary

In summary of this literature review, DGBL activities whether used on computers, tablets, game consoles, or other small devices for teaching mathematics in primary grades may

have positive influences on certain attributes as well as mathematical achievement. Educators who use DGBL activities can give students chances to engage with the material through interaction, play, and effort. Educators will see their students' motivation to learn math increase whether resulting from intrinsic factors such as interest, fun, and usefulness, or extrinsic factors such as rewards and competition. Educators should be aware of how DGBL activities promote academic self-perception and how a student's judgment of their mathematical ability is positively influenced by it. While not always resulting in greater mathematical achievement, educators should be aware of the relationship between mathematical achievement and academic self-perception. The third chapter of this paper will lay out insights gained from the research, applications to the classroom, limitations, and suggestions for future research.

Chapter Three: Discussion, Application, and Future Studies

The following highlights found in the literature review were related to the research question, In light of what is known about how primary grades (K-6) learn mathematics, how shall educators best teach using digital game-based activities? These highlights listed below were based on how DGBL activities affect the domains of academic engagement, motivation, and academic self-perception and the relationship with mathematical achievement in the primary grades. When following these highlights, teachers may improve their instructional methods for teaching primary mathematics with DGBL activities.

Academic engagement encouraged by DGBL activities, must be utilized properly through participation, interaction, and play. Evidence from the literature suggests that it is an effective influence on mathematical achievement despite some studies showing math improvement as a mixed reaction. Motivation, with its intrinsic and extrinsic factors, is another highlight. Practice, feedback, enjoyment, rewards, and skill improvement are some of the intrinsic and extrinsic factors that DGBL activities promote. It has been found that the relationship between motivation and mathematical achievement is correlated and usually leads to positive impacts on students' overall mathematical achievement. For academic self-perception, DGBL activities can change students' perception of mathematics into a positive outlook. By increasing desired learning attitudes and decreasing mathematical anxiety, DGBL activities will positively change student perceptions towards mathematics. They may affect mathematical achievement over time or when combined with contemporary methods. When using DGBL activities that encourage all three affective domains, lower-ability or lower-grade students have the most to gain. The activities can be adjusted effectively to have higher ability or higher-grade students achieve even higher.

Insights Gained from the Research

When analyzing the Article Tracking Matrix in Appendix A of this paper, there are a few insights to be made from the articles of the research. The first is that the themes of interaction, intrinsic factors, and student self-efficacy are the most common factors shared in most of the studies. Interaction, a factor of academic engagement, can be explained as students who interacted with the DGBL activity. These interactions were done through pressing, swiping, or another input that was under the control of the student. Intrinsic factors were the second most common as students were motivated by enjoyment, interest, or a motive that was in the game itself. Student self-efficacy is the belief of the student in their capabilities including intrinsic motives that allow the student to gain confidence that they are getting better at the skill when playing the activity. When applying these insights to the research question, it seems most studies support DGBL activities for their effects on interaction, intrinsic factors, and student self-efficacy. The theme of investment or student mastery encouraged by DGBL activities was the least shared. Students seemed to be driven by the game's activities, and how they perceived mathematics rather than mastering a particular skill or standard.

When analyzed on the effects of mathematics improvement, 53.3% of the studies reported high improvement with 33.3% as mixed improvement and 13.3% as no improvement. Quantitative methods dominated the review with eleven studies while mixed-method and qualitative methods had two studies each. The high improvement percentage can be seen as an undesired outcome for teachers who want an activity with full confidence but some of these percentages were affected by their studies and their respective limitations as listed later in the paper.

Two studies stood out as outliers of the research. The study by Bouzid et al. (2021) is one of the two qualitative studies that had the most themes in its study yet reported no improvement. They acknowledged that measuring performance based on either the game or paper-test raw scores would be beyond their scope and that DGBL implementation would not reach educational goals alone. They also hypothesized that if they gave students more time to play, they would have exceeded their actual scores eventually (Bouzid et al., 2021). Another study that stood out as an outlier was by Hoffman et al. The study had the fewest shared themes with mixed results, but the researchers acknowledged that the game motivation could have been overshadowed by the math motivation, thus missing qualitative data on how students felt about the game activity being a math activity. They also acknowledged that the limited timeframe and small sample size could have affected the results and that a longer study needed to be conducted (Hoffman et al., 2020). Educators, administrators, parents, and students can learn from these insights and apply this approach to various benefits.

Application

Application of the research in this literature review should be considered by primary mathematics teachers and early mathematics specialists who want to implement activities related to mathematics on digital devices as the research affected students from kindergarten through sixth grade. Primary educators should consider DGBL activities as an alternative to traditional methods of teacher-centered instruction as the impacts of these student-centered activities on mathematical achievement are mostly positive when compared. Primary educators should also consider DGBL activity's effects on lower-level grades as Bang et al. (2022) concluded that students in kindergarten had more to gain. DGBL activities and their application to all ability levels should also be considered by primary educators as the studies of Jay et al. (2019) and

Bang et al. (2022) concluded. Primary educators should also be aware that DGBL activities should provide an appropriate level of challenge to keep students engaged and motivated as the study of Brezovsky et al. (2019) concluded. Finally, it should be concluded that the studies conducted by Fokides (2018) and Thai et al. (2021) that DGBL activities by themselves do not always result in higher mathematical achievement. DGBL activities should be implemented with contemporary methods that are based on prior knowledge to have the best impact.

Primary school administrators will benefit from this research when purchasing digital devices and software for students and teachers. All studies used various forms of devices, although handheld devices seemed to dominate the research. Although the software was varied, there seemed to be an increased number of ready-made software tailored to primary students compared to teacher-made software.

For parents, the view of DGBL activities as leisure activities should change based on the research of Ng et al. (2022). Parents should consider their children to be highly engaged in DGBL activities outside of the classroom to change student perceptions towards mathematics positively. If there is less engagement, it may result in worse perception and may affect mathematics achievement. For primary students, the intrinsic and extrinsic motivation encouraged by DGBL activities based on student engagement levels will have a positive effect on their self-perception towards mathematics thus leading or eventually leading to higher mathematics achievement or performance. However, limitations were noticed in this literature review and must be considered before making a final decision on whether to implement this approach.

Limitations

When analyzing the limitations, the Article Limitation Matrix in Appendix B of this paper was used to analyze the limitations in all studies. The most common limitation was the limited timeframe in when the studies took place or how long the activity lasted. Researchers had remarked that the timeframe of the study or gameplay was too short to assess the sustainability of learning retention of the DGBL activities. The second most common was other teaching methods being applied or needed. For control groups, the other methods that teachers used were not observed or controlled and for experimental groups, the need for additional methods was needed to explain the mathematics of the game better. The last common limitation was game factors, such as difficulty in playing the game, understanding the game, or data collected by the game.

For the limitations of this literature review, a total of fifteen primary sources would be considered a limitation. Although fifteen primary sources are considered to provide helpful information, there might not be enough information to make a well-informed decision to implement DGBL activities. A second limitation is the periods of the studies. Nine of the fifteen studies took place before the COVID-19 pandemic. Since 2020, the educational landscape has changed to more virtual methods of delivery and these studies may not be as relevant. A third limitation is each section's age of participants. While the studies may have researched certain age groups or grade levels, no section has studies that cover all grades or all ages. Each study is missing participants from third grade. In the motivation section, samples from kindergarten, first, and second grades are missing while the academic self-perception section has samples missing from kindergarten. These limitations must be considered when looking at the results of this literature review and results must not be generalized based on these limitations. An outlier of the

research when analyzing the limitations is the study by Tazouti et al. (2019) because it reported no limitations. (Tazouti et al., 2019)

Recommendations for Future Studies

There are three recommendations for future research based on the limitations previously mentioned on DGBL activities in primary-grade mathematics learning. The first would be to study the effects of learning retention or sustainability for a period after the activity is introduced. By further investigation, educators can consider if a DGBL activity can turn surface learning into facts when the engagement, motivation, and perception of the game wears off. Further research can give a more accurate study of DGBL activities.

The second recommendation is to investigate how DGBL activities affect mathematical achievement when combined with other methods. An example could be combining DGBL activities with collaborative learning to increase academic engagement for students still struggling to engage on their own. Further study in this area can create new methods of teaching or revitalize traditional methods along with more positive results on academic engagement, motivation, and academic self-perception.

The third recommendation is to research all primary grades and their affective factors separately when learning with DGBL. By researching each grade separately, DGBL may become more effective in approaching students with games tailored to that grade level or mathematics standard. A separate grade approach may lead to more detailed information for educators teaching a specific grade level. For example, research involving a sample of third-grade students would fill in the gaps of the scope while providing detailed information to third-grade educators.

Conclusion

In conclusion, educators who choose to implement DGBL activities in mathematics learning may have their class be academically engaged, motivated, and have positive academic self-perception. While DGBL activities have mixed mathematical achievement in one affective domain, DGBL activities will commonly utilize all three, thus mathematical achievement will gradually or rapidly grow. These potential benefits will introduce, nurture, and encourage students in their mathematics to make them reach heights that they could not have achieved with traditional methods. However, DGBL cannot stand alone, “When schools are again confronted with new pedagogical challenges and innovation pressure to meet the rising demands of society, game-based learning may be one piece of the puzzle” (Greipl et al., 2020, p, 35). Researchers are still trying to solve the puzzle that is education, but DGBL provides a monumental step forward in the right direction.

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Appendix A.

Article Tracking Matrix

	Method: Qual, Quan, or Mix	Interaction	Participation	Investment	Intrinsic factors	Extrinsic factors	Student Attitude	Student Self-Efficacy	Math improvement? Yes/No/Mixed
Bang et al. (2022) K-2nd	Mix	x		x	x			x	Mixed
Bouzid et al. (2021) 1st, 4th, 6th	Qual	x		x	x	x	x	x	No
Brezovsky et al. (2019) 4th-6th	Quan	x	x		x				Mixed
Chiu & Hsieh (2017) 2nd	Quan	x			x	x	x		Yes
Fokides (2018) 1st-2nd	Quan	x	x		x			x	Mixed
Gok and Inan (2021) 6th	Qual	x	x			x		x	Yes
Hoffman et al. (2020) 6th	Quan	x			x				Mixed
Hulse et al. (2019) 2nd	Quan	x	x		x				No
Jay et al. (2018) 2nd	Quan	x		x	x				Yes
Kim & Ke (2016) 4th	Quan	x				x		x	Yes
Ng et al. (2022) 5th-6th	Quan	x	x		x		x	x	Mixed
Ninaus et al. (2017) 6th	Quan	x			x	x			Yes
O'Rourke et al. (2017) 4th-5th	Mix	x	x		x	x	x		Yes
Tazouti et al. (2019) 4th-5th	Quan	x	x		x		x	x	Yes
Thai et al. (2021) K	Quan	x		x	x			x	Yes

Appendix B.

Article Limitation Matrix

	Needs qual data	Needs further questions	Inadequate timeframe	Other methods used or needed	inaccurate assessment	Too small sample	Needs more diversity	Outside factors	Development factors	Game factors	Student experience factors	Study factors
Bang et al. (2022) K-2nd				x	x		x	x	x			
Bouzid et al. (2021) 1st, 4th, 6th			x									x
Brezovsky et al. (2019) 4th-6th				x								x
Chiu & Hsieh (2017) 2nd										x	x	
Fokides (2018) 1st-2nd										x	x	
Gok and Inan (2021) 6th				x	x					x	x	
Hoffman et al. (2020) 6th		x	x			x	x					
Hulse et al. (2019) 2nd		x										
Jay et al. (2018) 2nd			x	x						x		
Kim & Ke (2016) 4th			x				x			x		
Ng et al. (2022) 5th-6th				x								x
Ninaus et al. (2017) 6th			x			x	x					x
O'Rourke et al. (2017) 4th-5th			x	x								
Tazouti et al. (2019) 4th-5th												
Thai et al. (2021) K	x	x	x									