Design and Evaluation of the Digital Algebra Game for Children

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Abstract: Children may find learning algebra challenging as the algebraic concepts are abstract for them. To address this challenge, contextualizing algebraic concepts through storytelling and gamification can foster a more enjoyable and comprehensive learning experience. In this study, we introduced the Digital Algebra Game (DAG), a low-fidelity prototype designed to leverage digital game-based learning and storytelling frameworks. Our evaluation involved 96 children aged 9 to 11, along with four teachers, in a primary school setting. Thematic analysis of interview data revealed a positive reception of DAG among both children and teachers. The most unique feature of this game lies in students' ability to transform equations into stories. This approach is believed to not only enhance students' creative thinking but also contribute to their success in mathematics Furthermore, the narratives constructed by students around equations within their daily lives with familiar objects are particularly noteworthy. These insights underscore the potential of incorporating personal experiences into educational game design to enhance engagement and understanding. By bridging the gap between abstract concepts and tangible experiences, educational games like DAG have the potential to enhance learning processes and make mathematics more accessible and enjoyable for children.

Keywords: Digital Game-based Learning, Algebra, Digital Storytelling, Participatory Design

1. Introduction

With the advancement of technology in today's world, the use of digital games in the educational landscape has become widespread. Prensky (2001) proposed the theory of **digital game-based learning (DGBL),** combining education design with digital games. After 20 years, DGBL continues to receive significant attention as a popular research topic in the field of education implying that there are still a number of open research questions to address (Brooks & Sjöberg, 2020).

Mathematics is commonly acknowledged as one of the most challenging subjects taught in schools. It holds significant importance in education systems worldwide and is believed to have an impact on students' future paths (Kayan et.al., 2022). Researchers assert that the process of learning mathematics may come with challenges that can lead to repeated experiences of failure and a lack of motivation (Doabler et.al.,2022). It is found that the use of digital games is beneficial not only for teaching mathematical concepts like numbers, algebra, and measurement but also for enhancing mathematical skills such as reasoning and inquiry (Hendriana et.al.,2018). Recent studies suggest that digital educational games (DEGs), when designed with real-world contexts and authentic tasks, can enable students to connect new information with their previous experiences (Yang & Chen, 2020). Determining which elements in a DEG make learning more enjoyable, engaging, and effective for learning is a crucial aspect of well-designed DEGs (Yang & Chen, 2020). Noteworthy is that perceptions of such qualities can be different from the student and teacher perspective, but empirical studies in this regard are limited (Mekler et.al., 2017). The potential of DGBL can be augmented by **digital storytelling (DST)** method, which has been used in education in recent years. Storytelling helps students understand the importance of mathematics in their daily lives (Bulut et.al.,2022).

The primary goal of our work is to identify which elements in our **Digital Algebra Game (DAG)** have effects on perceived usability, usefulness, attractiveness, and acceptance from the perspective of students and teachers. Following the Human-centered Design approach, the prototypes will be iteratively evaluated with representative end-users (i.e., students aged 9-11) to enhance the game's design. This paper presents our empirical study with 96 students and 4 teachers, who were involved in evaluating the initial DAG prototype. Results thereof address two research questions (RQs):

> **RQ1**: Which elements of DAG based in digital game-based learning and digital storytelling are perceived as usable, useful and attractive for students and teachers?

> **RQ2**: (a) What are the quality of stories created by 9-11-year-old students based on algebraic equations?

Overall, the contributions of this paper are twofold: First, identifying the DGBL and storytelling elements conducive to the acceptance of DAG from the student and teacher perspective. Second, gaining insights into

student ability to understand and contextualize abstract algebraic equations by creating stories around them. Both aspects can enrich the body of knowledge in the realm of DEGs.

2. Background

Our DAG has been created by integrating DGBL into DST (Section 2.1) to enable learners to delve deeper into the understanding of algebra. This integration is linked to two established learning theories (Section 2.2); each theory is briefly described due to the space limit.

2.1 DGBL and DST

According to research conducted in mathematics education (Majid & Ridwan, 2019), DGBL has been found to enhance students' problem-solving and critical-thinking skills, and DEGs can enhance understanding, particularly in challenging abstract topics, subjects requiring a longer comprehension process, and strategic planning in mathematics education (Majid & Ridwan, 2019). Games where students take on a designer role positively impact their academic performance, creativity, and motivation (Bulut et.al.,2022). Therefore, game design has become increasingly important for a student's development. In this regard, young people are interested in being game creators and designers. Hence, it is crucial to identify a mechanism that can support students to take on a designer role. This is where DST contributes to.

Digital storytelling presents interactive digital narratives based on sound, visuals, videos, music, and text in a digital environment (Albano et.al.,2020). Most importantly, students can establish a strong connection between real life and mathematics subjects. Through storytelling, meaningful contexts can be established for students regarding mathematical problems, making mathematics more accessible and facilitating easier learning of mathematics for students (Casey et.al., 2008). DST relates to daily life, providing a means to concretize abstract mathematical concepts (Albano et.al.,2020). According to Niemi (2018) using DST could engage students actively and increase their participation. Students using DST in class changed their attitudes toward negative numbers and improved their algebraic thinking (Casey et.al., 2008). Nonetheless, there are only limited studies exploring the integration of DGBL and DST on children's algebra learning.

2.2 Learning Theories

One of the well-recognised learning theories for DGBL is the Experiential Learning Theory developed by Kolb (1984). Accordingly, the learning process is divided into four stages for learning to be effective: concrete experience, reflective observation, abstract conceptualization, and active experiment. Many students see mathematics as an unrelated subject that have no real relevance to what they encounter in their lives (Clark, et.al.,2013). The Experiential Learning Theory as a teaching method is especially useful for building the relationship between mathematics and daily life. This method gives students the opportunity to reach abstract symbols based on a concrete experience (Morris, 2020).

Another prominent theory is the Constructivist Learning Theory. Accordingly, individuals do not passively receive knowledge; instead, they actively reconstruct it in their minds by comparing new information with existing knowledge (Bodner, 1986). According to Pelech (2021) new principles have been proposed to create a constructivist learning environment during lessons. Firstly, students should learn from various sources, not just their teachers, to build their own knowledge. The advancement of technology has increased the possibilities for students to acquire knowledge from different sources. Secondly, the importance of "authentic products and society" is emphasised. In learning environments, real-world conditions and unique topics closely related to students' lives create effective learning outcomes (Pelech, 2021).

3. Methodology

The aim of the user-based evaluation study presented in the following was to collect feedback from students and their teachers on our initial DAG prototype (Section 3.1). The data gathered were to inform the game's further development as well as address our RQs (Section 1).

3.1 Development of DAG Prototype

The 'Digital Algebra Game' (DAG) is an interactive journey where students design real-life stories, incorporating elements from their daily lives using given mathematical equations.

We have applied the learning theories (Section 2.2) as a design framework to inform the development of the game. The game offers three levels. In the first level, students are asked to select the correct story that aligns with the chosen character and place, enabling them to connect the abstract equation to a concrete scenario. This is consistent with the principle of exploration upheld by the Experiential Learning Theory. Moving on to the second level, the goal is to fill in the blank spaces within the story related to the chosen equation, character, and place. In the third level, the most challenging, encourages players to unleash their creativity. Here, the objective is for the player to create an entirely original story, incorporating the chosen equation, character, and place. At this level, the student encounters real-world conditions, aiming for active learning that aligns with the principle of authenticity advocated by the Constructivist Learning Theory. In these three levels, students experience an interactive learning process through active experience. Additionally, their ability to concretize abstract concepts promotes conceptual learning. This approach is consistent with the learning theories (Section 2.2). This multi-level structure not only helps students relate mathematical concepts to their daily lives but also ensures that the first two levels efficiently prepare players for the challenges of the third level. The experience concludes upon the completion of all three levels. In a collaborative twist, players can invite their friends to join the game after the third level, allowing them to view and interact with the stories created by other participants (Figure 1).

Figure 1: An example page from the prototype.

The most unique feature of this game lies in students' ability to transform equations into stories. It is grounded in a unique mindset that connects mathematical equations with stories. We provide students with an equation and encourage them to weave it into a compelling story. This approach is believed to not only enhance students' creative thinking but also contribute to their success in mathematics. An illustrative example is presented in the prototype (Fig. 1). The aim is to help students grasp the connection between equations and daily life, demonstrating how abstract elements like 'x' can be concretized through the use of DAG. In the initial stages of the game idea, the plan was to develop it for a mathematics class, given that the first author was a mathematics teacher. It was observed that students struggled with the subject of algebra as they found unknown expressions (such as x, y, z) particularly abstract. Hence, the aim was to ground the game in the tangible aspects of algebra and its real-world applications. Building upon the storytelling theme, paper-based storyboards, visuals, and scenarios were developed (Figure 1), realising the idea of integrating DGBL and DST (Section 2.1).

3.2 Participants

The study was granted an ethics approval by ANONYMOUS; participant information sheets were provided and consents from students, teachers and parents were obtained. The target group of DAG was students aged 9-11 years old. The first author visited primary school to collect data. Participation in the study was voluntary without involving any kind of compensation. A total of 96 students and 4 teachers from 4 different classes, spanning three age groups (9, 10, and 11 years old), took part in the study conducted at the school (Table 1).

Table 1: Participants detail

Role	Class Code	Age	Year Group	Girls	Boys	n
Students	A	9-10 years old	5	11	11	22
Students	B	9-10 years old	5	15	10	25
Students	C	11 years old	6	13	11	24
Students	D	11 years old	6	12	13	25
Teachers	-	-	-	-	-	4
Total						96 students and 4 teachers

Unique codes were generated for each participant. For students, the code is structured as [Class Code: A/B/C/D]-[Participant number: two-digit] (e.g. D-15). For teachers, the code is simply designated as T1, T2, T3 and T4.

3.3 Data Collection

The evaluation process included both individual and group-based settings. Students were asked to evaluate the game after watching the prototype presentation. These evaluations aimed to provide the researcher with insights into the game's understandability and playability from the user perspective. Additionally, the study aimed to examine students' perceptions of the idea of creating stories inspired by equations and to analyse the stories they create within a mathematical context.

Semi-structured interviews and focus groups using the same set of questions on perceptions of the game's quality) were conducted. These qualitative data methods were used to enable comprehensive data to be obtained. The game was introduced in four different classes using the whiteboard to present the DAG prototype. Each session lasted approximately 40 minutes, with the duration varying with the number of questions students asked about the game. After concluding the DAG presentation, to allow all students to provide feedback on the prototype, blank sheets of paper were distributed. Recognizing that not all students might feel comfortable expressing their opinions orally, this method enabled students to give feedback with written text and drawing. After distributing the blank papers, individual and group interviews were conducted. Some students volunteered to be interviewed individually (n=38) whereas other students preferred to be interviewed in a group format (n=45); there were altogether 9-10 groups with the group size varying from 4 to 5. All interviews were audio-recorded. Semi-structured interviews were also conducted with four teachers individually at school.

4. Results

Data from teachers and students were collected and analysed separately using an inductive approach.

4.1 Analyses of Student Data

We performed a thematic analysis, identifying three main themes and associated sub-themes (Table 2). The inter-rater reliability (IRR) between the two DGBL researchers on the sub-themes was high with Cohen's kappa of 0.85. Consensus on different codes was reached after discussion.

Table 2: Themes and sub-themes for student data

Theme	Sub-theme	Description
DGBL Design	Content (equation)	Presentations of different equations, including symbols used
	Challenge (levels)	Game mechanics for moving up to next level with more challenging equations
	Reward (points)	Collecting points as reward for solving an equation
Storytelling	Characters	Options of non-player characters for stories
	Places	Options of places as contexts of stories
Perception	Positive	Game features positively perceived and commented
	Negative	Game features negatively perceived and commented

4.1.1 DGBL Design and Storytelling

The highest proportion of students' comments (52%) were related to characters. Many of them suggested adding additional character options and making them more personalized (Table 3).

Table 3: Student themes with subthemes, examples, and frequencies (descending order)

Theme	Sub-theme	Examples of sub-themes	f	%
Storytelling	Characters	More characters are needed like animals, superhero.	48	52%
		Add names the characters.		
		More personalize needed and some more features.		
	Places	Add more places such as airport, shop, campsite, or village.	41	45%
DGBL Design	Content	Equation can be change.	37	40%
		The equations are easy but ideal for creating stories.		
	Structure	Add more levels (ex. tutorial level).	40	43%
		I would add bonus level and power-ups.		
	Reward	Add collect point section.	6	7%
Total			96 Students	

Some student comments are intriguing, for instance, D14 remarked, *"… more family members, like cousins, aunt, neighbor, and older brother or sister because... mmm I guess I want it to be more familiar*." This indicates their preference for characters that closely resemble their own lives. Many students also mentioned the absence of animal figures. Some students favoured the option to design their own characters, expressing their preference for a more personalized and customized gaming experience. By allowing students to physically manifest themselves in the game through the characters they create or choose, a sense of empathy and emotional connection is established between the player and the game (Stenros, 2017). Such emotional connections can significantly enhance student motivation and a sense of ownership towards the game. Gee (2008) points out that effective game design improves the learning process which is achieved through players' attachment to characters they care about.

Students have expressed their interest in naming characters after their family members, and those with pets, such as dogs and cats, have expressed a desire for the option to select animals as characters. This situation can be linked to students' preference for game environments that mirror their real-life circumstances. Emphasizing game environments that replicate real-world situations is seen as a means of directing students toward solving real-life problems, which is the concept of well-designed games (Stenros, 2017). Consequently, game environments that reflect real-world situations capture their attention effectively. Students express a strong desire to design their own characters. Gee (2008) emphasizes that deep learning includes not only a strong sense of ownership but also the ability to create.

Regarding the sub-theme *"Content"*, a group of students commented that the equations were simple but ideal for creating stories. Other students suggested that the equations should be different at each level and that the difficulty of equations should increase with level. D4 commented that *"Equations should be a little harder for level 3. I think this is a bit more challenging for beginners but in a fun way, this is very understandable"*.

Regarding the sub-theme *"Challenge"*, a group of students expressed that the levels were understandable and clear, suggesting that more levels could be added. D1 proposed the addition of a tutorial level to enhance understanding, especially as the game progresses. D5 mentioned, *"I would add a bonus level and power-ups."* Another group of students highlighted that level 3 was the most creative and enjoyable part. D7 shared, *"I like level 3 because I can create my own story, it offers more flexibility. I feel freedom and more creativity."*

Regarding the sub-theme *"Reward"*, some students expressed that incorporating a point-collecting feature during the game could enhance creativity and competitiveness. A16 suggested a creative idea by drawing a picture and proposing that students could receive certificates based on the points they collect upon completing the game.

4.1.2 Perceptions of Game Features

In general, students perceived the game as fun, expressing a desire to play it during class. While the game serves an educational purpose, it is crucial for it to be enjoyable and truly playable for students (Kafai &Burke, 2015). Another positively perceived feature is "sharing with your friends", It can promote social interaction, collaboration, communication, and competition among peers (Gee,2008).

Some students (~13%) pointed out that making a story with simple equations could be challenging. B11 remarked, *"This game is so easy, but I'm not sure I can create a story."* According to the literature, in schools

many students excel in traditional exams but face challenges when it comes to applying and interpreting their knowledge in real-life scenarios, an important and prevalent issue in education today (Gardner, 2011; Slater, 2022). This highlights the importance of students developing interpretative skills, which go beyond merely solving problems on paper. Some students found the game's gradual difficulty progression logical. Facing these difficulties prompts them to revisit previously learned tactics and develop more effective approaches. This situation may encourage the enhancement of players' skills and thoughts. Such incentives contribute to enriching players' learning experiences (Gee,2008).

4.1.3   Sample Stories of Students

Students were provided with opportunities to create their own stories after being introduced to the prototype. Additionally, to gain a deeper understanding of the DAG (turning equations to story), we aimed to incorporate the stories created by students following their examination of the prototype.

Table 4: Sample stories

Student	Equation	Story
C15	$x-4=12$	"A boy went to a shop to buy some food with his mother. A boy has some money. A boy bought a bag of apples for 4 pounds. And he has 12 pounds later. How much money is there first time?"
D17	$a+4=5$	"Mike is in the park. Mike plays football. If he is gonna gain 4 points, he is gonna total 5 points. What are the first-time points?"
A12	$x-4=12$	"A girl has lots of pencils. We can say x for these pencils. Minus 4 pounds equals 12 pounds. Can you find x?"
B9	$a+4=5$	"Daisy and her cat went to park to play ball. She has a ball, and if she gains 4 ball. Now she has 5 balls.
D14	$b-5=14$	"Lily likes school. Lily like painting. Lily goes to school and has 14 colorful pencils. Lily gave 5 pencils to friends, what's happens?"

Five stories were selected from the students' narratives to serve as examples, as shown in the table above. Various criteria have been used in the literature to evaluate the constructed stories (word problems). As noted by Silver and Cai (2005), the most used criteria for problem construction are "quantity," "originality," and "complexity." Quantity refers to the number of correctly constructed problems considering the given problem construction tasks, originality emphasizes the personalization of the constructed problems, and complexity indicates the extent of mathematical relationships embedded within the problem situation. In the study, difficulties encountered in story construction include failure to provide sufficient information to achieve the goal (B9), inclusion of unnecessary information (D14), and failure to use question sentences (B9). Upon examination from a quantitative perspective, it was observed that some stories were solvable (C15), while others lacked mathematical knowledge. Furthermore, students were observed to construct original stories, adhere to the DAG prototype, and create narratives based on their immediate surroundings. When examined for complexity, it was noticed that some students' stories (C15, D17) were more closely related to mathematical content, while others exhibited livelier narratives and better depicted real-life contexts where algebraic equations could be applied (C15, D17). Additionally, students showed enthusiasm for creating stories from their daily lives using mathematical equations, as evidenced by the numerous illustrations they produced, including their pets in many instances.

4.2 Analyses of Teacher Data

A coding scheme was derived by applying thematic analysis to teacher data. The IRR between the two researchers was reasonable with Cohen's kappa of 0.602. Consensus on divergent coding was reached after discussion.

Table 5: Themes and sub-themes for teacher data

Theme	Sub-theme	Description	f
Storytelling	Places	Add familiar places like Wingate village.	2
DGBL Design	Content	Equations can be change.	3

Theme	Sub-theme	Description	f
		There be a single equation for each level.	
	Structure	Add more levels (ex. tutorial level).	3
		It can be free play mode.	
	Reward	Students can collect points	2
Perception	Positive	This game helps students by allowing them to solve and create, fostering their creativity.	3
	Negative	The game is not quite suitable for 9-year-olds	2

4.2.1 Comments on DGBL Design and Storytelling

Two of the four teachers commented that Characters and Places needed to be improved in a way similar to the remarks made by their students, incorporating familiar individuals and places from students' surroundings to enhance acceptance. Regarding the sub-theme "Content", three teachers remarked that generating diverse stories from the same equation at every level could enhance student creativity. T2 stated, "*Let there be a single equation for each level and let's see students' various stories based on that single equation. This approach would make more sense and be more interesting for students.*" Concerning the sub-theme "Structure", T3 commented: "*Free play mode? It can be a mode where students can play comfortably without the purpose of competition.*" As discussed in (Gee,2008; Stacey & Macgregor,1999). if players do not feel comfortable during the game, they may struggle to move and explore within the game, which may negatively impact their learning experiences. For "Reward", T2 mentioned that "*Students can gather points, which would make the competition more intense and could be engaging for students.*"

4.2.2 Perceptions of Game Features and Impacts

T3 evaluated the game positively, commenting that the idea is logical and interesting, and noted that in general students struggle with independently creating stories or problems based on given equations, a skill covered in their lessons. The DAG provides a step-by-step approach, guiding students in the process of creating stories or problems and encouraging creativity. Furthermore, two teachers appreciated the sharing feature. T4 stated that *"… share with other classes and year groups. We can see variations."* Nonetheless, two teachers expressed concerns regarding the game's appropriateness for 9-year-old students, suggesting that it is more suitable for 10-11-year-olds. They proposed using symbols, such as squares or triangles, instead of x, y, and z for younger students. This approach aligns with the idea that using different variable concepts and symbols can aid in comprehending unknown and algebra (Edwards, 2000).

5. Discussion

In our study, we collected and analysed data from both students and teachers on our DAG prototype in terms of its perceived usability, usefulness, and attractiveness (RQs, Section 1). The participants assessed the usability of the DAG positively in general. Both students and teachers generally agreed that the incorporation of the DAG in learning algebra education would be beneficial for learning algebra in an engaging and constructive way.

In the third level of DAG, digital storytelling has been integrated to enhance students' creativity and relate mathematical concepts to daily life (Section 2.1). This part of the game has received positive reactions from both students and teachers. Additionally, some students argue that the progressively challenging levels are the most captivating game element. The gradual increase in difficulty of these levels has facilitated students' step-by-step progress in the game. In accordance with the Constructivist Learning Theory (Section 2.2), it realised that, based on the students' perspectives on the game, the students have the potential to progress step by step by discovering and experimenting rather than receiving direct information. Participants, both teachers and students, expressed dissatisfaction with the character and setting choices in the game, suggesting a preference for selecting familiar locations and individuals from their immediate environment, such as relatives, friends, and pets. They showed a desire to represent everyday activities and people from their communities rather than fantastical settings.

The inclusion of characters and places in the game allows students to establish a connection between mathematics and daily life. It is crucial for students to experience mathematics in the classroom rather than just listening to their teachers and then trying to apply it later. This method enables students to understand abstract

symbols based on concrete experiences. According to Kolb (1984) (Section 2.1), the Concrete Experience Learning cycle increases students' confidence and develops a more positive attitude towards learning content. When examining the stories created by students (Section 1-RQ2), the constructed problems were analyzed in terms of clearly expressing the problem situation, the structure and nature of the problems, solvability, and originality criteria, as defined by Silver and Cai (2005) in the context of "measuring problem construction." Considering these criteria, it was observed that students are eager to create stories but face several challenges. Literature suggests that students often attempt to create ordinary, trivial, unsolvable problems due to their inability to acquire problem-solving skills (Silver & Cai, 2005; Van Harpen & Sriraman, 2013). One could argue that creating the story in this way encourages students to reflect more deeply and understand the equations they are working with. This approach has the potential to help students link equations to real-life contexts, fostering effective learning and creativity. In the next stage of the research, it is aimed to address this deficiency through the teaching process, and it is expected that students will gradually improve their problem-solving skills in terms of language and expression and mathematical appropriateness throughout the instruction.

The tests and evaluation studies conducted primarily focused on usability. But two learning theories (Experiential Learning Theory, Constructivist Learning Theory) have been instrumental in constructing the game, including designing levels 1, 2, and 3. These theories helped in designing the content of the game, not the interaction. The learning theory explanations and constructivist approaches are primarily used for the pedagogical design of the game. However, it can be argued that these theories are more relevant to the design and content of the game's design rather than its usability aspects. It has been observed that the students enjoy the game, which suggests that the theory is effective. This observation is further substantiated by empirical data, indicating that the students' enjoyment supports the validity of the theory.

Like many empirical studies, ours has some limitations. First, the study is limited to the DAG; the generalizability to other mathematical concepts may be limited. Second, the study is limited to a sample from one school; the demographic variables of students could influence how they perceived the game.

6. Conclusion

This study involves the development of DAG, which facilitates the real-life contextualization of abstract subjects like algebra for students. The findings obtained from our user-based evaluation may be of practical interest to educators seeking suitable tools to enhance similar learning experiences for students.

In our future research, we aim to improve the reliability of our findings by expanding the participant pool. Given that DAG is designed to benefit a broad spectrum of students, our strategy involves increasing the diversity of sample by recruiting individuals from diverse backgrounds with different socio-economic backgrounds to ensure a more comprehensive and representative analysis. The interactive high-fidelity DAG will be implemented with the state-of-the-art game development technologies such as Py-game. The learning impact of the interactive DAG game can be measured through systematic control with pre- and post-tests when implemented in the classroom to determine if it creates a genuine effect. Our future studies will aim to iteratively improve DAG through systematic user-based evaluations, focusing on both the cognitive and experiential aspects of the learning and teaching process that the current game aims to support.

Acknowledgements

References

Albano, G., Coppola, C., Iacono, U. D., Fiorentino, G., Pierri, A. and Polo, M., 2020. Technology to enable new paradigms of teaching/learning in mathematics: the digital interactive storytelling case. *Journal of E-learning and Knowledge Society*, 16(1), pp.65-71.

Bodner, G. M., 1986. Constructivism: A theory of knowledge. *Journal of Chemical Education*, 63(10), pp.873.

Brooks, E. and Sjöberg, J., 2020. Problem Solving and Collaboration when School Children Develop Game Designs. In: 4th EAI International Conference on Design, Learning and Innovation, DLI 2019. Springer.

Bulut, D., Samur, Y. and Cömert, Z., 2022. The effect of educational game design process on students' creativity. *Smart Learning Environments*, 9(1), pp.8.

Casey, B., Erkut, S., Ceder, I. and Young, J. M., 2008. Use of a storytelling context to improve girls' and boys' geometry skills in kindergarten. *Journal of Applied Developmental Psychology*, 29(1), pp.29-48.

Clark, L. M., Badertscher, E. M. and Napp, C., 2013. African American mathematics teachers as agents in their African American students' mathematics identity formation. *Teachers College Record*, 115(2), pp.1-36.

Doabler, C. T., Clarke, B., Kosty, D., Sutherland, M., Turtura, J. E., Firestone, A. R. et al., 2022. Promoting understanding of measurement and statistical investigation among second-grade students with mathematics difficulties. *Journal of Educational Psychology*, 114(3), pp.560.

Edwards, T. G., 2000. Some big ideas of algebra in the middle grades. *Mathematics Teaching in the Middle School,* 6(1), pp.29-35.

Gardner, H. E., 2011. *The unschooled mind: How children think and how schools should teach.* Basic Books.

Gee, J. P., 2008. Video games and embodiment. *Games and Culture*, 3(3-4), pp.253-263.

Hendriana, H., Johanto, T. and Sumarmo, U., 2018. The Role of Problem-Based Learning to Improve Students' Mathematical Problem-Solving Ability and Self Confidence. *Journal on Mathematics Education*, 9(2), pp.291-300.

Kafai, Y. B. and Burke, Q., 2015. Constructionist Gaming: Understanding the Benefits of Making Games for Learning. *Educational Psychologist*, 50(4), pp.313-334.

Kayan-Fadlelmula, F., Sellami, A., Abdelkader, N. and Umer, S., 2022. A systematic review of STEM education research in the GCC countries: Trends, gaps and barriers. *International Journal of STEM Education*, 9(1), pp.1-24.

Kolb, B., 1984. Functions of the frontal cortex of the rat: a comparative review. *Brain Research Reviews,* 8(1), pp.65-98.

Majid, N. W. A. and Ridwan, T., 2019. Development of the traditional digital games for strengthing childhood's verbal skill. *Jurnal Pendidikan Vokasi*, 9(1), pp.75-82.

Mekler, E. D., Brühlmann, F., Tuch, A. N. and Opwis, K., 2017. Towards understanding the effects of individual gamification elements on intrinsic motivation and performance. *Computers in Human Behavior,* 71, pp.525-534.

Morgan, S., 2006. Foreword: What a Writer Does Best. *The Missouri Review*, 29(2), pp.5-7.

Morris, T. H., 2020. Experiential learning–a systematic review and revision of Kolb's model. *Interactive Learning Environments,* 28(8), pp.1064-1077.

Pelech, J., 2021. *Student-centered research: Blending constructivism with action research.* IAP.

Silver, E. A. and Cai, J., 2005. Assessing students' mathematical problem posing. *Teaching Children Mathematics*, 12(3), pp.129-135.

Slater, C., 2022. Let the Games Begin: Why Structured and Unstructured Play Should be Utilized in the Classroom. *International Journal of the Whole Child*, 7(02), pp.124-134.

Stenros, J., 2017. The game definition game: A review. *Games and Culture*, 12(6), pp.499-520.

Van Harpen, X. Y. and Sriraman, B., 2013. Creativity and mathematical problem posing: an analysis of high school students' mathematical problem posing in China and the USA. *Educational Studies in Mathematics*, 82, pp.201-221.

Vergne, M. J., Simmons, J. D. and Bowen, R. S., 2019. Escape the lab: An interactive escape-room game as a laboratory experiment. *Journal of Chemical Education*, 96(5), pp.985-991.

Yang, J. C. and Chen, S. Y., 2020. An investigation of game behavior in the context of digital game-based learning: An individual difference perspective. *Computers in Human Behavior,* 112, 106432.