Article Received: 08th October, 2020; Article Revised: 15th February, 2021; Article Accepted: 20th March, 2021

Game-Based Number Learning Effects on Special Education Students' Mathematics Performance and Motivation

Alvaro Perez-Civera[1], Francisco Alegre[1*]
[1]Universitat Jaume I, Spain
*falegre@uji.es

ABSTRACT

This paper presents a study of game-based number learning in special education settings. The experience was carried out at a Singular Education Action Center in Spain, that is, a center in which students' socioeconomic status is low and their academic performance is under average compared to the national standards. A pretest-posttest design with no control group was carried out to evaluate the mathematics performance of the students before and after the game-based number learning experience. Likewise, focus groups were held to find out students' motivation towards this methodology. Statistical significant improvements (Students' t-test = 4.58, $p < 0.01$) and a moderate effect size (Hedge's $g = 0.32$) was reported for students' mathematics performance after the GBNL implementation.

Keywords (Times New Roman, bold, 9)
game-based learning; mathematics performance; motivation; special education

Introduction

More than fifty years ago, Ablewhite (1969) warned about the problems caused by learning operations, and how students with difficulties were the ones who suffered the most since they were taught through abstract and unsuitable algorithms. An algorithm may be defined as a systematic method to solve numerical operations, which consists of a finite set of steps guided by rules that allow us to economize the calculation and reach an exact result. In most classrooms, the four basic operations (addition, subtraction, multiplication and division) are still taught, as they were decades ago, without diminishing the concern about students' low performance (Corcoran et al., 2018). Many years have passed since Ablewhite's warning and yet, in most classrooms, they continue to be taught in the same way regardless of the advances that have been made in child psychology about how children acquire knowledge (Rodán et al., 2019). If we look at academic results, the average scores obtained by Spanish students are below the OECD average. This result is explained by the large percentage of students (28%) who are at the lowest levels of competence (compared to 20% in the OECD), since the percentage reaching the highest levels (5 and 6) is very similar to the OECD average (Ginsburg, Wu & Diamond, 2019).

In view of this reality, both the universal references on mathematics education and the current normative frameworks of developed countries emphasize the importance of fostering the development of the so-called "numerical sense" in schoolchildren (Alegre-Ansuategui & Moliner-Miravet, 2017). This is understood as a broad concept that refers to the development of skills as important as flexible mental computation, appreciation of number size, number estimation and quantitative reasoning, among others, all with an approach aimed at developing mathematical competence (Campos et al., 2020). Many authors highlight in their studies the permanence and reproduction of the traditional methodology in spite of the low yields it produces (Rodríguez & Suárez, 2019; Cai et al., 2019). The most relevant methodological changes at present, involve a greater emphasis on mental calculation, estimation skills and the use of the calculator, as well as an earlier initiation to the problems of initiation to calculus. In the case of school mathematics, and more specifically in relation to the mastery of calculus in the first years of mathematical learning, many voices are raised calling for methodological changes (Cai et al., 2019; Fuchs et al., 2019). As we mentioned earlier, Ablewhite already warned of the problems derived from learning basic operations. A few years later, the appearance of calculators made the teaching of traditional procedures and their role in school begin to be questioned (Kearney & Garfield, 2019). Therefore, if students have different needs than those of 40 years ago, why is mathematics still being taught in the same way if the results are not adequate? It is therefore necessary to explain other more innovative methods of teaching mathematics so that students can have more advanced calculation. In the present work, a research is carried out with an innovative method for learning Mathematics: the game-based number learning.

Game-based Number Learning

Game-based number learning (GBNL) may be defined as a type of learning in which content acquisition is achieved by means of a game. This learning can take place at any educational level. It may go from simple memorization and recall to high level learning. The game may be used in an intrinsic or supplemental way, may take place face-to-face with or without physical objects and with or without a computer. It should be noted that most of the times such learning is "open", since there is no single way to perform it and each student can solve it in a flexible way according to his or her development and mastery of calculus. "Number-based" indicates that it is based on numbers, unlike traditional procedures that are based on figures, in the sense that they break down all the numbers contained in the number and treat them all equally (Scalise et al., 2020). Many authors indicate this is the most effective way for students to understand math basic facts (Carducci, 2020). Why are better results obtained through GBNL than with traditional methodology? Because GBNL method is a natural method, which takes into account the way the brain processes calculations in an intuitive way (Wang, Wang, Yu, Wang & Li, 2020). In addition, this method takes advantage of the innate knowledge of the student (Sung et al., 2017). In the traditional methodology, students have to start from zero, but this method takes into account the previous knowledge of the student since it enhances the number sense in a dynamic way (Hamari et al., 2016).

Theoretical Foundations of GBNL

What characterizes this teaching methodology is its openness (it is possible to find the right solution in different ways) and the fact that the basis on which the students work is numbers. In this method, units, tens and hundreds are freely composed and decomposed without applying a certain rule or criterion for their final resolution (Nasrullah, 2015). All of this confers autonomy on the student to apply his or her criteria according to his or her capacity for calculation, reasoning and mathematical logic according to the educational stage in which he or she is (Ninaus et al., 2017).

When we talk about constructivism, we are talking about the need to give the student tools that allow him/her to build his/her own procedures to solve a problematic situation, which implies that his/her ideas are modified and he/she keeps on learning (Baroody et al., 2009). This method is characterized by providing tools so that children can solve problems and operations by themselves. It empowers each child to follow the steps that he or she believes are appropriate, since in this way he or she will build up his or her own knowledge since he or she will understand the steps that have been followed. Contrary to traditional methodology, the steps to be followed are not marked and this circumstance cannot be given. Therefore, it is not a matter of seeing examples or theories, but of learning through your own creation (Shin et al., 2012).

By promoting autonomy in the students, greater problem-solving skills are developed, school performance and the ability to perform mental computation operations improves (Ramani et al., 2012). At all times students understand the process they are following. They are the ones who have decided it and can explain at all times why they are doing it. For his part, some authors notes that with the GBNL method the attitude towards learning mathematics is very positive and academic performance is improved (Plass et al., 2015). In addition to all the above, the purpose of GBNL is that students do not acquire mathematical content mechanically and by memory, but that the student manages to perform operations and solve problems in various possible ways, given the freedom and flexibility of the method (Plass et al., 2015).

Practical Foundations of GBNL

The proposed methodology has a key element: the use of the number table. It is characterized by the use of manipulative material and daily use such as chopsticks, through which hundreds, tens, units are represented. Working with this type of material, children manage to experiment in a closer way, acquiring mathematical concepts that in traditional methodology are distant and abstract. When children manipulate the chopsticks and break down the number as they want and is experiencing, they achieve significant learning because they understand the process they have carried out, because they have decided to do so (Wiersum, 2012). When we talk about significant learning, we are talking about the importance of knowing the student's previous knowledge, in order to establish a relationship with what he must learn, so that the new information acquired can interact. According to Scalise et al. (2020) a combination of cognitive, motivational, affective, and sociocultural perspectives is necessary for game design to fully capture the potentiality of GBNL. Therefore, with this method, calculus is promoted in a very positive way. It is crucial that mathematical learning be based on meaningful learning and that it be worked on intensely, otherwise there will be problems in learning to calculate, as we are currently seeing in a large number of children with difficulties in mathematics (Zaretsky, 2018; Moliner & Alegre, 2020).

A practical example of the calculations that students would do with ABN is shown in Figure 1.

Student A

77+31=108

ADDITION	ADDEND	REMAINING
+	77	31
10	87	21
10	97	11
10	107	1
1	108	

Student B

77+31=108

ADDITION	ADDEND	REMAINING
+	77	31
30	107	1
1	108	

Figure 1. Different ways of adding through

GBNL

As we see the first column contains the number that is added to the sum, the central column is the result that is obtained and the last column the numbers that we have to add. Here is where you can see the importance of breaking down a number, since this way the sum is done in a faster and easier way. When breaking down the number there is no "I take one", which is one of the most frequent errors in children, because they forget to add a unit if it is more than ten. There is evidence that shows that when faced with the same sums, or the same problems, children solve some types of exercises better than others, since some are more suitable than others (Campos & Moreira, 2016). With the GBNL method this error disappears completely as when breaking down the number the "I carry one" does not appear anywhere. In addition, the children's strategy is enhanced to be able to do the addition with fewer steps, so the work of decomposition will be fundamental in the GBNL method. An example of subtraction using the GBNL method is shown in figure 2.

Student A

76-39= 37

SUBTRACTION	MINUEND	SUBTRAHEND
-	76	39
30	46	9
6	40	3
3	37	

Student B

76-39=37

SUBTRACTION	MINUEND	SUBTRAHEND
-	76	39
10	66	29
10	56	19
10	46	9
6	40	3
3	37	

Figure 2. Different ways of subtracting through GBNL

These operations, as an example, could have been carried out by two different students. In both, the correct solution of addition and subtraction is reached, however the process is different and even one of the two processes is longer than the other. We can observe here the principles commented before about this method, like for example the adaptation to the personal rhythm of the student, being able to need more steps to arrive at the result.

Outcomes of Previous GBNL Experiences

Previous reviews in the field have pointed at the potentiality of GBNL. According to Qian and Clark (2016) game-based learning approach might be effective in facilitating students' 21st century skill development. Kiili et al. (2018) showed how GBNL improved aspects of fourth graders conceptual rational number knowledge (decimals and fractions). Spires et al. (2011) and Chang et al. (2012) reported positive effects for problem solving in middle school students. Kazimoglu et al. (2012) also highlighted the potentiality of GBNL in computional thinking. Ke (2009) reported improvements through GBNL in an implementation for learning basic math facts. Papastergiou (2009) showed that the gaming approach not only was more effective in promoting students' mathematical knowledge, but it also improved more students' motivation than others non-gaming approaches. The motivational factor has also been addressed by other authors (Hung et al., 2019). When comparing GBNL with other nongame-based methodologies, Hess and Gunter (2013) revealed that the motivation of those students who participated in GBNL motivation was higher. Studies in other psychological factors such as students' anxiety has also shown promising results in the field (Mavridis & Tsiatsos, 2017)

GBNL and Special Education Previous Studies

The literature in the field regarding GNBL with special education studies is still very scarce. Nevertheless, recent studies in the field by Lin et al. (2017), Lan et al. (2018) and Aguilar (2019) have shown promising results in related studies. In this sense, authors such as Vasalou et al. (2017) state that game-based learning may increase self-esteem of children with special education needs as well as reveal learning processes offering intervention opportunities.

Materials and Methods

This section develops the design of the research, the objectives, the hypotheses, the participants, the development of the program, the materials and resources and the instruments used

Research Design

A pretest-posttest group without control group design was employed in this research (Valente & Mackinnon, 2017). Although the use of control groups is highly recommended by several authors in educational research (Lee et al., 2019), researchers of this study could not access to a control group due to ethical and organizational restrictions.

Objectives, Hypothesis and Research Questions

The first objective of this research question was to investigate the effects of GBNL on students' mathematics performance. Given the previous positive results for most of the studies in the field as indicated above, it is hypothesized that students' mathematics performance will improve significantly after the GBNL intervention. Hence, the first research question (RQ) of this study is defined as it follows.

RQ1: What is the effect of GBNL on students' mathematics performance?

The second objective of this study was to investigate students' satisfaction with GBNL. Given the psychological benefits above indicated in the field, it is hypothesized that students' will be highly motivated and satisfied with the GBNL methodology. Hence, research question two is defined as follows:

RQ2: How does GBNL affect students' motivation participating in the experience?

Participants

This experience was carried out in a 2nd year Primary Education classroom made up of 10 students, 9 boys and 1 girl. All students were 7 or 8 years old during the implementation of the GBNL program. This experience was carried out at a Singular Educational Action Center in Spain, that is, a special education public school in which students' socioeconomic status is low and their academic performance is under average compared to the national standards. Students participating in the experience were Spanish (4, 40%), Arab (3, 30%) and Romanian (3, 30%). Two of these students presented significant curricular adaptations since they had difficulties in reading and therefore do not follow the same rhythm as the rest of the class, one of them is diagnosed with a slight mental deficiency. Moreover, there were two students who presented ADHD, one with hyperactivity and the other with hyperactivity combined with aggression. In addition, a child had just arrived from Morocco and had difficulty understanding Spanish. However, he did understand mathematical language. All participants were informed of the objective of the study, and the corresponding permits were requested from the school management.

PSYCHOLOGY AND EDUCATION (2021) ISSN: 0033-3077 Volume: 58(4): Pages: 553 - 564
Article Received: 08th October, 2020; Article Revised: 15th February, 2021; Article Accepted: 20th March, 2021

Organizational Settings

GBNL was implemented four times per week during two weeks. Each session lasted approximately an hour of time. Students were distributed in groups of three or four, switching teammates and games during the sessions.

Mathematics Contents Worked Through GBNL

Through this project, the students worked on some of the contents of the first cycle of Primary Education. Three digit addition and subtraction operations and exercises were studied. Students had to use the development of personal strategies for mental calculation and also for an approximate calculation. Likewise, they had to carry out exercise where they have to make calculations within activities that can awaken the interest and curiosity of the student towards the search for solutions.

Development of the GBNL Experience

GBNL methodology is based on working with everyday manipulative materials to make it easier for children to use familiar material that they have used before. In addition to working with manipulative material, it is characterized by learning by playing, that is to say, games are proposed where a content is worked on and thus, while the children are playing, they are learning. It is a more playful way of learning where children have fun and learn.

As mentioned above, we work with manipulative material, specifically with chopsticks. The chopsticks represent the number in question to be added, subtracted, multiplied or divided. Therefore, we start with a grouping so that the children understand what each toothpick represents, that is, each toothpick will represent the unit. When we have 10 toothpicks (1 ten) they will be tied with a rubber band so that they are well grouped and later it will be easier to identify what the ten represents. When we have 10 groups of tens, the hundred will be formed and this will be grouped with a larger rubber band. The children will know how to differentiate the ten from the hundred, by its size, and if this is not enough, the ten will be grouped with a red rubber and the hundred with a green rubber (see Figure 3).

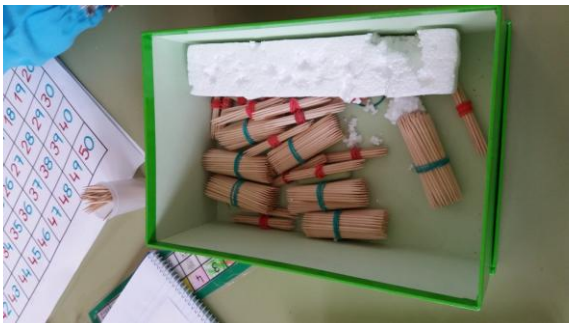

Figure 3. Chopsticks and rubbers used in the GBNL implementation

To do this it will be necessary to know the complementary numbers of 10, that is, those numbers that their addition gives us the ten. In class we can call them "the friends of 10" to make the vocabulary closer and therefore they can understand better.

It is advisable to work previously on these complements with manipulative materials: toothpicks, tweezers, bottle caps, hangers... taking 10 and doing all the possible decompositions and taking a certain number and asking for the "one we need to complete 10".

In order to carry out the methodology successfully, it is necessary to carry out playful activities so that the children learn to decompose numbers and to do the additions and subtractions correctly.

In the following activities we are going to work all the pairs that add 10, by means of a playful activity as it is the one of the hangers. We will use manipulative material and daily use so that the children know and experiment with it. Learning these numbers by heart is very important since it will give them the ability to form a new ten, to make the calculation in a faster way. In this activity the children will be given a hanger with a number of clips not exceeding 9 and the children will have to put the necessary hangers to reach the ten. You can tell them that if they do not complete the ten the hanger will fall down. This way they will understand that they have to complete the number of clamps to achieve the ten.

Once they understand that they have to look for the remaining number to complete the ten, the level of difficulty will increase and they will become "the friends of 100", where the children will have to look for the remaining number to reach the hundred. The steps to follow are the same as in "the friends of 10", but now a further step is added. First, they try to complete the ten, and once they have done so, they proceed to look for the hundred.

Many games can be used to work on the concept of the tenth and hundredth unit. In the "what's in my head" game children have to put a sticker on their head with a number written on it and they have to guess it. To be able to guess it they will ask questions like: Do I have 4 units? If so, they will proceed to ask for the tens. Do I have 6 tens? And they will have guessed the number. Once understood, it can be expanded with larger numbers by introducing the hundred.

Another game to work on the concept of unity ten and hundred is the “Who's Who?” A table of numbers from 1 to 100 will be used, where the children will have to guess the number the partner has on a card on the table. In order to find out this number, the children will ask the following questions: Do you have 4 units? If the answer is no, they will put bottle caps on all the numbers that have 4 units. Once the units are correct, they will move on to the tens. The size of the table can be enlarged so that numbers with hundreds can be entered. Besides working on the concept of tens and units, the variant can be used saying it is the number after 45, to work on the concept of before and after.

Bingo is a game of chance that most families have at home and, although we do not realize it, it can have an educational purpose since it works with mathematical concepts such as the unit and the ten. This game consists of a drum with 99 numbered balls inside. The players play with cards with random numbers written on them. A student plays the announcer and removes balls from the drum, announcing the numbers aloud. If a player has that number on their card, they cross it out, and the game continues until someone manages to mark all the numbers on their card. When he has it, he sings "BINGO!" aloud and is the winner of the game.

Addition and subtraction dominoes were also used. This game is the classic game of dominoes where 6 dominoes are given out to each student. Each domino is divided in two, one part has a number on it and the other part has the addition or subtraction. It should be noted that the addition and subtraction are of one number so that the calculation is quick and the game is more dynamic. The objective of the game is that the student places the pieces until he runs out of any, these will have to be placed with the corresponding numbers. For example, if the number 6 appears, the student can only place a piece that adds or subtracts 6.

Research Instruments

In this research, students’ mathematics performance was analyzed through quantitative instruments and students’ motivation was analyzed through qualitative instruments.

A worksheet containing four exercises was used to evaluate the academic performance of the students. This worksheet was administered before and after applying the GBNL methodology in order to asses if there was an improvement in students’ mathematics performance. Students could achieve a maximum score of 10 points in the worksheet. There were four exercises and the maximum score for each exercise was 2.5 points. The higher the score, the higher students’ mathematics performance was. Two exercises included basic math facts (additions and subtractions with three figures) and the other two exercises were basic math word problems.

Students’ motivation towards GBNL was assessed through focus group (Brown & Danaher, 2019). The ten students participating in the study were divided in three groups with three students in two of them and four students in the other group. Some of the questions that researchers asked them during the development of the focus groups were the following:

Question 1. What did you think of the games, did you like them?

Question 3. How did you feel about playing these games?

Question 4. How do you like to work on the class content, with the book or with these games?

Question 5. How did you learn more?

Question 8. Which game did you like the most? Why?

Statistical Analysis and Software

SPSS version 25 was used to carry out all the quantitative analysis in this research. Averages and standard deviations were calculated and students’ t-test was used to address the differences between the pretest and the posttest (Jankowski et al., 2018). The effect size of the intervention was calculated and Hedge’s g was used as a measure of the effect size. According to Lee et al. (2020) an effect size of less than 0.2 may be considered as small, an effect size between 0.2 and 0.5 may be considered as moderate and an effect size greater than 0.5 may be considered as large.

Atlas.ti version 8.1 was employed to analyze all the qualitative data. Information coming from the focus groups was coded as follows FG (focus group), number of focus group with one digit and number of student. For instance, an answer in focus group 1 by student number 3 may be reported as follows: FG_1_3.

Results

In this section, quantitative and qualitative results are reported

Quantitative Results

Average scores for the pretest and the posttest ($\bar{X}$) , standard deviations (SD) and the number of participants (N) in the pre-test and post-test are shown in table 1.

	Pretest			Posttest		
	$\bar{X}$	SD	N	$\bar{X}$	SD	N
Mathematics	4.60	2.12	10	5.30	2.26	10

Table 1. Averages, standard deviations and number of participants for students' mathematics performance.

RQ1: What is the effect of GBNL on students' mathematics performance?

Student's t-test showed statistical significant improvements (t=4.58, p<.01) between the pretest and the posttest. The reported effect size for the experience was moderate (Hedge's g = 0.32). According to these results, the stated hypothesis that students would improve their mathematics performance through GBNL is confirmed and it can be stated that GBNL had a positive and significant effect on students' mathematics performance.

Qualitative Results

The following are some of the most relevant answers from the students obtained through the focus groups:

FG_1_2: *Yes, I've really liked the whole games of bingo and dominoes.*

FG_1_3: *At first I didn't feel well because I didn't know how to do them and I got a little nervous, but when a partner helped me and I understood, I felt very good.*

FG_2_4: *I like it better with games, because I find the book boring and I get very distracted, but with games I find it more entertaining.*

FG_2_5 *With games, because it's become clearer to me, I often forget the things we teach in class. But when I do it with games, I remember what had to be done and I do it well.*

FG_3_8 *I liked the bingo game the most, because I sang bingo twice and was very happy. Also the nervousness when I was only one to complete the whole table, I had a lot of fun.*

FG_2_3 *Yes, I liked them very much because I had a lot of fun. Also at the beginning when I didn't understand the game well, a colleague who did know how to play helped me and I was able to play well.*

FG_3_1 *I felt very comfortable because we were working on similar exercises in class and I knew how to play the games.*

FG_2_6 *I like working with the games much better, because while we play we learn without realizing it.*

FG_3_10 *With the games, because the classes flew by and we were learning at the same time as playing.*

FG_2_5 *I liked the "what's in my head" game better because it was a lot of fun since everyone could see the number you had, except me, until I finally got it right.*

RQ2: How does GBNL affect students' motivation participating in the experience?

According to the qualitative results shown above, it can stated that students felt motivated during the implementation of GBNL and that they were highly satisfied with this learning methodology. Hence, the hypothesis that students' motivation would increase is confirmed.

Discussion

The fact that students mathematics performance improved by means of GBNL is consistent with previous analogous studies in the field (Liao et al., 2019; Taub et al., 2020). Nevertheless, the high level of significance ($p < .01$) and the considerable effect size reported in this research were not expectable taking into account previous research. Although game-based learning is expected to improve students' performance, these improvements are supposed to be moderate and effect sizes are supposed to be smaller (Anastasiou et al., 2018). Moreover, educational outcomes with special education students or students with disabilities as those who participated in this research are most of the times small given the extra difficulties that may appear during the development of the programs (Hurwitz et al., 2020). In this sense, further research is needed since the quantitative results reported in this research appear to be somewhat greater than those that could be expected from the literature in the field.

The fact that students' motivation improved after the GBNL experience and that they were highly satisfied with this methodology is consistent with previous studies in the field (Nietfeld, 2020). Students are expected to enjoy through game-based learning methodologies and be satisfied with these types of methodologies (Chen & Law, 2016). Moreover, the qualitative results regarding motivational issues are consistent with the reported improvements in mathematics performance. Hence, it makes sense that students improved through GBNL as they were enjoying the experience at the same time they were working with mathematics contents (Hung et al., 2015).

Limitations

Although the results shown in this research may seem very promising, caution is needed when interpreting them and readers should be aware of the fact that there are several limitations regarding this research. First, the absence of a control group must be taken into account, as the effects of GBNL would have been more precise if a control group would have been included (Bowers, 2017). Moreover, the sample size is very small and cannot be considered as representative of any medium or large population (McNeish, 2017). Hence, results of this research must not be generalized. Access to participants in special education settings is always a challenge (Douglas et al., 2016). In this research, the absence of a control group and the lack of a higher number of participants is due to the administrative and organizational difficulties to obtain a larger sample. In addition to the indicated above, it must also be considered that the implementation time of the GBNL program was small (two weeks, eight sessions). A larger implementation would have enabled a better understanding of the processes and outcomes that emerge from GBNL (Stockard, 2020).

Conclusions

The main conclusion is that GBNL may be very beneficial for special education students from both, academic and psychological perspectives. Small to moderate effects and significant improvements may be expected when carrying out analogous studies in the field. As results shown in this manuscript belong to a study with a small sample size, future research with larger samples are needed in the field to address in a more precise way the effects of this methodology on students' mathematics performance and emotions.

Acknowledgement

The authors want to thank all the members of the school (students, teachers, school principal…) for their collaboration and their participation in this research.

References

[1] Ablewhite, R. C. (1969). *Mathematics and the less able*. London: Heinemann Educational for the Social Science Research Council.

[2] Aguilar, L. (2019). Learning Prosody in a Video Game-Based Learning Approach. *Multimodal Technologies and Interaction*, *3*(3), 51. https://doi.org/10.3390/mti3030051

[3] Alegre Ansuategui, F. J., & Moliner Miravet, L. (2017). Emotional and cognitive effects of peer tutoring among secondary school mathematics students. *International Journal of mathematical education in science and technology*, *48*(8), 1185-1205. https://doi.org/10.1080/0020739X.2017.1342284

[4] Anastasiou, D., Sideridis, G. D., & Keller, C. E. (2018). The Relationships of Socioeconomic Factors and Special Education with Reading Outcomes across PISA Countries. *Exceptionality*, 1-15. https://doi.org/10.1080/09362835.2018.1531759

[5] Baroody, A. J., Eiland, M., & Thompson, B. (2009). Fostering at-risk preschoolers' number sense. *Early Education and Development*, *20*(1), 80-128. https://doi.org/10.1080/10409280802206619

[6] Bowers, A. J. (2017). Quantitative research methods training in education

leadership and administration preparation programs as disciplined inquiry for building school improvement capacity. *Journal of Research on Leadership Education*, *12*(1), 72-96. https://doi.org/10.1177/1942775116659462

[7] Brown, A., & Danaher, P. A. (2019). CHE principles: Facilitating authentic and dialogical semi-structured interviews in educational research. *International Journal of Research & Method in Education*, *42*(1), 76-90. https://doi.org/10.1080/1743727X.2017.1379987

[8] Cai, S., Liu, E., Yang, Y., & Liang, J. C. (2019). Tablet-based AR technology: Impacts on students' conceptions and approaches to learning mathematics according to their self-efficacy. *British Journal of Educational Technology*, *50*(1), 248-263. https://doi.org/10.1111/bjet.12718

[9] Campos Soto, M. N., Navas-Parejo, M. R., & Moreno Guerrero, A. J. (2020). Realidad virtual y motivación en el contexto educativo: Estudio bibliométrico de los últimos veinte años de Scopus. *ALTERIDAD. Revista de Educación*, *15*(1), 47-60. https://doi.org/10.17163/alt.v15n1.2020.04

[10] Campos, H., & Moreira, R. (2016). Games as an educational resource in the teaching and learning of mathematics: an educational experiment in Portuguese middle schools. *International Journal of Mathematical Education in Science and Technology*, *47*(3), 463-474. https://doi.org/10.1080/0020739X.2015.1075614

[11] Carducci, O. M. (2020). Card trick exercise leads to improved reading of mathematics texts. *PRIMUS*, *30*(2), 142-146. https://doi.org/10.1080/10511970.2018.1506536

[12] Chang, K. E., Wu, L. J., Weng, S. E., & Sung, Y. T. (2012). Embedding game-based problem-solving phase into problem-posing system for mathematics learning. *Computers & Education*, *58*(2), 775-786. https://doi.org/10.1016/j.compedu.2011.10.002

[13] Chen, C. H., & Law, V. (2016). Scaffolding individual and collaborative game-based learning in learning performance and intrinsic motivation. *Computers in Human Behavior, 55*, 1201-1212. https://doi.org/10.1016/j.chb.2015.03.010

[14] Corcoran, R. P., Cheung, A. C., Kim, E., & Xie, C. (2018). Effective universal school-based social and emotional learning programs for improving academic achievement: A systematic review and meta-analysis of 50 years of research. *Educational Research Review*, *25*, 56-72. https://doi.org/10.1016/j.edurev.2017.12.001

[15] Douglas, S. N., Chapin, S. E., & Nolan, J. F. (2016). Special education teachers' experiences supporting and supervising paraeducators: Implications for special and general education settings. *Teacher Education and Special Education*, *39*(1), 60-74. https://doi.org/10.1177/0888406415616443

[16] Fuchs, L. S., Fuchs, D., Malone, A. S., Seethaler, P. M., & Craddock, C. (2019). The Role of Cognitive Processes in Treating Mathematics Learning Difficulties. In *Cognitive Foundations for Improving Mathematical Learning* (pp. 295-320). Academic Press. https://doi.org/10.1016/B978-0-12-815952-1.00012-8

[17] Ginsburg, H. P., Wu, R., & Diamond, J. S. (2019). MathemAntics: a model for computer-based mathematics education for young children/MathemAntics: un modelo de enseñanza de matemáticas asistida por ordenador para niños. *Infancia y Aprendizaje*, *42*(2), 247-302. https://doi.org/10.1080/02103702.2019.1589966

[18] Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on

engagement, flow and immersion in game-based learning. *Computers in human behavior*, *54*, 170-179. https://doi.org/10.1016/j.chb.2015.07.045

[19] Hess, T., & Gunter, G. (2013). Serious game-based and nongame-based online courses: Learning experiences and outcomes. *British Journal of Educational Technology*, *44*(3), 372-385. https://doi.org/10.1111/bjet.12024

[20] Hung, C. Y., Sun, J. C. Y., & Liu, J. Y. (2019). Effects of flipped classrooms integrated with MOOCs and game-based learning on the learning motivation and outcomes of students from different backgrounds. *Interactive Learning Environments*, *27*(8), 1028-1046. https://doi.org/10.1080/10494820.2018.1481103

[21] Hung, C. Y., Sun, J. C. Y., & Yu, P. T. (2015). The benefits of a challenge: student motivation and flow experience in tablet-PC-game-based learning. *Interactive Learning Environments*, *23*(2), 172-190. https://doi.org/10.1080/10494820.2014.997248

[22] Hurwitz, S., Perry, B., Cohen, E. D., & Skiba, R. (2020). Special education and individualized academic growth: A longitudinal assessment of outcomes for students with disabilities. *American Educational Research Journal*, *57*(2), 576-611. https://doi.org/10.3102/0002831219857054

[23] Jankowski, K. R., Flannelly, K. J., & Flannelly, L. T. (2018). The t-test: An influential inferential tool in chaplaincy and other healthcare research. *Journal of health care chaplaincy*, *24*(1), 30-39. https://doi.org/10.1080/08854726.2017.1335050

[24] Kazimoglu, C., Kiernan, M., Bacon, L., & Mackinnon, L. (2012). A serious game for developing computational thinking and learning introductory computer programming. *Procedia-Social and Behavioral Sciences*, *47*, 1991-1999. https://doi.org/10.1016/j.sbspro.2012.06.938

[25] Ke, F. (2013). Computer-game-based tutoring of mathematics. *Computers & Education*, *60*(1), 448-457. https://doi.org/10.1016/j.compedu.2012.08.012

[26] Kearney, W. S., & Garfield, T. (2019). Student Readiness to Learn and Teacher Effectiveness: Two Key Factors in Middle Grades Mathematics Achievement. *RMLE Online*, *42*(5), 1-12. https://doi.org/10.1080/19404476.2019.1607138

[27] Kiili, K., Moeller, K., & Ninaus, M. (2018). Evaluating the effectiveness of a game-based rational number training-In-game metrics as learning indicators. *Computers & Education*, *120*, 13-28. https://doi.org/10.1016/j.compedu.2018.01.012

[28] Lan, Y. J., Hsiao, I. Y., & Shih, M. F. (2018). Effective learning design of game-based 3D virtual language learning environments for special education students. *Journal of Educational Technology & Society*, *21*(3), 213-227.

[29] Lee, H., Chung, H. Q., Zhang, Y., Abedi, J., & Warschauer, M. (2020). The Effectiveness and Features of Formative Assessment in US K-12 Education: A Systematic Review. *Applied Measurement in Education*, 1-17.

[30] Lee, J., Finn, J., & Liu, X. (2019). Time-indexed effect size for educational research and evaluation: Reinterpreting program effects and achievement gaps in K–12 reading and math. *The Journal of Experimental Education*, *87*(2), 193-213.

[31] Liao, C. W., Chen, C. H., & Shih, S. J. (2019). The interactivity of video and collaboration for learning achievement, intrinsic motivation, cognitive load, and behavior patterns in a digital game-based learning environment. *Computers & Education*, *133*, 43-55.

[32] Lin, H. C., Chiu, Y. H., Chen, Y. J., Wuang, Y. P., Chen, C. P., Wang, C. C., ... & Ho, W. H. (2017). Continued use of an interactive computer game-based visual perception learning system in children with developmental delay. *International journal of medical informatics*, *107*, 76-87.

[33] Mavridis, A., & Tsiatsos, T. (2017). Game-based assessment: investigating the impact on test anxiety and exam performance. *Journal of Computer Assisted Learning*, *33*(2), 137-150.

[34] McNeish, D. (2017). Challenging conventional wisdom for multivariate statistical models with small samples. *Review of Educational Research*, *87*(6), 1117-1151

[35] Moliner, L., & Alegre, F. (2020). Attitudes, beliefs and knowledge of mathematics teachers regarding peer tutoring. *European Journal of Teacher Education*, 1-20. https://doi.org/10.1080/02619768.2020.1803271

[36] Nasrullah, N. (2015). Semiotics Progress In Traditional-game-based Number Learning For Primary School Students. *Cakrawala Pendidikan*, (3), 87134.

[37] Nietfeld, J. L. (2020). Predicting transfer from a game-based learning environment. *Computers & Education*, *146*, 103780.

[38] Ninaus, M., Kiili, K., McMullen, J., & Moeller, K. (2017). Assessing fraction knowledge by a digital game. *Computers in Human Behavior*, *70*, 197-206.

[39] Papastergiou, M. (2009). Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & education*, *52*(1), 1-12.

[40] Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist*, *50*(4), 258-283.

[41] Qian, M., & Clark, K. R. (2016). Game-based Learning and 21st century skills: A review of recent research. *Computers in Human Behavior*, *63*, 50-58.

[42] Ramani, G. B., Siegler, R. S., & Hitti, A. (2012). Taking it to the classroom: Number board games as a small group learning activity. *Journal of educational psychology*, *104*(3), 661.

[43] Rodán, A., Gimeno, P., Elosúa, M. R., Montoro, P. R., & Contreras, M. J. (2019). Boys and girls gain in spatial, but not in mathematical ability after mental rotation training in primary education. *Learning and Individual Differences*, *70*, 1-11.

[44] Rodríguez, M. M. C., & Suárez, Ó. M. (2019). La enseñanza emocional en el aula invertida: Promover valores viendo cortometrajes. *ReiDoCrea: Revista electrónica de investigación y docencia creativa*, (8), 86-102.

[45] Scalise, N. R., Daubert, E. N., & Ramani, G. B. (2020). Benefits of playing numerical card games on head start children's mathematical skills. *The Journal of Experimental Education*, *88*(2), 200-220.

[46] Scalise, N. R., Daubert, E. N., & Ramani, G. B. (2020). Benefits of playing numerical card games on head start children's mathematical skills. *The Journal of Experimental Education*, *88*(2), 200-220.

[47] Shin, N., Sutherland, L. M., Norris, C. A., & Soloway, E. (2012). Effects of game technology on elementary student learning in mathematics. *British journal of educational technology*, *43*(4), 540-560.

[48] Spires, H. A., Rowe, J. P., Mott, B. W., & Lester, J. C. (2011). Problem solving and game-based learning: Effects of middle grade students' hypothesis testing strategies on learning outcomes. *Journal of Educational Computing Research*, *44*(4), 453-472.

[49] Stockard, J. (2020). The impact of administrative decisions on implementation fidelity of direct instruction and student achievement. *Learning Disability Quarterly*, *43*(1), 18-28.

[50] Sung, H. Y., Hwang, G. J., Lin, C. J., & Hong, T. W. (2017). Experiencing the Analects of Confucius: An experiential game-based learning approach to promoting students' motivation and conception of learning. *Computers & Education*, *110*, 143-153.

[51] Taub, M., Sawyer, R., Lester, J., & Azevedo, R. (2020). The Impact of

Contextualized Emotions on Self-Regulated Learning and Scientific Reasoning during Learning with a Game-Based Learning Environment. *International Journal of Artificial Intelligence in Education*, *30*(1), 97-120.

[52] Valente, M. J., & MacKinnon, D. P. (2017). Comparing models of change to estimate the mediated effect in the pretest–posttest control group design. *Structural equation modeling: a multidisciplinary journal*, *24*(3), 428-450.

[53] Vasalou, A., Khaled, R., Holmes, W., & Gooch, D. (2017). Digital games-based learning for children with dyslexia: A social constructivist perspective on engagement and learning during group game-play. *Computers & Education*, *114*, 175-192.

[54] Wang, J., Wang, R., Yu, F., Wang, Z., & Li, Q. (2020). Learning continuous and consistent strategy promotes cooperation in prisoner's dilemma game with mixed strategy. *Applied Mathematics and Computation*, *370*, 124887.

[55] Wiersum, E. G. (2012). Teaching and learning mathematics through games and activities. *Acta Electrotechnica et Informatica*, *12*(3), 23-26.

[56] Zaretsky, E. (2018). The Impact of Using Logic Patterns on Achievements in Mathematics Through Application-Games. In *Philosophical Perceptions on Logic and Order* (pp. 73-95). IGI Global.