

Script for short video on Chapter 2 of the GAMMA Handbook

Audio: text, other sound, music	Video: what is displayed in video, images, photograph, illustrations, animations	Remarks about camera angles, and other	Time
What does the world of academic research say about Digital Game-Based Learning in Mathematics Education? Which are the main findings regarding its benefits and shortcomings in teaching and learning of mathematics? What has been done and what is missing? What is yet to be done? How could digital games transform mathematics education? Which is the real pedagogical potential of digital games? the art on Learning and Teaching Mathematics with Digital Game-Based Learning and try to give some answers on these questions.	Figure 1	Camera slowly move-zooming out/ in the picture	0:00
DGBL is a fresh, under-explored domain on which mathematics education has just started focusing on, in order to reveal its prospects. To date, only a small, though increasing, amount of studies have reported many important benefits of digital games in mathematics education that deal with some crucial problems of the traditional instruction. However, their full potential on mathematics learning is not yet fully revealed.	Figure 2		0:20
This rapid awareness is a part of general wave of digital transformation of society and education. Today we encounter new generations of computer literate students -known as “digital natives”- that have different needs and expectations from their education, where computers ought to play an integral role. In addition to this, the use of technology is one method of bridging these digital natives’ needs with the instilling mandated	Figure 3		

21st-century skills that aim to prepare them for the technological aspects of the world outside of high school.			
Another reason that Digital Game-Based Learning has gained interest from within mathematics education is the complexity and the difficulties which students encounter with the discipline of mathematics. Traditional instruction of mathematics is connected to negative attitudes, disengagement and lukewarm interest, lack of motivation and purpose and lack of enjoyment. To most students, mathematics is connected with stress, anxiety, a sense of helplessness, and a lack of relevance to their socio-cultural lives, while doing far from sparking their curiosity and creativity.	Figure 4		0:35
Digital games, on the other hand, provide a promising rich learning environment for digital learners that could be a solution to this intertemporal problem. Many studies have been pointing out the benefits and the potentials of existing digital games. There are numerous studies that report the effectiveness of DGBL on improving student's motivation and positive attitudes.	Figure 5		0:55
For example, Bai et al. (2012) used the 3D game "DimensionM", where students were asked to decipher mathematical concepts in algebra. Findings from this study suggest that DimensionM can improve students' mathematics achievement at middle school levels and it also helps to sustain student motivation to learn and pursue the goals of its activities.	Figure 6		1:15
Some studies focus on specific mathematical or interdisciplinary skills developed during students' interaction with a digital game and have reported positive results. For example, Gros (2007) examined the evolution of the design of videogames in order to analyze the main contributions and characteristics of DGBL environments. She supported that digital games through their challenges can enhance the skills that future citizens will need in a digital society, such as developing	Figure 7		1:35

problem solving strategies and computer literacy.			
Another study conducted by Nugraha and Rusmin (2015) investigated the effect of an educational game called “VidyaNusa” on learning the Pythagorean Theorem. The authors of this study concluded that Game-Based Learning methods can improve students’ learning results significantly and promote students’ motivation and interest to study	Figure 8		1:55
Apart from educational games, which are specifically designed for educational purposes, some studies focus on investigating the pedagogical potential of commercial games, such as Minecraft and The Sims. Both of these commercial games include a “building mode” which is supported to promote students’ creativity, geometry and spatial skills and mathematical activity in general.	Figure 9		2:15
For instance, Minecraft has been used in several studies involving both algebraic and geometrical concepts and investigating students’ understandings on them.	Figure 10		
Finally, several researchers investigated the social aspect of Digital Game-Based Learning and reported its effectiveness in students’ attitudes or learning. For example, Ke (2008) examined the effects of cooperative game playing on students’ attitudes towards mathematics. The findings suggest that cooperative game-based learning is especially effective in facilitating positive math learning attitudes.	Figure 11		
The majority of the existing studies agrees on the improvement of students’ motivation and attitudes towards learning mathematics, providing a solution to a crucial problem of traditional instruction – the lack of students’ interest and motivation in engaging in learning. However, after reviewing a significant amount of studies, Byun and Joung (2018) make some critical points that need to be considered.	Figure 12		

Firstly, a surprising realization was that only 15.2% of the reviewed studies on DGBLM were published within the field of mathematics education, while the majority of studies (more than three-quarters) were published in the field of educational technology (Figure 2.12). In other words, even though the main interest of these studies is the effect of DGBL on learning mathematics, they have been predominantly conducted by researchers of educational technology without a mathematical background and/or outside the field of mathematics education.	Figures 13,14		
In addition, most of the reviewed studies predominantly used drill-and-practice games, which is a kind of gamified version of traditional paper-based exercises where procedural skills are required. Such digital games, although having some of the main features of commercial games (e.g. goal, rewards, or embedded scaffolding), are limited to repeating simple calculations (arithmetic or algebraic). Therefore, it is self-evident that these gamified exercises can improve students' performance in paper-and-pencil exercises of the same kind, in the same or similar way that a lot of traditional practice would improve it. In this way, DGBL seems to provide a "chocolate-covered broccoli" in order for mathematics to be less repulsive.	Figure 16		
Byun and Joung (2018) also concluded that the majority of the existing studies were conducted with elementary school-level students and the most popular mathematical topics that research has focused on are number and algebraic operations, measurement, data analysis and probability calculation. Simpler procedural mathematics, like these, can be easily transformed to drill and practice games. On the other hand, complex mathematical topics from higher levels of school education cannot be effectively integrated into this kind of gamification. In simple words, how much "gaming camouflage" can cover the complex, abstract, elusive advanced mathematics? Kafai (2006, 2015) refers to this issue as a deeper philosophical matter hidden within the premise of these instructional games: the need to "sweeten" the learning of difficult or boring ideas through games. She poses the questions: "Do we need instructional	Figure 17, 18		

games to make difficult ideas easy and fun to learn? What messages about learning are we sending to students playing these games?”			
	Figure 18		
Regarding the most investigated aspects of DGBLM, many studies have focused on affective factors such as students' motivation, confidence, attitudes, interest, self-efficacy and enjoyment after playing a digital educational game with mathematical content. Fewer studies have focused on more cognitive aspects and mainly conducted quantitative studies. Even though many benefits have been reported – as mentioned in the previous section-, some studies did not note statistical significant differences between the groups and found no significantly positive results for students' performance after playing a digital game	Figure 19		
A final yet important point is that the majority of studies on DGBLM are not based in any learning theory of mathematics education. In fact, in most existing studies, the term “mathematics learning”, which is under investigation, refers to students' achievement in paper-and-pencil tests. Moreover, Byun and Joung (2018) noted that there is little consensus in existing literature on how to define DGBL from the view of mathematics education. They observed that the term DGBL was defined in many different ways, such as computer simulation, game making activity, or even gamification. This phenomenon has sprayed research attention towards various different directions, making it difficult to share common considerations on DGBLM among researchers in mathematics education. As a result, there is a deep gap on the foundations of research in DGBL and a lot of unexplored aspects for researchers to focus on.	Figure 20		

Most instructional games designed for the purpose of mathematics learning follow a drill-and-practice formation, which serves as an enhancer of the traditional paper-and-pencil procedural, limited in imagination, creativity and meaningful mathematical context practices. As a result, the effectiveness of DGBL on students learning of mathematics remains unanswered. This fact can be explained by the philosophy of enhancing a traditional practice by covering up its flaws with the “gaming camouflage”, since it cannot lead to a remarkable pedagogical change. Moreover, it can be explained by the lack of theoretical foundation that characterizes the existing studies on DGBL in mathematics education. There is an intense need for changing the research foundations of DGBL. It is important to integrate a theoretical background from learning theories of mathematics education into the design of digital games for learning mathematics and for analyzing students’ learning of mathematics through their engagement with them. There is a need for designing transformative games- i.e. games that would be able to transform learning rather than facilitating it- in order to change the traditional practices towards more meaningful pedagogical approaches that fully exploit digital games’ affordances. Digital games alone cannot necessarily bring change to educational settings; there needs to be a pedagogical background that supports this change alongside with the game design. Constructionist learning approaches can be used in order to support the transformation of educational games towards this direction. Through programming and constructing digital artefacts or game principles, students become designers and their designs become the object of their learning. In this way, learning of mathematical concepts can be published and, thus, studied and analyzed in order to provide evident answers for the learning potential of DGBL.	Figure 21		
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Figures (in details)

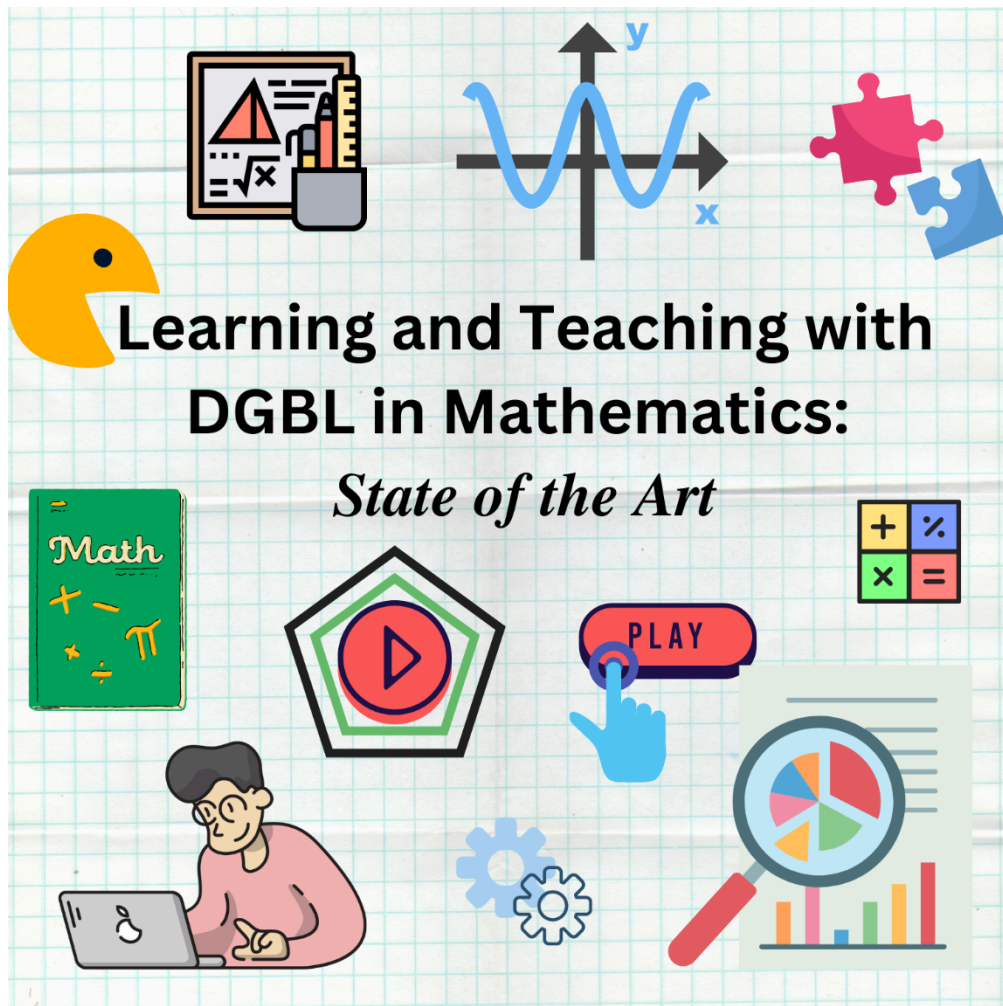
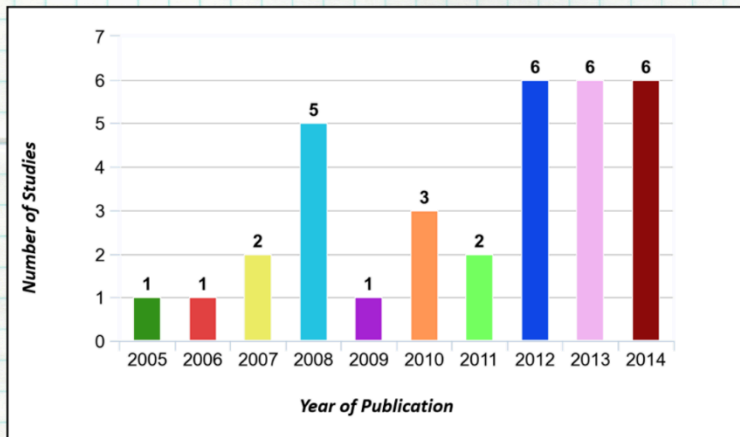


Figure 1



Byun and
Joung
(2018)

Tokac,
Novak and
Thompson
(2019)

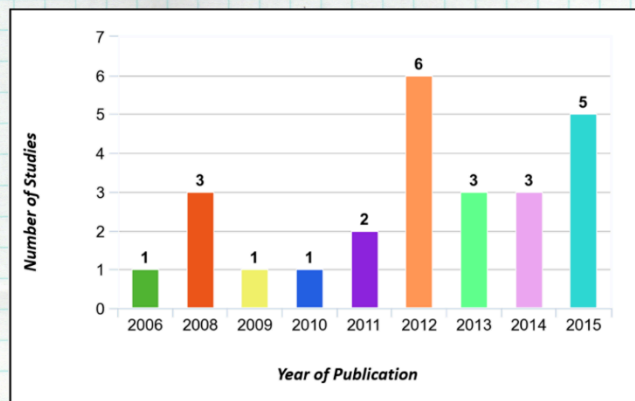


Figure 2

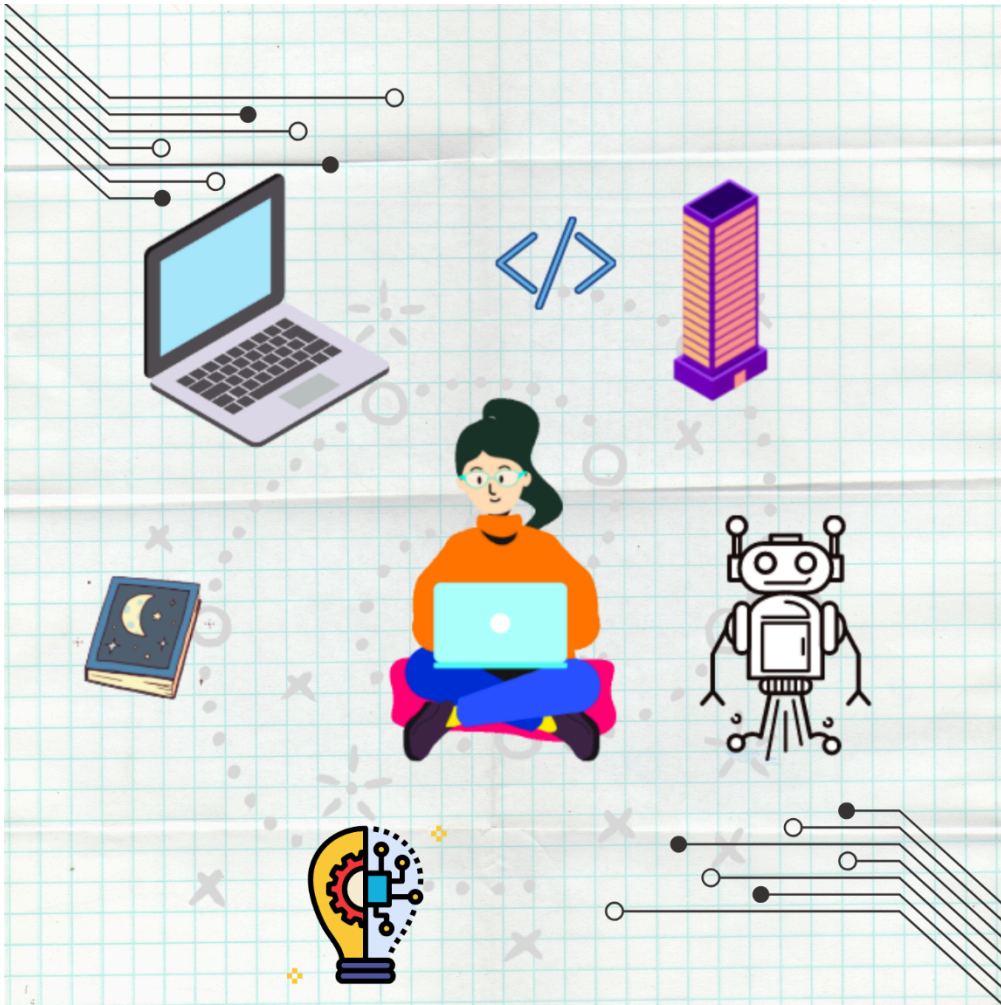


Figure 3

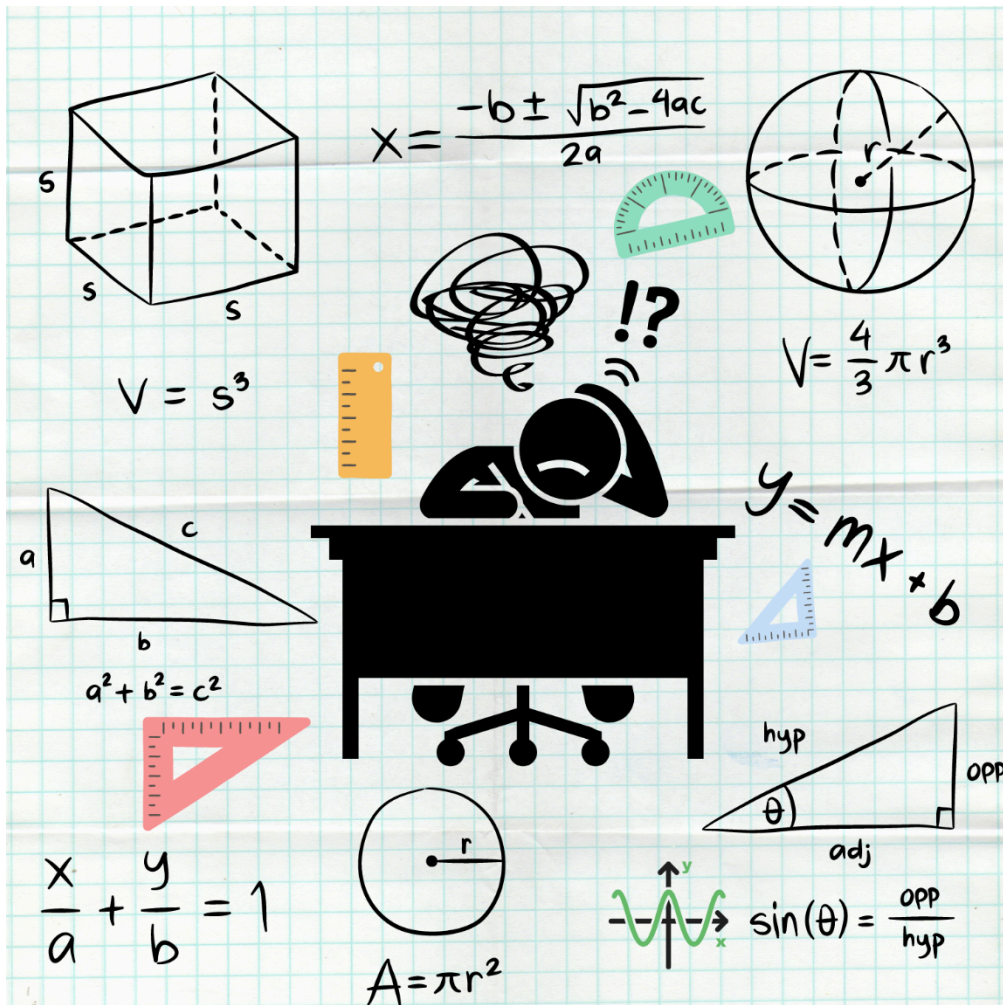


Figure 4



Figure 5



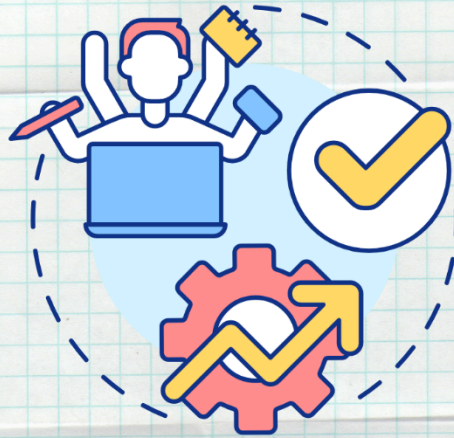
Figure 6

Dimension M



Tabula Digita, Inc., 2007; Bai et al., 2012

Figure 7



problem-solving skills and performance

Figure 8



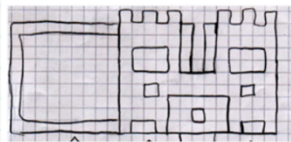
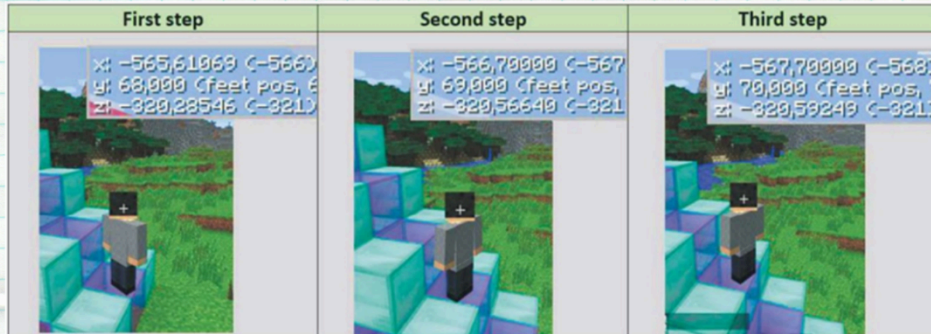
Nugraha and Rusmin, 2015

Figure 9

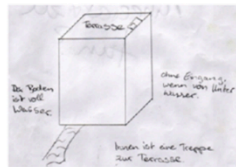


Figure 10

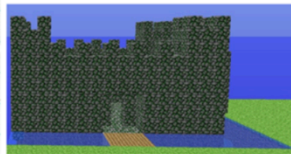
Minecraft



Sketch of a castle (grade 5).



Sketch of a cubic building (grade 6).



Construction of the castle above.



Construction of the cubic building above.

Figure 11



Figure 12



Critical Points

by Byun and Joung (2018)

Figure 13

Academic Background of authors

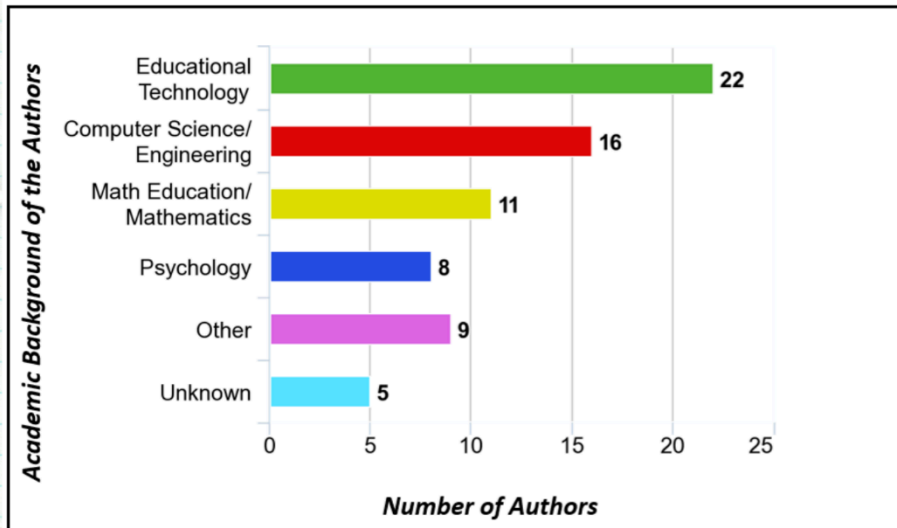


Figure 14

Academic Background of authors

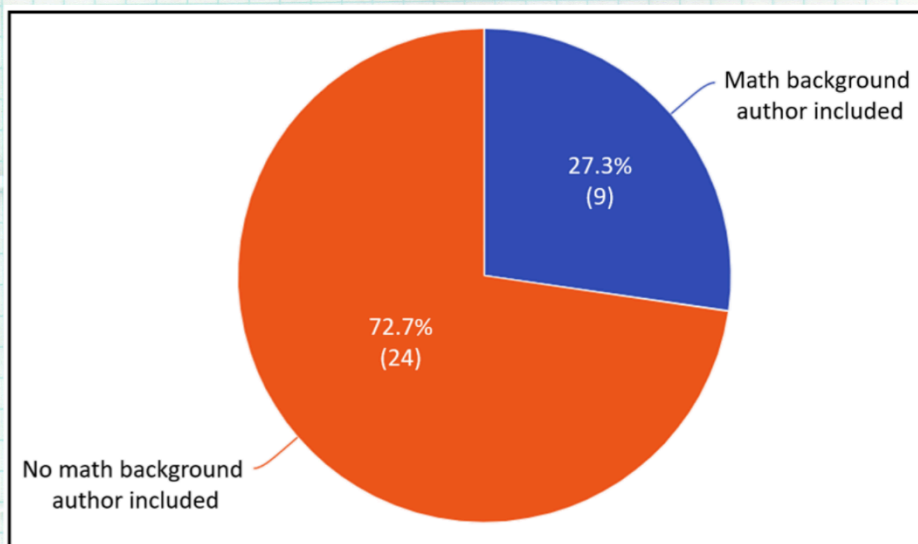


Figure 15

Type of games

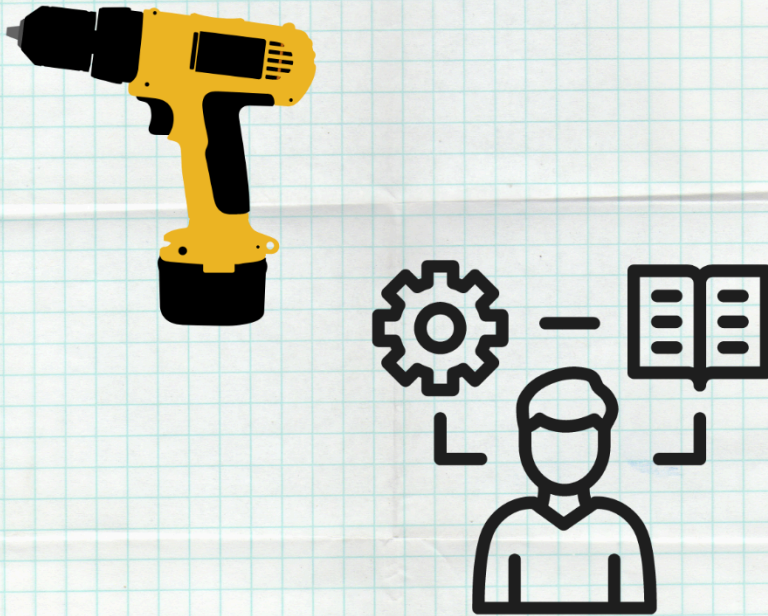


Figure 16

Participants

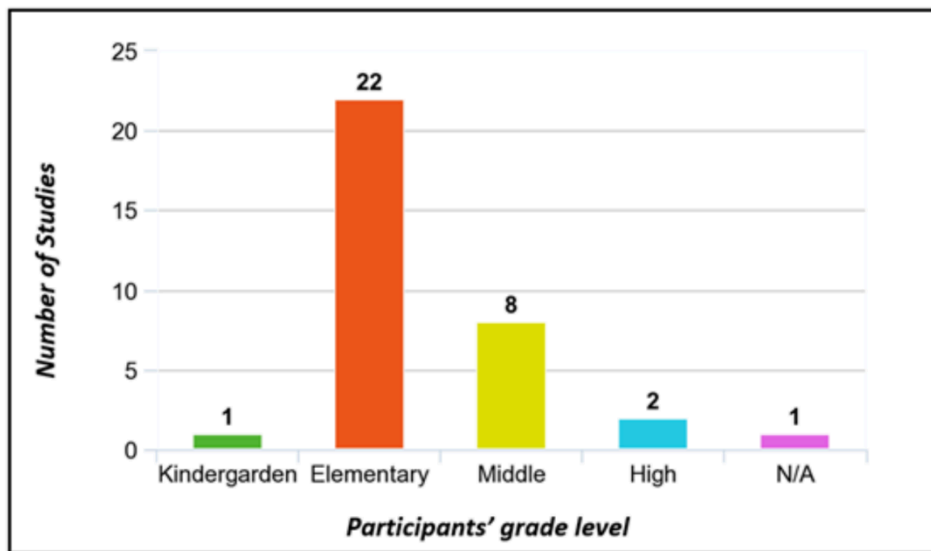


Figure 17

Mathematical Content

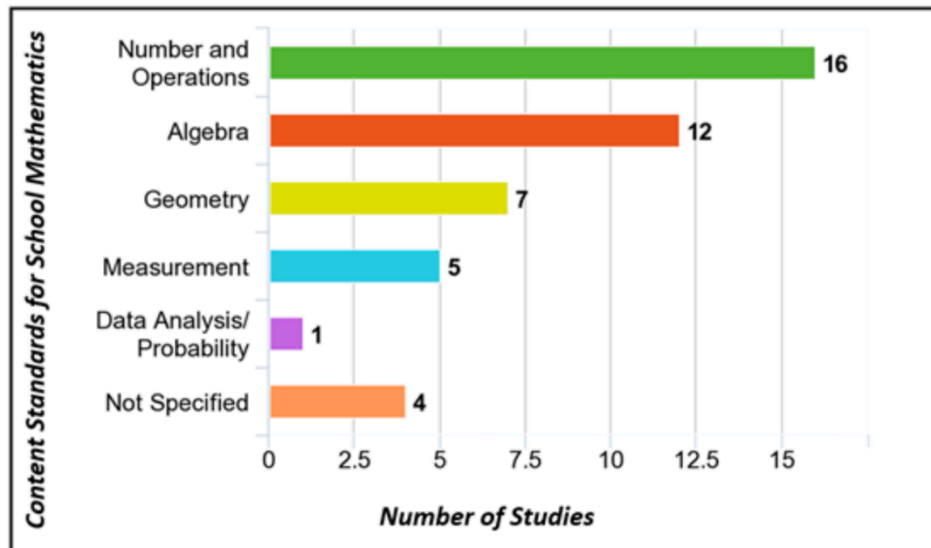


Figure 18

Research Objects



Figure 19

Learning Theories



Figure 20

Transformative Games



Figure 21