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Article

GeoBlocks: A Game-Based Approach for Teaching Geometry in Primary Education

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Abstract

This study introduces GeoBlocks, an innovative educational project inspired by the game Tetris, designed to support the development of geometric reasoning and mathematical skills among Primary Education students aged 10 to 12. The main objective is to propose a novel pedagogical tool for teaching geometry, utilising game-based learning (GBL) through pentomino manipulation to cover concepts such as shape recognition, measurement, and area calculation. The game's design aligns with the Mathematics' competencies required for this age group. It follows a descriptive-exploratory design, where university students enrolled in a Geometry Teaching course tested the game and evaluated its pedagogical value using a Likert scale survey. Findings suggest potential benefits of GeoBlocks in increasing engagement, encouraging understanding of geometric concepts, and promoting teamwork and communication. While the study does not include pre-post comparisons, the results provide preliminary insights into the possible benefits of GBL in Geometry education. The originality of the study lies in the creation of this educational game, integrating classic game mechanics with hands-on learning strategies. The implications highlight GeoBlocks as a promising tool for fostering a more interactive approach to Geometry, suggesting its potential for broader implementation in the classroom. These findings invite further research into its long-term educational impact.

1. Introduction

In Primary Education, students exhibit a wide spectrum of cognitive abilities, highlighting the importance of personalized and adaptive teaching strategies to cater to individual needs [1]. Howard Gardner's theory of multiple intelligences [2] underscores this notion, emphasizing that students may excel in different domains. Nowhere is this more critical than in Mathematics, a subject often perceived as challenging and abstract, particularly when it comes to Geometry. It is a fundamental component of the STEM curricula, providing students with essential skills such as spatial reasoning, problem-solving, and logical thinking [3]. Studies have shown that early exposure to geometric concepts not only aids in the understanding of shapes and spaces but also enhances general cognitive development and mathematical achievement in later years [4]. However, traditional methods of teaching Geometry, often reliant on abstract representations, can be limiting, particularly for young learners who benefit more from interactive learning environments [5]. To address this challenge, it is crucial to explore innovative pedagogical approaches that foster a deeper understanding of geometric concepts through active learning. Hands-on, manipulative-based activities have proven to be effective in facilitating the internalization of geometric ideas, enabling students to transition from concrete to abstract reasoning [6]. Physical interaction with geometric shapes helps students visualize and comprehend properties such as symmetry, rotation and transformation, which are often difficult to grasp through textbook illustrations alone [7].

The project presented in this paper introduces "GeoBlocks," an educational tool inspired by the popular game Tetris, designed to enhance geometric reasoning in primary school students. What makes GeoBlocks novel is its combination of physical manipulatives, curriculum alignment, and collaborative gameplay, which together create an engaging and effective learning environment distinct from traditional and purely digital approaches. While games like Tetris can enhance spatial reasoning, they often focus on individual play and abstract manipulation, which may not foster collaboration or directly align with educational curricula. GeoBlocks addresses these issues by integrating collaboration aligning with specific geometric competencies [8]. By the use of tangible geometric shapes that students manipulate on a large-scale grid, it encourages them in activities that promote the identification, classification, and transformation of two-dimensional figures. Central to GeoBlocks is its foundation in GBL, which frames Geometry instruction within a purposeful and motivating context. Rather than presenting concepts in isolation, the tool embeds geometric reasoning in a collaborative, goal-driven activity that promotes engagement and active exploration. GBL supports meaningful learning by encouraging students to test ideas, receive immediate feedback, and solve problems in a way that feels intuitive and enjoyable. This pedagogical approach fosters not only conceptual understanding but also teamwork and perseverance, making abstract geometric concepts more accessible to young learners.

As outlined in the Ley Orgánica 3/2020 [6] which defines the national framework of key competences for students of all age groups and the European Parliament and Council's Recommendation on Key Competences for Lifelong Learning (2018/C 189/01) [7], GeoBlocks effectively fosters both concrete and abstract geometric reasoning aligning with the competencies required for children aged 10-12.

This study adopts a descriptive-exploratory approach to propose and validate the GeoBlocks tool. The methodology involves testing the tool with university students enrolled in a Geometry Teaching course, who implemented the activities and evaluated its pedagogical value through surveys. This approach aligns with the study’s goal by focusing on initial tool development and formative evaluation, providing practical insights into its usability, engagement potential, and curricular relevance. Given that this is an early-stage study, the exploratory design allows us to gather meaningful feedback that can guide future refinement and more rigorous testing, rather than seeking definitive proof of effectiveness at this stage. The specific objectives of the study are twofold: first, to propose GeoBlocks as a new tool for teaching Geometry, making it available for future use by educators; second, to validate its effectiveness through the evaluation of university students, focusing on its ability to foster basic geometric concepts, engagement, and the development of spatial reasoning and problem-solving skills through play-based, hands-on activities. The exploratory nature of the study is reflected in its focus on gathering initial insights into the tool's potential impact, providing an early evaluation of its applicability and benefits for Geometry education. In conclusion, this paper explores the potential of GeoBlocks as an innovative tool for teaching Geometry in Primary Education, emphasizing its benefits in enhancing spatial reasoning, problem-solving and engagement through a playful, hands-on approach.

2. Pedagogical Foundations

Mathematics, as one of the core subjects in Primary Education, plays a pivotal role in equipping students with the skills necessary to analyse and solve both local and global challenges. The subject enables students to understand the environment, make informed decisions, and tackle social, economic, and environmental issues through logical reasoning and problem-solving techniques [9]. Particularly, Geometry serves as an essential component of the STEM curricula, fostering spatial reasoning and critical thinking.

The importance of developing a solid foundation in Mathematics during the early years of schooling cannot be overstated. Research emphasizes that Primary Education is the ideal stage to introduce fundamental mathematical concepts in a way that is accessible and engaging to all students [4], [10]. However, many students find Mathematics, particularly Geometry, challenging due to its abstract nature. To mitigate these difficulties, educators must adopt teaching strategies that make geometric concepts more concrete and relatable. One effective approach to teaching Geometry is through the use of active learning methodologies that involve hands-on experiences. Studies have demonstrated that manipulative-based activities enhance student understanding of geometric shapes and their properties, supporting the transition from concrete to abstract reasoning [5], [11]. These activities, which allow students to physically interact with geometric figures, also promote problem-solving and analytical skills by encouraging students to explore properties such as symmetry, congruence, and transformations [12].

To support the progression of geometric understanding, one of the most widely recognized frameworks is the Van Hiele model of geometric thought. This model outlines five levels of geometric reasoning through which students' progress: visualization, analysis, informal deduction, deduction, and rigor [6]. Each level builds upon the previous one, allowing students to move from recognizing shapes based on visual characteristics to understanding and applying geometric properties and axioms through formal reasoning and abstract thought. The role of the teacher is to provide structured learning experiences that encourage students to advance through the levels at their own pace. The use of manipulatives, digital tools, and collaborative activities helps facilitate this progression[13]. By designing lessons that are aligned with the students' current level of geometric understanding, educators can create an environment that promotes active learning and critical reflection.

In addition to the Van Hiele model, there is growing support for the integration of GBL in Mathematics education. GBL literature demonstrates that games help students remain motivated, foster teamwork, and offer real-time feedback, which are essential for both cognitive and emotional learning. Moreover, serious games offer a dynamic and engaging way to teach complex concepts, allowing students to explore Geometry in a playful and interactive context [14]. Educational games have been shown to improve motivation, encourage collaboration, and provide opportunities for students to apply geometric reasoning[15]. These benefits align with the broader goals of promoting active learning and fostering curiosity in Mathematics [16].

Regarding the classification of GeoBlocks, we acknowledge that, based on Juul's framework, there is a distinction between games and gamified tasks [17]. These features position GeoBlocks as a serious game, blending game-based elements with a clear educational focus. The incorporation of game-based elements into educational tools goes beyond enhancing student engagement; it facilitates active, hands-on learning by framing challenges within an immersive context that motivates students to solve problems [18]. As the literature suggests, such integration makes the learning process both more effective and enjoyable, creating a learning environment that balances intellectual challenges with intrinsic motivation [19].

GeoBlocks integrates hands-on learning with game-based elements to teach geometric concepts. By manipulating geometric shapes on a large-scale grid, students engage in activities that promote spatial reasoning, shape classification, and the exploration of geometric properties. Through the integration of hands-on activities and collaborative problem-solving, GeoBlocks aims to enhance students' understanding of Geometry in a way that is both meaningful and enjoyable.

3. Methods and Material

The present paper proposes an innovative educational project which has been created for students in Primary School aged 10 to 12, to help them with the understanding of geometric shapes, properties, and spatial relationships. By integrating active learning methodologies with the structure of a familiar and engaging serious game, this approach seeks to provide a more accessible and effective pathway for students to develop the critical spatial reasoning skills necessary for more advanced mathematical concepts. The design of the tool is grounded in core principles of GBL, such as challenge, goal-orientation, immediate feedback, and a rule-based structure that fosters engagement and sustained motivation. Furthermore, the collaborative nature of the activities is intended to promote communication and teamwork, further enriching the learning experience. By embedding these GBL elements into structured, curriculum-aligned tasks, GeoBlocks not only enhances conceptual understanding but also transforms the classroom into a dynamic space for playful exploration and problem-solving.

3.1 Normative Framework

The project is grounded in several educational theories and principles that underscore its approach to enhancing geometric reasoning through game-based learning. The project aligns with the following key competencies outlined in the Ley Orgánica 3/2020 [20] and the European Parliament and Council's Recommendation on Key Competences for Lifelong Learning (2018/C 189/01) [21]:

- Linguistic Communication Competence: Developed through verbal communication and understanding instructions during gameplay, enhancing students' ability to articulate ideas and comprehend language.
- Mathematical Competence and Basic Competencies in Science and Technology: Supported by activities related to geometric shapes, measurement, and spatial reasoning, reinforcing students' mathematical understanding and application of these concepts in practical scenarios.
- Social and Civic Competence: Promoted through teamwork and inclusive practices, creating a collaborative environment that encourages respect for diversity and effective problem-solving.

- Sense of Initiative and Entrepreneurial Spirit: Nurtured by allowing students to design and create game pieces, fostering creativity, independence, and an entrepreneurial mindset.
- Cultural Awareness and Expression: Developed through collaborative activities that emphasize the importance of teamwork and cultural respect, enhancing students' appreciation for diversity and collective effort.

Moreover, the present methodology follows the Constructivist Learning Theory. According to Jean Piaget, learners construct their understanding through active engagement with their environment [22]. The project embodies this principle by offering students opportunities to interact with geometric shapes in a hands-on manner. The game encourages students to explore spatial relationships and solve geometric problems actively, facilitating a deeper understanding of geometric concepts through direct manipulation and experimentation. The integration of gamification elements within GeoBlocks is informed by Deci and Ryan's Self-Determination Theory, which highlights the importance of intrinsic motivation in learning [23]. By providing a stimulating and rewarding learning experience, it aims to foster a sense of accomplishment and competence, thereby encouraging students to persist and excel in their geometric reasoning tasks. The project also incorporates principles from multimodal learning theory, which advocates for the use of multiple sensory modalities to enhance learning. GeoBlocks provides a rich sensory experience by involving students in activities that engage visual and kinesthetic channels [24]. Recent research confirms the effectiveness of multimodal approaches in fostering deeper engagement and improving retention [25], particularly for abstract subjects like geometry. By incorporating tactile interaction, visual stimuli, and verbal collaboration, the tool caters to diverse learning preferences and enhances students' spatial reasoning and problem-solving skills. This multimodal approach supports active learning and strengthens students' ability to apply geometric concepts, aligning with contemporary pedagogical practices that leverage multiple learning channels [26].

3.2 Game Design

GeoBlocks is structured into 12 sessions over approximately 6 weeks, with two sessions per week, each lasting two hours. The sessions are conducted in a regular classroom setting, led by the Mathematics' teacher with assistance from a support teacher. Figure 1 provides a detailed description of each session, outlining the specific concepts addressed, the corresponding tasks and the theoretical outcome expected from each session.

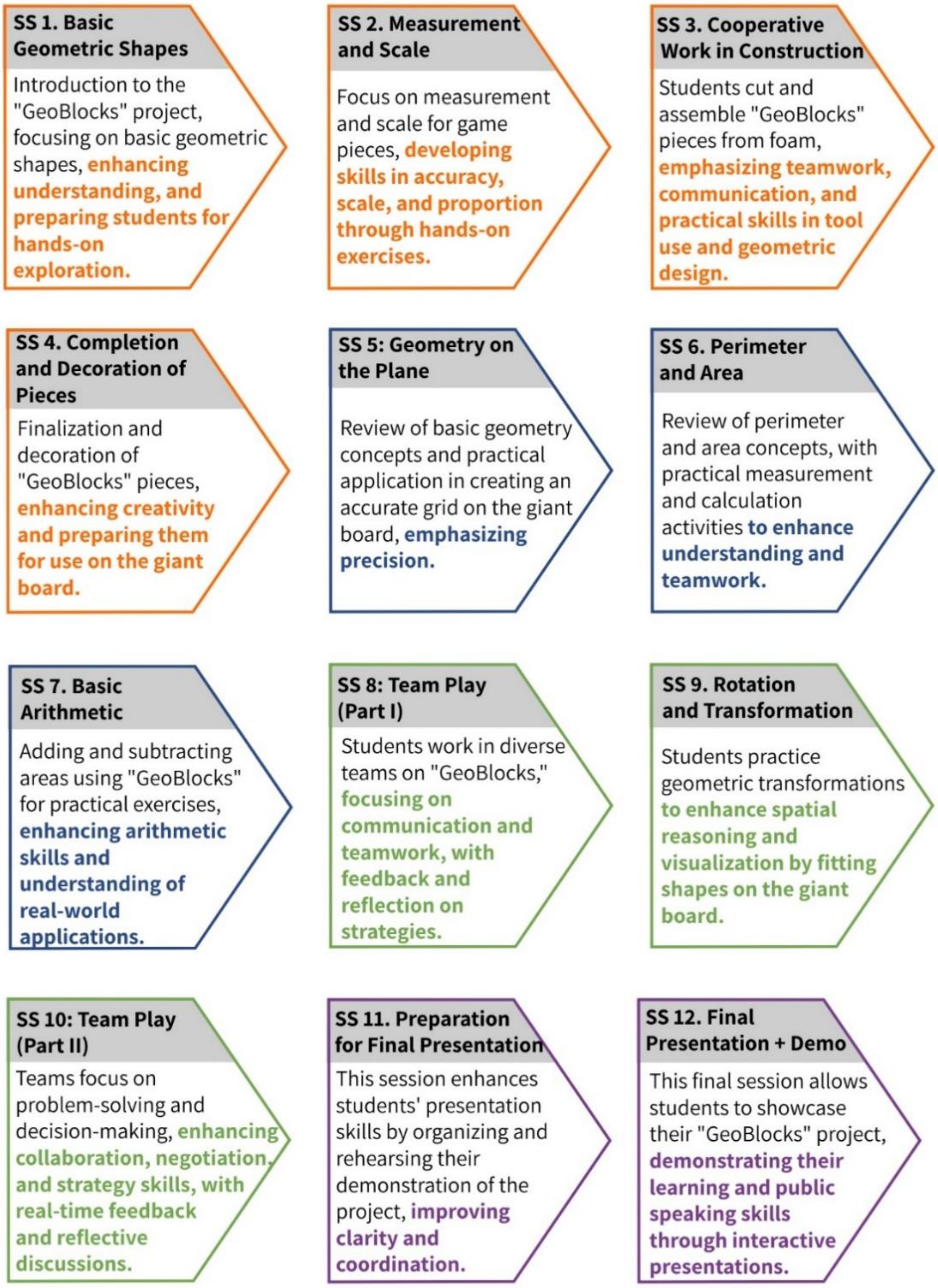

Figure 1. Overview of GeoBlocks Design Game Sessions

3.2.1 Rules of GeoBlocks

The game is played in small teams, each consisting of two to three students. Each team receives an A3-sized sheet, which serves as the game board. This board includes clearly defined boundaries and designated zones for the placement of pieces. Gameplay unfolds in turns. Each team takes one turn at a time, during which players must place a geometric piece onto the board within a strict time limit of one minute and thirty seconds. At the beginning of a turn, the teacher distributes one piece at random to each member of the team, introducing an element of unpredictability and ensuring that no team can plan in advance.

During their turn, the team must collaborate to decide where and how to place the given piece. All pieces must fit entirely within the boundaries of the board and cannot overlap with those already placed. The primary objective is to complete rows across the board without leaving gaps. To achieve this, teams are encouraged to experiment with spatial transformations such as rotation and reflection. Students are expected to discuss strategies and come to a consensus

before making any placement decision. Scoring is based primarily on the successful completion of rows, with one point awarded per complete row.
A printable version of these rules is provided in Annex II, which educators may use as a handout or reference during gameplay.

3.2.2 Session 1: Basic Geometric Shapes

In the first session, GeoBlocks is introduced to the students with the primary goal of reviewing and reinforcing their understanding of basic geometric shapes, including squares, rectangles, triangles, and circles. The teacher highlights the importance of these shapes in both academic and real-world contexts, explaining their central role in the project's activities. A brainstorming session follows, during which students identify and discuss geometric shapes they already know. This activity aims to activate prior knowledge, assess initial understanding, and set the stage for future learning. By establishing a foundation for the exploration of Geometry through GBL, the session helps students connect theoretical concepts with practical application. The session is expected to enhance students' recognition and conceptual understanding of basic geometric shapes, activate prior knowledge, and prepare them for more in-depth exploration of geometric concepts through hands-on, game-based activities.

3.2.3 Session 2: Measurement and Scale

The students focus on measurement and scale, essential for accurately creating the game pieces for GeoBlocks. The session starts with an introduction to measurement tools, such as rulers and measuring tapes, accompanied by a brief explanation of their use. Students then apply these tools to design the pieces, following the templates provided in Annex I. The activity involves practical exercises where students measure and draw the geometric shapes on paper, ensuring accuracy in their dimensions with the help of the Mathematics' teacher. This hands-on experience helps students grasp the significance of scale and proportion, bridging theoretical concepts with practical application. Students are also encouraged to discuss and reflect on the challenges they encounter in scaling shapes, deepening their understanding of how measurement impacts geometric design. This session is designed to develop their measurement skills and understanding of scale and proportion.

3.2.4 Session 3: Cooperative Work in Construction

This is one of the most relevant sessions in the game. Students will actively cut and assemble pieces using foam layered with various materials, engaging in a hands-on activity designed to build teamwork and communication skills. Working in teams, they will use cutting and assembly tools to construct geometric shapes they have previously designed with the teacher's guidance. This collaborative approach not only develops their practical skills with tools but also reinforces the importance of cooperation and effective communication. The session fosters a cooperative learning environment where students practice collaboration, negotiation, and shared responsibility. Moreover, by assembling 2D pieces into a 3D model, students will strengthen their spatial visualization skills, which are essential for mastering geometric concepts.

3.2.5 Session 4: Completion and Decoration of Pieces

The students will finalize the construction and decoration of their GeoBlocks' pieces. After completing the assembly in earlier sessions, they will now focus on painting and decorating their geometric shapes. This activity provides an opportunity for students to enhance their creative expression while developing manual dexterity as they apply paint and other decorative elements to their pieces. The session not only adds a personal and artistic touch to each shape but also prepares the pieces for use on the board in subsequent activities. This session allows students to see their work come to life, bridging the gap between theoretical design and practical application. By engaging in the final touches and decoration, students experience the satisfaction of completing a project and prepare for the practical use of their decorated pieces in game activities. This process reinforces the connection between creative effort and functional outcomes in a collaborative educational project.

3.2.6 Session 5: Geometry on the Plane

The session begins with a review of basic Geometry concepts, such as coordinates, lines, and angles, using charts and visual aids to illustrate these principles. The teacher will explain the objective of creating a precise grid on the giant board, showcasing a model of the anticipated result to guide students. Equipped with materials such as a plastic sheet, long rulers, measuring tapes, squares, and markers, students will work in groups to plan and mark the grid on their designated sections of the board. They will ensure that the lines are straight and evenly spaced, making necessary adjustments to guarantee accurate alignment. The session will conclude with a group discussion where students reflect on their experiences and the challenges they faced during the grid marking process. This discussion will emphasize the importance of precision in measurements and the practical application of Geometry in creating a well-organized planar grid. This session reinforces the understanding of geometric principles through practical application, highlighting the critical role of accuracy and attention to detail in constructing a functional geometric grid.

3.2.7 Session 6: Perimeter and Area

The session begins with a concise introduction to the concepts of perimeter and area, employing visual examples and basic formulas to clarify these measurements. Students will then engage in practical exercises using GeoBlocks' pieces to calculate the perimeter and area of various shapes. Working in pairs or small groups, they will measure and compute these dimensions for the physical pieces, promoting collaborative learning and discussion. Each group will record their results on a worksheet, detailing the measurements of each side, the calculated perimeter, and the area. Following the practical activity, a group discussion will be conducted where students will present their findings and the methods used to achieve their results. This session reinforces students' comprehension of geometric concepts related to perimeter and area.

3.2.8 Session 7: Basic Arithmetic

The session begins with a brief explanation of how to perform addition and subtraction of areas, supplemented by practical examples using the "GeoBlocks" pieces. Students will work in pairs or small groups to measure the areas of various pieces and then apply addition or subtraction to obtain combined results. Utilising the pieces allows students to visualize the areas and perform arithmetic operations in a practical and tangible way. The session concludes with a group discussion where students share their methods and results, enhancing their understanding of basic arithmetic operations and their relevance to everyday problems. This session is designed to strengthen students' grasp of basic arithmetic operations.

3.2.9 Session 8: Team Play (Part I)

In this session, the teacher will organize students into teams of 2-3 members, ensuring a diverse mix of skills and personalities to promote an inclusive and collaborative environment. The session begins with a review of the game's rules. The emphasis will be on effective communication and consensus-building to achieve common objectives. Teams will start taking turns to select and place pieces on the giant board with the goal of completing rows without gaps. Throughout the game, the teacher will observe the teams, taking notes on their collaboration, strategies, and problem-solving approaches. Real-time feedback will be provided to encourage clear communication and teamwork, with positive examples highlighted and suggestions offered for improvement. The session concludes with a group discussion where students will reflect on their experiences, share successful strategies, and identify areas for enhancement. This session is designed to enhance students' communication and teamwork skills through structured gameplay. By requiring students to articulate strategies and coordinate their actions, the session fosters the development of strategic thinking and collaborative problem-solving.

3.2.10 Session 9: Rotation and Transformation

The objective of this session is for students to explore various ways to fit and transform shapes on the giant board, enhancing their spatial understanding and visualization skills. The teacher will start with a brief explanation of geometric transformations, including rotations, reflections, and translations. Visual examples and demonstrations using GeoBlocks' pieces will illustrate these concepts, showing how each piece can be rotated and transformed to fit different parts of the board. Students will observe how the orientations and positions of the pieces change with different transformations. Then, they will be divided into the same teams and given several pieces. They will work together to experiment with rotations and transformations, trying to fit the pieces into a section of the giant board. This hands-on activity allows them to practically apply the concepts learned. At the end of the session, a group discussion will be conducted where students will share their experiences and challenges encountered. This session aims to deepen students' comprehension of geometric transformations by providing a practical context for applying rotations, reflections, and translations. The activity promotes an understanding of how geometric transformations can be used to address spatial challenges and emphasizes the practical application of these concepts in real-world scenarios.

3.2.11 Session 10: Team Play (Part II)

In this session, the teacher will begin with a brief review of the previous session, highlighting collaborative strategies and rules, and discussing observed positive examples and areas for improvement. Teams will resume their matches, with a specific focus on problem-solving and team decision-making. Students will be required to discuss and plan each move collaboratively. Emphasis will be placed on listening to all team members' opinions and making consensual decisions. With the learned knowledge from the previous session, students will play again in the same team, taking turns to select and place pieces on the giant board with the goal of completing rows without gaps. At the end of the session, a group discussion will be conducted where students will reflect on the strategies and decisions made during the game. They will share their experiences, identify successful tactics, and discuss areas for improvement. This session aims to deepen students' collaborative skills and decision-making abilities by focusing on strategic problem-solving during gameplay. Real-time feedback and reflective discussions support the refinement of teamwork dynamics and highlight the significance of cooperative problem-solving in achieving shared goals.

3.2.12 Session 11: Preparation for the Final Presentation

In this session, students will focus on organizing and rehearsing the demonstration of GeoBlocks that they will present to the rest of the class, other teachers, and families. The goal is for each student group to clearly understand their role in the presentation and ensure that all aspects of the demonstration are well-coordinated. Each group will plan their specific parts of the presentation, including writing scripts for presenters, practicing explanations and game demonstrations, and coordinating with other groups to ensure smooth transitions between segments. During the rehearsal, the teacher will provide feedback on the clarity of explanations, the effectiveness of the demonstration, and the overall coordination of the presentation. This session aims to enhance students' presentation and organizational skills by requiring them to prepare and rehearse a comprehensive demonstration of their project. While students can provide feedback during this session, it will be focused on the presentation process itself rather than the pedagogical tool.

3.2.13 Session 12: Final Presentation and Demonstration

In this final session, students will present and demonstrate the GeoBlocks project to the school and their family members. This is the culmination of their work, where they showcase what they have learned and how they have applied their knowledge in both educational and playful contexts. Each group will present their segment of the project, demonstrating the functionality and educational value of the game. Students will explain their design choices, highlight key learning outcomes, and engage with the audience through interactive elements of the game. This session is designed to provide students with an opportunity to apply and showcase their cumulative knowledge and skills developed throughout the project. By presenting their work, students will enhance their public speaking abilities, demonstrate their understanding of geometric concepts, and reflect on their learning journey.

3.3 Alignment of Theoretical outcomes with key competencies

The sessions of the project were designed to address various educational outcomes, which are closely aligned with key competences outlined in the Ley Orgánica 3/2020 [20] and likewise encompassed by the European Parliament and Council's Recommendation on Key Competences for Lifelong Learning (2018/C 189/01) [21]. The main theoretical outcomes include:

- Geometric Understanding, which supports Mathematical Competence and Basic Competencies in Science and Technology. This involves grasping geometric concepts such as shapes, perimeter and areas, fostering a deep understanding of mathematical principles.
- Measurement and Accuracy, which also falls under the same competences, emphasizes precision in measurement and accurate application of mathematical concepts.
- Arithmetic Skills, focus on the application of basic arithmetic operations, enhancing students' ability to solve mathematical challenges.
- Collaboration and Communication, linked to Linguistic Communication Competence, Social and Civic Competence and Cultural Awareness and Expression, developed through verbal communication and understanding instructions. This outcome promotes teamwork, negotiation, and inclusive practices, essential for effective group work.
- Practical Application and Problem-Solving, in addition of supporting Mathematical and Basic Competencies, supports Sense of Initiative and Entrepreneurial Spirit. It involves applying mathematical concepts to real-world problems.
- Reflective Practice and Feedback, related to Social and Civic Competence and Sense of Initiative and Entrepreneurial Spirit, includes providing and receiving feedback, which fosters reflective practices and supports personal and collective growth.

Figure 2 displays how the GeoBlocks project's main theoretical outcomes are distributed across its 12 sessions. Each theoretical outcome is color-coded and mapped to the session numbers in which it appears, illustrating the emphasis placed on each outcome over the course of the project. This distribution reflects the project's focus on key skills and provides an overview of how these outcomes are integrated into the learning process.

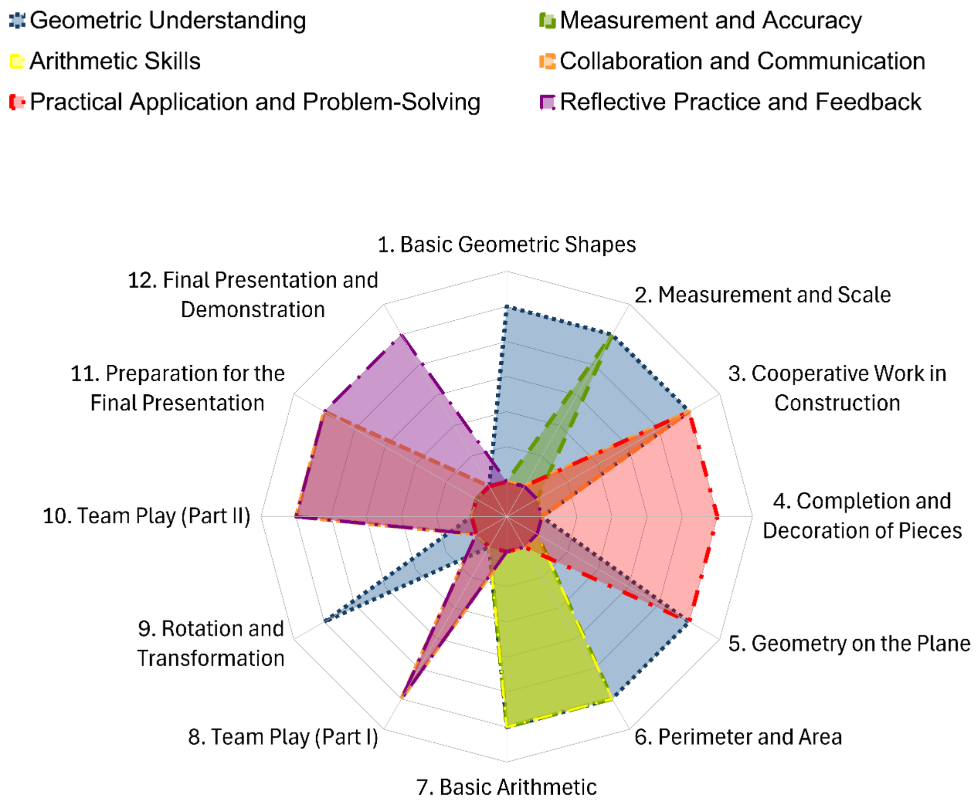

Figure 2. Frequency of Theoretical Outcomes Across 12 Sessions

The most emphasized outcome is "Geometric Understanding," which appears in seven sessions (Outcomes 1, 2, 3, 5, 6, 7 and 9). This encompasses skills such as recognizing geometric shapes, understanding transformations, and developing spatial reasoning. "Measurement and Accuracy" is addressed in three sessions (Outcomes 2, 6 and 7), focusing on precision and understand scale and promoting careful measurement and calculation. "Arithmetic Skills" are integrated mainly in Outcomes 6 and 7, where students apply basic arithmetic operations within geometric contexts, reinforcing their mathematical proficiency. "Collaboration and Communication" is central throughout GeoBlocks, promoting teamwork and interaction among students in nearly every session. However, it is directly featured in four specific outcomes (Outcomes 3, 8, 10, and 11), where structured group activities and tasks are designed to strengthen students' ability to work together, communicate effectively, and share ideas constructively. "Practical Application and Problem-Solving" are highlighted in Outcomes 3, 4, and 5, immersing students in hands-on challenges that develop critical thinking and adaptive problem-solving skills. Lastly, "Reflective Practice and Feedback" are incorporated in Outcomes 8, 10, 11 and 12, encouraging students to reflect on their learning experiences and participate in feedback discussions to deepen their understanding of their progress and areas for improvement.

This breakdown in Figure 2 provides a clear overview of how each session aligns with specific outcomes to foster a comprehensive learning experience in Geometry. The methodology ensures that students are actively involved in their learning process, with each session building upon the previous one to reinforce and expand their knowledge.

4. Results

To meet the objectives of the Geoblocks project and assess its practical application, the tool was implemented to university students and future generation teachers. Following its application, participants evaluated the project through a self-developed questionnaire that assessed 10 aspects of the pedagogical tool. Their responses were measured on a 5-point Likert scale, ranging from ‘strongly disagree’ (= 1) to ‘strongly agree’ (= 5).. The sample included 43 students from the third year of the Primary Education degree program. The participants, enrolled in the Geometry Didactics subject, had prior teaching practice experience with 10-12 years old Primary Education students, enabling them to provide informed feedback on the implementation and execution of GeoBlocks. The university students were introduced to the full scope of the project, encompassing 12 sessions. However, for practical purposes, they primarily engaged in recreating and playing through sessions 1 through 10, as illustrated in Figure 3.

Figure 3. Primary education degree students assembling GeoBlocks project pieces

Following their participation in GeoBlocks, a discussion was conducted to gather insights and suggestions for improvement, which were recorded manually. Participants provided valuable feedback regarding the materials and assembly of the game. While they found the size of the game pieces to be appropriate, it was suggested that using a sturdier material, such as cardstock, would enhance the durability of the pieces compared to the current paper material. Additionally, participants noted that the adhesive used for assembling the pieces was insufficient; the use of a stronger bonding material to improve stability was recommended. These suggestions highlight students’ awareness of the importance of usability and durability in classroom materials, particularly when tools are meant to support active, hands-on learning. The call for clearer grids and borders also reflects their understanding of how spatial organization impacts learners’ ability to engage meaningfully with geometric tasks. Regarding the game board, participants expressed the need for a grid to assist in piece placement. They suggested incorporating a grid on the board to provide clearer guidance for aligning the pieces, along with a border around the edges to prevent pieces from extending beyond the designated playing area.

Lastly, a questionnaire was administered based on a 5 points Likert scale as follows:

1. Strongly Disagree – I completely disagree with the statement and find no agreement or validity in it.
2. Disagree – I disagree with the statement but may find some limited agreement or relevance.
3. Neutral – I neither agree nor disagree with the statement.
4. Agree – I agree with the statement and find it mostly valid or relevant.

5. Strongly Agree – I completely agree with the statement and find it entirely valid or relevant.

Table 1 and Figure 4 present survey data collected from participants regarding their perceptions of GeoBlocks as an educational tool for primary school learning. The table summarizes responses to ten questions, each designed to assess specific educational benefits, including improvements in verbal communication, spatial reasoning, and teamwork. By analysing metrics such as mean, mode, and standard deviation, insights were gained into the overall effectiveness of GeoBlocks in promoting cognitive and social skills.

Table 1. Likert Scale Responses and Statistical Measures for GeoBlocks Evaluation

Question	Likert scale							
	1. Strongly Disagree	2. Disagree	3. Neutral	4. Agree	5. Strongly Agree	Mode	Mean	SD
Q1. GeoBlocks would help primary school students improve their verbal communication by explaining their ideas and opinions during the game.	4.7%	2.3%	18.6%	37.2%	37.0%	4	4.00	1.05
Q2. Primary school students would benefit from developing their ability to describe geometric shapes and their properties using appropriate mathematical language.	2.3%	0.0%	9.3%	37.2%	51.2%	5	4.35	0.84
Q3. GeoBlocks would reinforce primary students' knowledge of geometric shapes, measurements, and areas.	2.3%	0.0%	16.3%	30.2%	51.2%	5	4.28	0.91
Q4. I believe the game is effective in improving primary students' spatial reasoning skills.	2.3%	2.3%	7.0%	30.2%	58.1%	5	4.40	0.90
Q5. GeoBlocks would promote respect and inclusion among primary students by encouraging teamwork.	2.3%	4.7%	16.3%	46.5%	30.2%	4	3.98	0.94
Q6. By allowing primary students to cut, paste, and shape the game pieces, GeoBlocks might stimulate their creativity.	2.3%	0.0%	16.3%	30.2%	51.2%	5	4.28	0.91
Q7. GeoBlocks would encourage primary students to be independent and take initiative in the process of solving each row.	2.3%	2.3%	20.9%	32.6%	41.9%	5	4.09	0.97
Q8. GeoBlocks allows students to analyse the shape of each figure and all its possible positions.	2.3%	4.7%	9.3%	30.2%	53.5%	5	4.28	0.98

Q9. GeoBlocks is an effective tool for developing spatial visualization skills in primary students.	2.4%	0.0%	14.3%	21.4%	61.9%	5	4.40	0.91
Q10. I believe that GeoBlocks can be easily integrated into daily teaching in primary school classrooms.	2.3%	2.3%	14.0%	27.9%	53.5%	5	4.28	0.96

The following analysis provides an in-depth interpretation of these results, focusing on the degree of consensus among respondents and highlighting areas where perceptions varied. The mean scores across all survey items range from 3.98 to 4.40, indicating that most participants responded with either "agree" or "strongly agree" across questions. High means on items related to spatial reasoning skills (Q4, mean = 4.40) and spatial visualization skills (Q9, mean = 4.40) suggest that respondents see GeoBlocks as especially beneficial for spatial development in students. The mode for most questions is 5, reflecting a tendency toward "strongly agree" across items, with several questions receiving this as the most common response, see Figure 4. This trend indicates a consistently high level of agreement on GeoBlocks' educational impact. Standard deviation (SD) values are relatively low across most items, with SD values below 1.0 in nine out of ten questions. This suggests strong consensus among respondents. For instance, Q2 (SD = 0.84) and Q5 (SD = 0.94) reveal a high level of agreement regarding GeoBlocks' ability to support the use of mathematical language and teamwork, respectively. Only Q1 (SD = 1.05) showed slightly higher variability, indicating more diverse opinions about whether the tool enhances verbal communication skills, potentially due to varied interpretations of this skill or differing educational priorities among respondents.

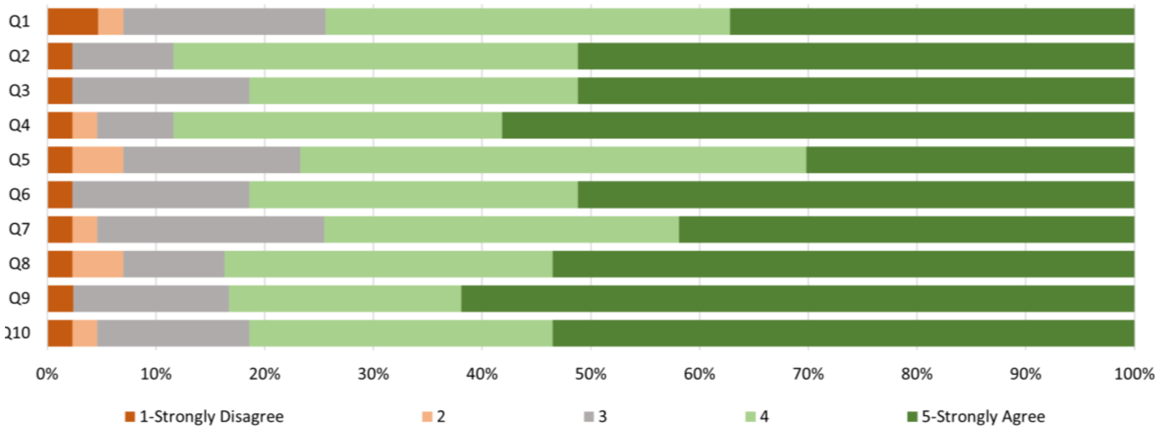

Figure 4. Likert scale responses diagram

Overall, the results from the questionnaire indicate that GeoBlocks is widely regarded as an effective tool for enhancing foundational skills in Primary Education. Respondents highlighted its significant contributions to developing spatial skills, reflected in high mean scores for spatial reasoning (Q4, mean = 4.40) and spatial visualization (Q9, mean = 4.40). Additionally, GeoBlocks is valued as an effective tool in reinforcing knowledge of geometric shapes and measurements (Q3, mean = 4.28) and fostering creativity through hands-on engagement with game pieces (Q6, mean = 4.28). The tool also garnered strong ratings for promoting mathematical language development (Q2, mean = 4.35) and encouraging student independence and initiative (Q7, mean = 4.09). Moreover, Q5 demonstrates its value in fostering teamwork and inclusion, with a mean score of 3.98, highlighting its potential to promote respect and collaboration among students. The high mean score for Q10 (mean = 4.28) further underscores

GeoBlocks's adaptability for daily teaching in primary classrooms, indicating that future educators find it practical and easy to integrate. While a small number of participants selected the lowest response categories “strongly disagree” and “disagree”, these were isolated responses and did not significantly affect the overall trend of positive evaluations. The standard deviation values across items further support a general consensus among participants. These findings reflect robust support for this innovative project as a versatile educational resource for teaching Geometry, making it a valuable addition to Primary Education curricula.

5. Discussion

GeoBlocks represents a novel approach to teaching Geometry through GBL. While the tool incorporates elements commonly associated with games, such as interaction and engagement, its primary goal is educational—specifically, to develop geometric reasoning, arithmetic skills, and collaboration through hands-on, practical application. Unlike many existing digital or abstract geometry games, GeoBlocks uniquely combines tangible manipulatives with structured collaborative gameplay designed to align directly with primary education curricula. This section explores how it meets educational objectives, reviews feedback from educational experts and predicts its potential impact on student learning. By integrating theoretical insights with practical application, the discussion aims to provide a comprehensive understanding of how GeoBlocks enhances geometric reasoning and collaborative skills among primary school students. This examination not only underscores the educational value of the serious game but also highlights its alignment with contemporary pedagogical practices and its potential to contribute positively to the learning environment.

The design and implementation of GeoBlocks are grounded in key educational theories. Piaget’s theory of cognitive development underscores the importance of concrete, hands-on activities for understanding abstract concepts [22]. In GeoBlocks, students engage in practical tasks which helps bridge the gap between theoretical knowledge and real-world applications. This approach not only reinforces geometric principles but also makes learning more accessible and engaging. Vygotsky’s social constructivist theory also informs the game's design. The emphasis on cooperative gameplay aligns with Vygotsky's view that social interaction is crucial for cognitive development. By working in teams, students practice communication and problem-solving skills, which enhances their learning experience. The collaborative nature of GeoBlocks supports Vygotsky’s notion that learning is a social process and that students benefit from shared knowledge and peer interactions.

Research indicates that interactive activities can significantly improve students' retention and application of educational content [27]. By providing a context where students apply geometric concepts in a tangible and enjoyable way, GeoBlocks is expected to enhance both their mathematical understanding and their ability to work collaboratively. The study conducted by Freina et al. suggested that strong visuospatial abilities positively influence mathematics achievement [28]. While empirical data on the impact of GeoBlocks is still forthcoming, the tool represents a promising contribution to the teaching and learning of Geometry in Primary Education, merging theoretical foundations with practice-oriented learning strategies.

In order to explore the potential effectiveness of GeoBlocks, the tool was tested with 43 Primary Education degree students, who had prior teaching experience with children aged 8–10. Their participation in developing and assembling sessions provided valuable feedback on the project's design and educational potential. They suggested practical improvements, such as sturdier materials, better adhesive, and adding a grid and border to the game board. These suggestions were not merely technical; they revealed a pedagogical awareness among the participants. Their emphasis on structure, material quality, and clarity reflects an understanding of how tangible factors directly affect young learners' ability to concentrate, collaborate, and engage meaningfully with the content.

Insights underscore how hands-on, collaborative play supports spatial reasoning, social skills, and offers a replicable model for serious game design in early math education. Participants' feedback also highlighted the importance of balancing challenge and clarity in gameplay mechanics. The addition of a grid and borders, for instance, can scaffold younger learners' spatial orientation, while also allowing for more structured, goal-directed tasks. The interactive nature of GeoBlocks allows students to apply geometric concepts in a tangible way, reinforcing their understanding. By incorporating gameplay into the educational process, the project aims to make abstract mathematical concepts more tangible and accessible. The anticipated outcomes suggest that the tool may enhance students' grasp of geometric concepts, while fostering teamwork and problem-solving abilities. This practical, curriculum-aligned approach advances current understanding of GBL in Geometry by demonstrating how physical construction and guided play can promote deeper conceptual understanding and student engagement. Educational interventions involving physical manipulatives have been shown to improve children's learning. A scoping review by Byrne et al. (2023) synthesized 102 studies on the use of concrete objects like building blocks and shape sorting in primary school settings, finding positive effects on children's spatial and math skills [29]. Similarly, a study by Çelik (2020) investigated the effects of modelling, collaborative, and GBL on geometry success. It was found that GBL significantly improved students' geometry performance, particularly when combined with collaborative and hands-on activities [30]. These findings align with the approach of GeoBlocks, which integrates physical manipulatives and collaborative game-based learning to enhance children's understanding of geometric concepts.

While GeoBlocks presents numerous educational benefits, some limitations must be acknowledged. First, the effectiveness of GBL can vary depending on individual student preferences and learning styles. Some students may find traditional methods more effective or may struggle with the game's collaborative elements, potentially affecting their engagement and learning outcomes [31]. Additionally, the success of the project depends on the teacher's ability to manage and facilitate collaborative gameplay effectively. Variations in teacher experience and classroom dynamics could influence the implementation and overall effectiveness of the project. Furthermore, while GeoBlocks aims to enhance geometric reasoning and collaborative skills, its impact on broader educational outcomes, such as long-term retention of mathematical concepts or transfer to other areas of learning, has not yet been studied. Future research could explore these aspects, particularly through pilot studies and empirical testing, to provide a more comprehensive understanding of the serious game's effectiveness. Additionally, future iterations of the project could integrate digital tools such as Augmented Reality (AR), which might further enhance student engagement and make abstract concepts more accessible. These extensions could offer additional practice opportunities outside the classroom, thereby reinforcing learning and increasing the tool's overall pedagogical impact.

6. Conclusions

The project GeoBlocks provides a novel approach to teaching Geometry by integrating key principles of GBL, such as goal-oriented tasks, rule-based systems and immediate feedback, with collaborative classroom activities. The game's structure encourages students to engage actively in constructing geometric forms, solving spatial problems, and reflecting on their strategies through gameplay. This paper outlines how the project's design, which combines interactive game mechanics and hands-on manipulation, is intended to enhance students' understanding of geometric concepts and foster essential collaborative skills.

The methodology and preliminary validation results highlight the potential of this GBL environment to increase engagement and make Geometry learning more accessible, enjoyable, and pedagogically effective. University students involved in the tool's development emphasized its benefits in promoting spatial reasoning and teamwork, while also providing useful feedback for improving usability. However, certain limitations must be acknowledged. While GeoBlocks shows promise as an educational tool, its broader educational outcomes—such as long-term knowledge retention, transferability to other mathematical domains, or classroom-wide implementation—have only been preliminarily and theoretically explored. So far, the tool has been tested primarily for validation purposes. Its actual application with Primary School students remains the subject of future research.

Looking ahead, it will be crucial to test GeoBlocks empirically to validate its effectiveness across different educational settings. Long-term assessments will be necessary to understand the sustained benefits and its potential for broader application. Additionally, exploring the integration of digital tools could further enhance engagement and reinforce learning. GeoBlocks represents an educative innovation in teaching Geometry at early stages, with further empirical validation and exploration of its broader applications, the project has the potential to make a meaningful impact on both teaching practices and student learning experiences.

Conflicts of interest

The authors declare no conflicts of interest.

References

[1] M. Li, C. Vale, H. Tan, and J. Blannin, "A systematic review of TPACK research in primary mathematics education," *Math Ed Res J*, May 2024, doi: 10.1007/s13394-024-00491-3.

[2] H. Gardner, *Frames of Mind. The Theory of Multiple Intelligences*. Basic Books, 1983.

[3] D. Olivares, J. L. Lupiáñez, and I. Segovia, "Roles and characteristics of problem solving in the mathematics curriculum: a review," *International Journal of Mathematical Education in Science and Technology*, vol. 52, no. 7, pp. 1079–1096, Aug. 2021, doi: 10.1080/0020739X.2020.1738579.

[4] D. H. Clements and J. Sarama, *Learning and Teaching Early Math: The Learning Trajectories Approach*, 3rd ed. New York: Routledge, 2020. doi: 10.4324/9781003083528.

[5] M. T. Battista, L. M. Frazee, and M. L. Winer, "Analyzing the Relation Between Spatial and Geometric Reasoning for Elementary and Middle School Students," in *Visualizing Mathematics: The Role of Spatial Reasoning in Mathematical Thought*, K. S. Mix and M. T. Battista, Eds., Cham: Springer International Publishing, 2018, pp. 195–228. doi: 10.1007/978-3-319-98767-5_10.

[6] P. M. van Hiele, "Developing Geometric Thinking through Activities That Begin with Play," Feb. 1999, doi: 10.5951/TCM.5.6.0310.

[7] G. Gejard and H. Melander, "Mathematizing in preschool: Children's participation in geometrical discourse," in *Innovative Approaches in Early Childhood Mathematics*, Routledge, 2020.

[8] J. M. Osuna and J. Munson, "Exploring what teachers notice about students' interactional dynamics during collaborative mathematics problem-solving and their connections to instructional practice," *Teaching and Teacher Education*, vol. 137, p. 104380, Jan. 2024, doi: 10.1016/j.tate.2023.104380.

[9] *BOE-A-2022-3296 Real Decreto 157/2022, de 1 de marzo, por el que se establecen la ordenación y las enseñanzas mínimas de la Educación Primaria.* Accessed: Jun. 15, 2025. [Online]. Available: https://www.boe.es/buscar/act.php?id=BOE-A-2022-3296

[10] F. Berisha and E. Vula, "Introduction of Integrated STEM Education to Pre-service Teachers Through Collaborative Action Research Practices," *Int J of Sci and Math Educ*, vol. 22, no. 5, pp. 1127–1150, Jun. 2024, doi: 10.1007/s10763-023-10417-3.

[11] E. M. Schoevers, P. P. M. Leseman, and E. H. Kroesbergen, “Enriching Mathematics Education with Visual Arts: Effects on Elementary School Students’ Ability in Geometry and Visual Arts,” *Int J of Sci and Math Educ*, vol. 18, no. 8, pp. 1613–1634, Dec. 2020, doi: 10.1007/s10763-019-10018-z.
[12] D. Götz and H. Gasteiger, “Reflecting geometrical shapes: approaches of primary students to reflection tasks and relations to typical error patterns,” *Educ Stud Math*, vol. 111, no. 1, pp. 47–71, Sep. 2022, doi: 10.1007/s10649-022-10145-5.
[13] N. O’Meara, P. Johnson, and A. Leavy, “A comparative study investigating the use of manipulatives at the transition from primary to post-primary education,” *International Journal of Mathematical Education in Science and Technology*, vol. 51, no. 6, pp. 835–857, Aug. 2020, doi: 10.1080/0020739X.2019.1634842.
[14] A. Karimov, M. Saarela, and T. Kärkkäinen, “Serious games in Science and Mathematics Education: a scoping umbrella review,” *International Journal of Serious Games*, vol. 11, no. 4, Art. no. 4, Nov. 2024, doi: 10.17083/ijsg.v11i3.765.
[15] I. Álvarez-Rey and L. Muñiz-Rodríguez, “Playful resources to improve the attitude of Primary Education students towards learning geometry,” *Educación matemática*, vol. 35, no. 2, pp. 268–292, 2023, doi: 10.24844/em3502.11.
[16] S. S. Dogruer and D. Akyuz, “Mathematical Practices of Eighth Graders about 3D Shapes in an Argumentation, Technology, and Design-Based Classroom Environment,” *Int J of Sci and Math Educ*, vol. 18, no. 8, pp. 1485–1505, Dec. 2020, doi: 10.1007/s10763-019-10028-x.
[17] J. Juul, M. Copier, and J. Raessens, “The Game, the Player, the World: Looking for a Heart of Gameness,” in *Level Up: Digital Games Research Conference Proceedings*, Utrecht: Utrecht University, 2003, pp. 30–45.
[18] Y. Gui, Z. Cai, Y. Yang, L. Kong, X. Fan, and R. H. Tai, “Effectiveness of digital educational game and game design in STEM learning: a meta-analytic review,” *International Journal of STEM Education*, vol. 10, no. 1, p. 36, May 2023, doi: 10.1186/s40594-023-00424-9.
[19] B. S. Anggoro, A. H. Dewantara, S. Suherman, R. R. Muhammad, and S. Saraswati, “Effect of game-based learning on students’ mathematics high order thinking skills: A meta-analysis,” *Revista de Psicodidáctica (English ed.)*, vol. 30, no. 1, p. 500158, Jan. 2025, doi: 10.1016/j.psicoe.2024.500158.
[20] *BOE-A-2020-17264 Ley Orgánica 3/2020, de 29 de diciembre, por la que se modifica la Ley Orgánica 2/2006, de 3 de mayo, de Educación.* Accessed: Jun. 15, 2025. [Online]. Available: https://www.boe.es/buscar/act.php?id=BOE-A-2020-17264
[21] “Council Recommendation of 22 May 2018 on key competences for lifelong learning (Text with EEA relevance.).” Accessed: Jun. 15, 2025. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=oj:JOC_2018_189_R_0001
[22] J. Piaget, *The origins of intelligence in children*. in The origins of intelligence in children. New York, NY, US: W W Norton & Co, 1952, p. 419. doi: 10.1037/11494-000.
[23] E. L. Deci and R. M. Ryan, “Self-determination theory: A macrotheory of human motivation, development, and health,” *Canadian Psychology / Psychologie canadienne*, vol. 49, no. 3, pp. 182–185, 2008, doi: 10.1037/a0012801.
[24] J. Sinnemäki, F. M. Abrori, T. Prodromou, Z. Lavicza, K. Fenyvesi, and D. H. Jarvis, “Exploring Educational Exergames in Wellbeing Education: A Study Finnish Primary School,” *International Journal of Serious Games*, vol. 12, no. 1, Art. no. 1, Feb. 2025, doi: 10.17083/ijsg.v12i1.869.
[25] S. Zhang, Y. Yang, C. Chen, X. Zhang, Q. Leng, and X. Zhao, “Deep learning-based multimodal emotion recognition from audio, visual, and text modalities: A systematic review of recent advancements and future prospects,” *Expert Systems with Applications*, vol. 237, p. 121692, Mar. 2024, doi: 10.1016/j.eswa.2023.121692.
[26] F. Liarokapis, S. von Mammen, and A. Vourvopoulos, “Advanced multimodal interaction techniques and user interfaces for serious games and virtual environments,” *J Multimodal User Interfaces*, vol. 15, no. 3, pp. 255–256, Sep. 2021, doi: 10.1007/s12193-021-00380-0.
[27] I. Lee and B. Perret, “Preparing High School Teachers to Integrate AI Methods into STEM Classrooms,” *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 36, no. 11, Art. no. 11, Jun. 2022, doi: 10.1609/aaai.v36i11.21557.

[28] L. Freina, R. Bottino, and L. Ferlino, “Visuospatial Abilities Training with Digital Games in a Primary School,” *International Journal of Serious Games*, vol. 5, no. 3, Art. no. 3, 2018, doi: 10.17083/ijsg.v5i3.240.
[29] E. M. Byrne, H. Jensen, B. S. Thomsen, and P. G. Ramchandani, “Educational interventions involving physical manipulatives for improving children’s learning and development: A scoping review,” *Review of Education*, vol. 11, no. 2, p. e3400, 2023, doi: 10.1002/rev3.3400.
[30] H. C. Çelik, “The effect of modelling, collaborative and game-based learning on the geometry success of third-grade students,” *Educ Inf Technol*, vol. 25, no. 1, pp. 449–469, Jan. 2020, doi: 10.1007/s10639-019-09983-3.
[31] S. Jablonski and M. Ludwig, “Teaching and Learning of Geometry—A Literature Review on Current Developments in Theory and Practice,” *Education Sciences*, vol. 13, no. 7, Art. no. 7, Jul. 2023, doi: 10.3390/educsci13070682.