A Game-Based Learning Method to Promote Soft Skills in Construction Education

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Abstract

In the world of ever-growing technology and multimedia devices, educators are actively exploring innovative methods to captivate students in immersive and enjoyable learning experiences. Games-based learning has demonstrated their effectiveness in K-12 education and is now gaining substantial traction in higher education. Particularly in engineering education, it focuses on enhancing learner engagement and motivation. However, the application of game-based learning in engineering and technology education, specifically in the field of Construction Engineering, has been relatively limited and its efficacy as a learning and training tool remains uncertain. To assess the impact of game-based learning on students' performance, this study utilizes game-based learning, employing LEGO sets, in teaching construction engineering students. The incorporation of LEGO as a means of enhancing learning activities allows learning by playing. The students engage in collaborative group of two students to construct a single-family home using LEGO sets. The primary objective is to facilitate the practice and enhancement of the main important skills for construction engineers: communication, leadership, analytical, and decision-making skills. The research process comprises three key phases: (1) Before pilot study: Introducing the project and guidelines and conducting a pre-summative assessment of students' prior construction skills. (2) Pilot study: Students embark on the construction phase, facing various challenges such as constructing their houses within specified parameters, including size, limited pieces, design requirements, and adhering to LEGO's set color guidelines for the design. (3) After pilot study: This final phase uses a post-summative assessment that evaluates the improvement in students' construction skills. The results demonstrate that well-designed LEGO tasks can enhance students' skills by improving communication, leadership, analytical, and decision-making skills. This approach seeks to equip future construction engineers with the practical skills necessary for success in their careers and to meet the industry's demands effectively.

Introduction

Education plays a pivotal role in teaching planning. A well-structured teaching method not only facilitates knowledge transfer but also encourages students to challenge their preconceptions and motivates them to learn [1]. When it comes to engineering education, there are unique peculiarities due to the specific competencies required in this field. Engineering education is characterized by a distinct design in most curriculums [2]. The aim is to cultivate interdisciplinary-minded and highly talented practitioners possessing innovative thinking and problem-solving abilities [3]. Engineers, being problem solvers, are compelled to instigate creative and critical thinking in their students. This is due to the need to either design new products or enhance existing ones [4]. To establish an effective learning for engineering education, various methods have been deployed to facilitate learning. These methods include lectures, hands-on learning, and collaborative learning. The incorporation of these methods is essential to nurture the skills and mindset required for success in the dynamic field of engineering [5].

In the role of construction engineers, professionals in the construction field are involved in all aspects of planning, designing, and constructing or repairing buildings and infrastructure projects to ensure the correct assembly of structures and systems. Depending on the job, construction engineers may participate in a project from its initiation to completion or focus on specific stages. Meeting these challenges necessitates a broad range of knowledge and skills that construction engineers need to possess and cultivate during their bachelor's degree [6]. These professionals must acquire essential qualities, including hard skills like technical skills (applied knowledge of industry concepts and practices) and business skills (preparing and adhering to project budgets, managing staff, and coordinating with other workers and managers). Additionally, they require soft skills such as communication skills (both orally and in writing), decision-making skills (choosing personnel and subcontractors for specific tasks), leadership skills (delegating tasks to construction workers, subcontractors, and lower-level managers), and analytical skills (planning strategies, investigating project cost variances, and problem-solving throughout a project) [6].

There is a growing interest in the development of soft skills within the engineering field. Despite this increasing focus on integrating soft skills into curricula, there is no common understanding of how to effectively teach or assess these essential skills. The teaching and assessment methods for soft skills vary widely among different countries and educational institutions, presenting a challenge that needs to be addressed [7]. Similarly, there is a high level of variability in the pedagogical sector to teach soft skills. It is widely acknowledged that soft skills cannot be acquired through passive knowledge acquisition. Students must actively engage and experience their capabilities, strengths, and weaknesses in relation to soft skills. As a result, various methods, as playing games or involving classroom debates, are being considered and described in the literature [9]. Within this context, the term "Education 4.0" has been highlighted by various studies that emphasized the influence of evolving innovations on the education sector over time. In contemporary times, methodologies, practices, and activities aim to personalize knowledge and skills generation, making them more efficient, accessible, and flexible [8]. Consequently, educational institutions actively support and encourage educators and researchers to lead initiatives and projects in educational innovation by designing and developing studies applying innovations to assess students' skills and knowledge [9].

Taking into account the broad heterogeneity and diversity in the integration of soft skills teaching in engineering, this study introduces the use of game-based learning, utilizing Lego sets. The aim is to enable construction engineering students to practice and enhance their soft skills essential for the construction field, including leadership, decision-making, analytical, and communication skills. A pilot study was introduced to allow students to build a single-story house using Lego, with some design specifications to challenge students to practice their soft skills. The study aims to facilitate active learning among students, ensuring a more natural and unbiased assessment of their soft skills during the game-based learning activity. Three assessment methods were implemented: a pre summative assessment to evaluate their prior skills, a post summative assessment to measure the improvement in their skills after the game, and observational skills to assess students' behavior.

Literature review

Education needs in construction engineering

In the rapidly evolving construction industry, there is a pressing need to address new management challenges, particularly those related to collaboration and social responsibilities. To meet these demands, it is crucial to enhance construction project management skills, allowing the sector to navigate the complexities of modern challenges effectively. This need education in construction engineering management, highlights the importance of equipping professionals with the necessary skills to succeed [10]. Communication skills are essential for construction engineers, enabling them to outstand in project management and achieve business objectives [10]. One of the most crucial factors that influence the success of a construction project is communication. However, past studies found that communication failure frequently occurs at civil engineering workplaces. Among communication failures reported were oral communications, such as giving instruction and briefing; skills, which are supposed to be mastered by engineering graduates during their study years. These skills, expected to be acquired during undergraduate degree, underscore the need for engineering students to gain effective oral communication before entering the professional path [11]. Moreover, construction engineers must develop communication skills to establish clear, shared goals, define roles, and foster effective team collaboration [12].

Leadership skills are equally essential in the construction field, enabling engineers to overcome challenges by technical skills, thinking outside the box, engaging with others, excellence in execution, and beliefs and attitudes [13]. This skill supports engineers in leading initiatives, lead teams, and inspire others [14]. Analytical skills are another critical area for construction engineers, particularly in managing design changes, which are often attributed to poor strategic planning, lack of attention to design details, and insufficient design capabilities. Such challenges create a need for a proactive approach to adjust managing project scope, cost, and time [15]. This adaptability is crucial not only for project success but also for meeting the broader needs of enterprises and clients [16]. Decision-making skills are equally crucial, enabling engineers to optimize cash-flow schedules and select the most economically and sustainably viable project variants, considering customer requirements. The decisions made in the early stages of a project significantly influence the ability to adhere to schedules, budgets, and client expectations [17]. Given the complexity of construction processes and the constraints of knowledge, time, and cognitive resources, decision-making is a complex skill to achieve due to the complexity of construction processes [18].

Teaching engineering today presents a multifaceted challenge, primarily due to the dynamic nature of the subject and the vast scope of learning material. The expectation for quality engineering education extends beyond possessing fundamental knowledge; it includes the mastery of so-called "soft" skills development [19]. Soft skills integrate set of knowledge, abilities, and values. It plays a pivotal role in facilitating the efficient acquisition of technical skills [20]. These soft skills are crucial for personal growth and for career advancement, complementing the technical knowledge that form the core of engineering education [21]. However, integrating soft skills into the engineering curriculum poses significant challenges. The traditional focus on technical knowledge often provides a noticeable gap in soft skills, making it difficult for students to adapt to problem-based learning, which are essential for their overall development. This gap underscores a broader issue within engineering education: the need to

create a mindset that cultivates these soft skills alongside technical knowledge [22]. Addressing this challenge requires innovative approaches to teaching, so one promising solution is the adoption of game-based learning [19].

Game-Based Learning

Game-based learning (GBL) serves as an innovative teaching aid that incorporates digital games to enhance learning outcomes, motivation, adaptability, and the overall effectiveness of teaching and evaluation in various courses [23]. Specifically, GBL has shown considerable promise in undergraduate engineering courses, where it effectively facilitates the acquisition of soft skills. By integrating game-based learning with traditional educational methods, there is a notable improvement in academic performance and student motivation, which, in turn, cultivates a deeper interest in engineering disciplines [24, 25]. Recent studies have expanded the application of game-based learning within construction engineering education, exploring novel digital technology. These technologies include virtual and augmented reality, alongside digital twin applications, all aimed at enriching construction courses with immersive and interactive learning experiences [26]. Moreover, some research delves into the utilization of both tabletop and digital games as educational resources. Digital games, characterized by their fully virtual environments, audio-visual feedback, graphic user interfaces, and artificial intelligence, provide a way for engaging students in complex problem-solving and design tasks in the engineering field. Also, tabletop games include activities played on a flat surface with paper, pen, board games, or card games. This GBL offers a more tactile and social learning experience [27]. The application of Minecraft in educational settings has also been explored, particularly for enhancing competencies in the construction engineering field. By leveraging the game's open-ended environment, students can experiment with construction concepts and design strategies in a risk-free and creative setting [28].

Within this context, Lego construction kits, with their interlocking plastic bricks, have transcended their original purpose as toys to become a valuable educational tool in engineering education. These kits encourage active involvement and foster collaboration among students, deepening their understanding of complex concepts through hands-on learning [29]. The engineering design-based modeling approach that utilizes Lego bricks serves as an effective tool for enhancing problem-solving abilities. This method not only engages students in practical design challenges but also encourages them to apply theoretical knowledge in creative and innovative ways [30,31]. The adaptability of Lego sets has been explored in various educational settings, including technical and vocational secondary education, particularly within Mechanical Engineering disciplines [32]. Furthermore, Lego has been employed as a game-based learning tool to teach concepts such as Six Sigma, enhancing entrepreneurship among engineering students by emphasizing quality and project management [33]. This usage underscores the potential of Lego sets to impact key educational outcomes positively, including team responsibility, accountability, collaboration, and an awareness of team risks and responsibilities [34]. In the realm of computer engineering, Lego sets have been utilized to facilitate the learning of programming languages and software engineering disciplines [35]. Additionally, in Systems Engineering education, Lego acts as an active learning tool, allowing students to experience key phases of the project lifecycle firsthand [36].

Methodology

This pilot study aimed to enhance the development of construction engineering students' skills in communication, analytical thinking, decision-making, and leadership. An innovative educational game design was implemented using Lego sets. To apply these skills, three groups of two students from the construction engineering degree were tasked with constructing a one-story single-family home using Lego sets (Figure 1), following specific requirements and a set timeframe. These requirements included an L-shaped house with a width of 10cm and a length of 20cm, featuring a foundation, slab, walls, roof, garden, doors, windows, and furniture, including a bed, sofa, TV, TV stand, dining table, and chairs. To increase the project's complexity, some obstacles were introduced, such as a limited number of Lego sets and color guidelines. For example, the foundation and soil were constructed using brown Lego sets, the slab in black, walls in white, roof in orange, and the garden in green. Each group was encouraged to use their creativity in their designs. While there was no specific model to adhere to, organization and time management were crucial due to the limited 30-minute timeframe for the project.

During this pilot study, students gained exposure to key construction engineering skills. The students displayed communication skills by collaborating within their pears to discuss and coordinate their building strategies. Analytical thinking was demonstrated through the process of interpreting the project requirements and translating them into a tangible structure. Decision-making skills were showcased as students had to make choices regarding the allocation of limited resources, to meet the project specifications. Lastly, leadership was evident as each member took on roles to lead different aspects of the construction process, ensuring the project's completion within the set timeframe.

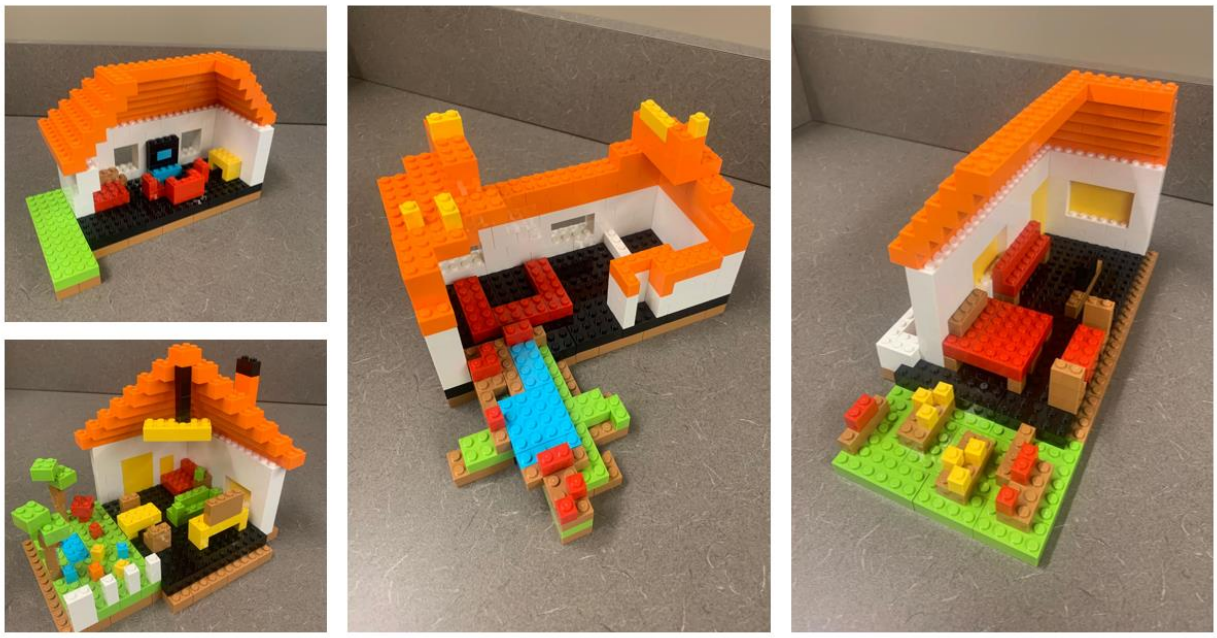

Figure 1: Single-family Home using Lego sets

The game-based learning followed this procedure: a 10-minute pre summative assessment

questionnaire was provided before the pilot study began, followed by the 30-minute pilot study. After that, to assess the effectiveness of the game-based learning, a 10-minute post-summative assessment questionnaire was given. At the end of the pilot study, the instructor filled out a checklist evaluating each student's behavior. To ensure a thorough observation, the entire pilot study was recorded to capture students' body language and communication patterns. It is important to note that the students were not informed about the research objective. This allowed the study to observe the natural interaction between the students without putting any pressure on them to consciously practice the targeted skills.

Pre-Summative Assessment Questionnaire

The pre-summative assessment involved a self-reflection questionnaire utilizing a 5-point Likert scale, ranging from strongly disagree to strongly agree. To avoid bias, for each skill - communication, analytical thinking, decision-making, and leadership - three questions were provided to prompt students to self-evaluate their proficiency in these skills prior to the pilot study. These questions are detailed in Table 1, offering a comprehensive view of the students' initial perceptions of their skills.

Table 1: Students' self-perceived levels of construction skills before pilot study

Skills	Self-reflection
Communication Skills	I feel confident expressing my ideas in a group
	I actively listen to other’s ideas during a group discussion
	I can effectively express my thoughts in verbal forms
Analytical Skills	I can identify problems quickly in group projects
	I am comfortable with coming up with creative solutions
	I can easily point alternatives to choose a solution
Decision-Making Skills	I can make decisions efficiently in a team setting.
	I stay committed to my decisions once made.
	I normally feel motivated to achieve a goal in a group project
Leadership Skills	I feel comfortable taking the lead in group projects.
	I can motivate others and delegate tasks effectively.
	I can manage conflicts and negotiate solutions in a team.

Post-Summative Assessment Questionnaire

The post-summative assessment was divided into three distinct parts. The first part encompassed a 5-point Likert scale questionnaire designed to gauge students' self-perception regarding the improvement in their skills following their participation in the pilot study (Table 2). This section aimed to capture the students' subjective assessment of their individual skill development. The second part of the post-summative assessment consisted of questions focused on gathering students' feedback on the learning support provided during the pilot study. This segment aimed

to assess the effectiveness of the educational game design and identify any areas for improvement in the learning process (Table 3). The third part involved questions seeking students' perceptions of Lego as an educational tool. This aspect aimed to explore the students' views on the ease of use of Lego and in enhancing their construction engineering skills and overall educational experience (Table 4).

Table 2: Students' self-perception of construction skills after pilot study

Skills	Statements
Communication Skills	I felt motivated to share information and ideas with other students in my group.
	The project improved my ability to listen to and incorporate others' feedback.
	I am now more confident in my verbal communication skills.
Analytical Skills	The project enhanced my ability to identify problems creatively.
	The project enhanced my ability to solve problems creatively.
	I learned to approach problems collaboratively in group throughout the project.
Decision-Making Skills	The activity enhanced my confidence in making decisions independently.
	I was able to make effective decisions under time constraints.
	I was able to make effective decisions during the project.
Leadership skills	I effectively coordinated with my team during the project.
	The project helped me improve my skills in guiding team members.
	The project enhanced my ability to lead discussions

Table 3: Students' feedback on learning supports.

The instructor/facilitator's guidance was comprehensive
The project guidelines were easy to comprehend

Table 4: Students' perception on LEGO

It was simple to play with LEGO
It was simple to understand how to use LEGO
I believe LEGO activity helps me to engage in classroom activities.
I enjoyed using LEGO in this class

I like the game-based learning environment more than a lecture-based
I am motivated to have game-based activities in other classes
I have previous experience using LEGO

Checklist Behavior

The checklist behavior was a crucial component of the summative assessment, it was filled out by the instructor for each student. By closely monitoring the students' performance throughout the pilot study and having the ability to observe their behavior through the pilot study's recorded video, the instructor evaluated three types of behavior for each construction skill. The checklist aimed to provide a comprehensive and objective measure of the students' practical application of communication, analytical thinking, decision-making, and leadership skills during the hands-on construction activity using LEGO sets. For each skill, the instructor marked either "yes" or "no" based on the observed behavior, offering a quantitative assessment of the students' proficiency (Table 5).

Table 5: Checklist Behavior

Skills	Behavior
Communication	The student felt confident expressing his ideas in a group
	The student actively listened to other’s ideas
	The student effectively expressed his thoughts in verbal forms
Analytical thinking	The student identified problems quickly
	The student comfortable came up with creative solutions
	The student easily pointed alternatives to choose a solution
Decision-Making	The student made decisions efficiently
	The student stayed committed to the decisions
	The student was excited to achieve the goal
Leadership skills	The student felt comfortable taking the lead
	The student motivated others and delegated tasks effectively.
	The student managed conflicts and negotiated solutions

Results and Discussions

Summative assessment: pre-test and post-test

The pilot study was conducted in three groups of two students from construction engineering

field. Pre-summative assessment and post-summative assessment evaluations were conducted for each participant to assess improvements in essential construction engineering skills, including communication, analytical, decision-making, and leadership skills. The graph below demonstrates the average scores from both assessments across each skill area. The results from these two types of assessments, as shown in Figure 2, reveal that post-summative assessment scores are significantly higher than pre-summative assessment scores across all skill areas. This indicates a substantial improvement in self-assessed skills. Moreover, this improvement is uniformly observed across all areas, with Analytical Skills exhibiting the most significant increase from pre- to post- pilot study.

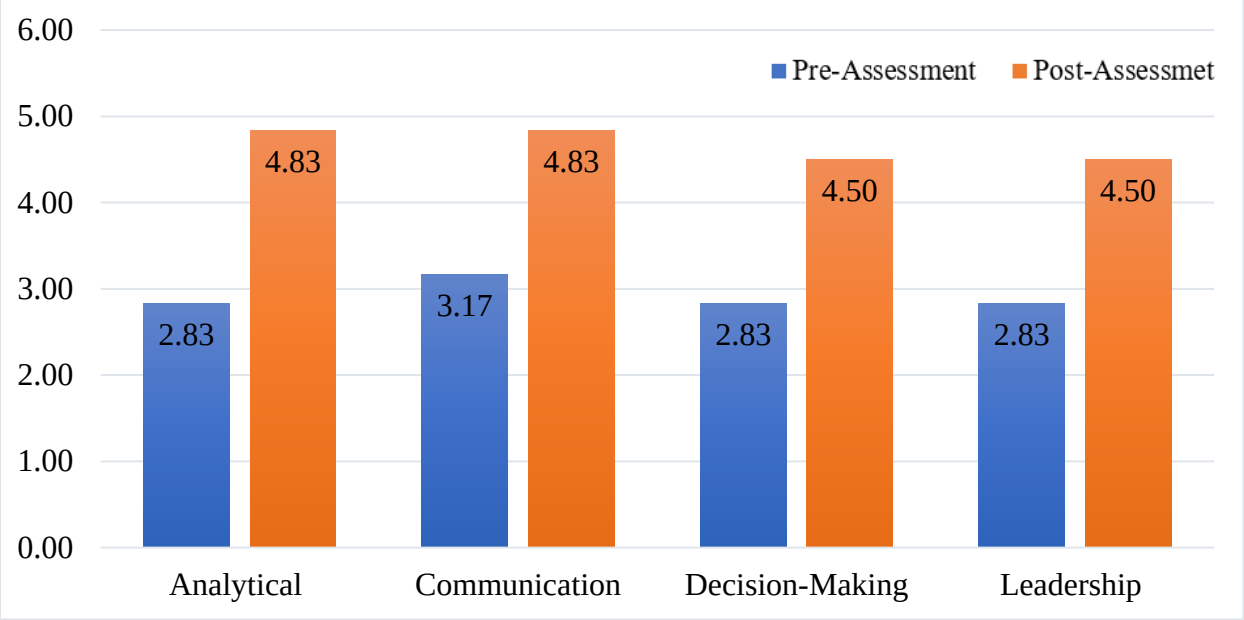

Figure 2: Student's pre- and post-summative assessment average improvement

Furthermore, a paired t-test was performed to compare the means of the pre-summative assessment and post-summative assessment scores, aiming to determine if there is a statistically significant difference between these means. The Null Hypothesis (H0) presents that there is no difference in the mean scores of skills before and after the intervention, this implies any observed difference is due to chance. Conversely, the Alternative Hypothesis (H1) presents that there is a significant difference in the mean scores of skills before and after the intervention. Results show that the p-values for each skill area are as follows: Analytical Skills: p-value = 0.000573; Communication Skills: p-value = 0.000521; Decision-Making Skills: p-value = 0.001894; Leadership Skills: p-value = 0.000521. The findings presents that the results for each skill are statistically significant at the commonly accepted significance level of 0.05. The low p-values suggest that the chances of observing such improvements are extremely slim, thereby confirming the effectiveness of the intervention using Lego sets in enhancing these skills among construction engineering students.

During the post-summative assessment, students also evaluated the learning support provided during the pilot study. All students were satisfied with the instructor guidance and with the printed project guidelines. Finally, participants were also asked questions regarding their feedback on using Lego, including its ease of use and their perceptions of utilizing Lego as a

game-based educational tool in the classroom. All participants agreed that the Lego sets were easy to use, facilitated engagement in the classroom, and were enjoyable to use during lessons. Furthermore, they reported that Lego contributed to a positive learning environment and enhanced their motivation.

Summative assessment: Behavior Checklist

In this study, an observational checklist was used by the instructor to assess students' skill improvements. The results confirmed that the students achieved these skills through game-based learning. The instructor marked “yes” to all students practiced their communication skills, demonstrated by confidently expressing their ideas and actively listening to each other's opinions. Also, 5 out of 6 students gained analytical skills by quickly identifying problems and devising creative solutions. The students also exhibited decision-making skills, showing excitement in achieving goals and commitment to their decisions. Finally, 5 out of 6 students displayed leadership skills by motivating one another and negotiating solutions.

Conclusion

The pilot study presented in this research underscores the potential of game-based learning, specifically using Lego sets, in enhancing the educational experience of construction engineering students. By integrating Lego into the curriculum, this study moved beyond traditional learning methodologies to provide an environment where students could actively engage in the development of crucial skills in construction field such as communication, leadership, problem-solving, and decision-making. The findings from this study contribute valuable insights into the field of engineering education, particularly by demonstrating that game-based learning can serve as an effective tool in cultivating the competencies required in the construction engineering field. The hands-on experience provided by the Lego tasks enabled students to immerse themselves in a learning-by-doing process, thereby solidifying their understanding and application of theoretical knowledge in a practical context. While the results of this study are promising, it is important to acknowledge its limitations. The scope of the research was confined to a pilot study with a limited number of participants, which may not fully represent the diverse range of experiences and outcomes possible in broader applications. Future research directions could include expanding the participant number. Additionally, comparative studies that assess the efficacy of various game-based learning tools could provide deeper insights into their respective impacts on student learning and skills development. Investigating the long-term retention of skills acquired through such interactive learning experiences could also offer significant contributions to the field.

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