Gamification in preschool science education

Aikaterini Xezonaki
Department of Preschool Education, University of Crete, Crete, Greece

Abstract: Over the last few years, rapid technological progress has developed our lives in all areas. The adoption of technology in the everyday lives of both adults and children through smart mobile devices has led to the foreseeable integration of digital tools in the educational process. Smart mobile devices and the applications that accompany them have been proven effective in the educational field since they allow students to acquire knowledge through activities with an interactive and playful character. A technique that has gained popularity among technology users in the last decades is gamification. Gamification combines mechanisms and elements of games, enhancing students' learning, motivation, and interest in various educational fields, such as mathematics and science. The usage of game elements in education is not encountered for the first time due to the spread of gamification in technology, but it has been mentioned since the early ancient Greek years. However, technology has reinforced gamification through components and techniques that provide students with all the necessary supplies leading to positive learning outcomes. This bibliographic review presents the literature findings on gamification through smart mobile devices in science teaching in preschool education.

Keywords: mobile learning, gamification, science education, natural Sciences, mathematics, preschool education

1 Introduction

Over time, teachers are constantly called to discover new teaching techniques and tools to apply in teaching practice. The ultimate goal of this constant search is to attract their learners' interest and attention. Applying game elements in education has always been a practical approach, as it enhances students' motivation and skills (Kapp, 2012).

The importance of play at an early age is already found in Ancient Greece, where Plato pointed out the importance of play in the education of young children, arguing that play contributes to the formation of tomorrow's citizens and the development of their discipline (Williams, 2010). Aristotle also emphasized the role of play in the cultivation of children's mental functions and especially imagination (Curren, 2000). According to Bruce (1987), play is an integral part of preschool education and is essential for young children's development. The importance of play in learning during preschool age is supported both by the literature (Ali, 2021) and the educational community, with play being an essential part of the preschool education curriculum in Greece (Pechtelidis & Stamou, 2017).

In education, play and learning are directly related, as it is argued that play is an educationally powerful process, where learning is achieved spontaneously, even if an adult is not present (Wood & Bennett, 1997). In particular, play enables children to take on roles and make decisions (Jones, 2000), developing their skills and knowledge (Fromberg, 1999) while enhancing their creative thinking (Bruner, 1972).

What differentiates the educational game from the out-of-school game is the teacher's educational goals when designing the game (Saracho & Spodek, 1994). In addition, games are a different approach to teaching lessons, such as math, as they promote excitement and enjoyment. At the same time, participation (Ernest, 1986) and cooperation (Humphreys & Smith, 1987) are enhanced by creating positive relationships between peers (Hartup, 1993). Also, by applying game elements in education, students can solve problems and perform tasks that require many solutions (Sylva Bruner & Genova, 1976).

In recent years, a technique that has become quite popular and utilizes the elements and mechanisms of games is gamification (Kapp, 2012). Gamification has appeared in recent decades in various fields, such as industry and education (Huotari & Hamari, 2012).
2 Gamification

There are several definitions for gamification in the literature, most of which share some standard features concerning thinking and game mechanisms to solve problems (Zichermann & Cunningham, 2011). Gamification is a process that aims to increase the external and internal motivation of users to engage them in the project through enjoyable activities (Buckle & Doyle, 2016). Internal motivation is the performance of an activity for the user’s internal satisfaction, while external motivation is mobilized by acquiring separate amplifiers (Fischer, Malycha & Schafmann, 2019).

Unlike “serious games”, which are specially designed games for non-entertainment purposes, gamification incorporates game mechanisms and elements to create engaging and motivating experiences for users (Deterding, Dixon, Khaled & Nacke, 2011). Game elements provide resources, in the form of game objects (3D environments, plot, points, challenges, time pressure, leader boards, self-representation with avatars, etc., see Figure 1) (Deterding et al., 2011) and mechanisms, which are the rules that define how these objects are distributed and handled (Khan et al., 2020). These elements can be used individually or in combination (Razali et al., 2020). Research has shown that players prefer different game elements depending on the individual characteristics of each user, such as gender (Jahn et al., 2021). Users can select and create from the beginning some elements, such as their avatar, which will represent them and interact with the system (Mohamad et al., 2018).

Points, badges and leader boards are three of the most common game rewards elements used in both in-game and off-game settings (Zichermann & Cunningham, 2011). More specifically, points and badges are awarded to users when they answer questions correctly or complete a structured task or other achievements. Next, the leader boards show the players’ scores, while time pressure influences users’ decisions and the direction of the game (Rahman et al., 2018).

Figure 1 Game elements (Deterding et al.,2011)

Game mechanisms make up the building blocks of a game (Schöbel et al., 2020). They are used to develop a gamified idea, selected and combined to create a pleasurable gaming experience (Blohm & Leimeister, 2013). Such mechanisms can be:

1. challenges;
2. competition;
3. collaboration;
4. rewards;
5. feedback, etc.

The above data are presented in detail in Table 1.

<table>
<thead>
<tr>
<th>Game Mechanics</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenges</td>
<td>Users can test their knowledge by applying it to overcome a challenge.</td>
</tr>
<tr>
<td>Competition</td>
<td>The user faces another user to achieve a common goal.</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Motivates participants to collaborate to achieve better results.</td>
</tr>
<tr>
<td>Rewards</td>
<td>Virtual symbols are used as a reward to signal users’ achievements.</td>
</tr>
<tr>
<td>Feedback</td>
<td>The measurement is used to inform users of where they stand concerning achieving their goals.</td>
</tr>
</tbody>
</table>
We refer to these mechanisms as critical components because designers selected and used them as the central elements for creating gaming concepts (Schöbel et al., 2020). Suppose the elements mentioned above are used correctly and appropriately in the educational process, the interest and the attention of the trainees’ increases, while simultaneously, the socio-emotional skills of the students are developed (Kapp, 2012). Therefore, applying these elements in education is essential and should be widely applied by teachers (Rahman et al., 2018).

3 Gamification in education

One of the main goals of gamification in education is to gain students’ attention and motivate them to engage in learning activities (Deterding et al., 2011; Zichermann & Cunningham, 2011). Gamification uses some basic reinforcement techniques mentioned above: competition and collaboration (Andrade & Law, 2018). Competition is the ability of the user to win, not by preventing his opponent from winning, but by optimizing his performance to achieve the desired goal (Andrade & Law, 2018). In contrast, collaboration refers to working together to achieve mutually pursued goals.

It is important to note that when we talk about gamification in education, we are not talking about games or Game-Based Learning, as its purpose is not fun. It is a differentiated form of learning, which approaches the concept of games by utilizing their mechanisms and elements (Deterding et al., 2011). Gamification aims to motivate the user using external motivations, such as medals and achievements (badges), so that, when it is applied in educational practice, it leads to positive learning outcomes (Kapp, 2012).

Gamification is a helpful tool that encourages students to actively participate in the educational process in various ways (Lamrani et al., 2018). Students learn through experimentation and discovery by the following complex, game-like rules systems (Lee & Hammer, 2011). At the same time, they have the freedom to perform tasks of varying levels of complexity and difficulty. This also implies the freedom to fail, as games allow many problem-solving efforts and provide different paths to achieving goals.

Furthermore, the process of co-designing has proved to be helpful. Teachers and students select and utilize gamification elements on a teaching object in this process. In this way, students have the feeling that they participate in the creation of their learning, and as a result, they involve pleasantly in the learning process, while at the same time, a better relationship develops between them and their teachers (Ramos-Vega et al., 2021). At the same time, teachers succeed in guiding the students, recognizing their efforts, and rewarding them through a system that offers feedback and does not promote failure (Hamari et al., 2014).

Overall, when the above elements are transferred to the learning process, the students’ motivations for learning and cognitive involvement are encouraged, leading to the best possible learning (Kapp, 2012; Lee & Hammer, 2011). In some cases, learners’ participation in lessons through gamification is greater and more active than their participation in other lessons, and students tend to find these lessons more exciting and engaging than those without gamification (Zsoldos-Marchis, 2020).

Figure 2  The process of gamification in education

4 Gamification and ICT

Gamification is not always done through specific elements and mechanisms (Huotari & Hamari, 2012). The omnipresence of information and communication technologies and our growing dependence on them have affected our lives in all forms (Surendeleg et al., 2014), and the field of gamification was not an exception. New technologies have strongly influenced educational gamification and appear in various forms, such as applications or video games (Dvoryatkina et al., 2021). The main advantages of utilizing gamification through new technologies are the low development cost and the exciting learning content created by game elements (Surendeleg et al., 2014).
The integration of new technologies in education is not something that is first encountered through gamification. A considerable amount of research has been done to examine smart mobile devices and computers in education, observing positive outcomes for children’s learning (Papadakis et al., 2016a). More specifically, over the last decade, the research community (Papadakis & Kalogiannakis, 2019) has shown through various researches that interactive tools, such as smartphones and tablets, offer students a better visualization of the teaching material (Fokides & Zachristou, 2020) functioning as a great complement to traditional teaching methods (Gasparini & Culin, 2011). Students can communicate with each other by asking and answering questions to solve a problem (Skaraki, 2021), while they can still create together using rich digital resources, even outside the classroom (West, 2013). Clark & Luckin (2013) believe that smart mobile devices in the learning process support collaborative learning, providing individualized learning experiences while enhancing universal education.

The massive variety of devices from which a teacher has to choose raises the question of whether and to what extent all of these devices are effective in the educational process (Davis et al., 2017). Studies have shown that desktop or laptop computers improve students’ stimulation and autonomy (Iskrenovic-Momcilovic, 2018). As mentioned above, similar results have been recorded from smart mobile devices in research conducted in education. Although both of the teaching approaches have great results in the learning process, it is considered that tablets are more effective in comparison to computers. This might be down to the ease of use via the finger, or the size of the tablet’s screen (Davis et al., 2017), elements that lead to the more active role children have when using these devices (Papadakis et al., 2021). Moreover, tablets are lightweight, portable, have wireless internet access, and their cost is lower than computers’ cost (Major et al., 2017).

Regarding the integration of smart mobile devices in preschool education, several studies have highlighted the advantages these devices provide to preschool children (Papadakis et al., 2021). More specifically, during an activity using a smart mobile device, children communicate with each other, discussing each time who will have access to the device and co-deciding on their actions, in order to be able to complete a task or an activity, sharing feelings of joy and enjoyment (Fantozzi, 2021). Combining mobile devices with appropriate educational applications promotes learning in a pleasant environment (Skaraki, 2021). In this way, children interact successfully with the learning object while developing listening, collaboration and autonomy (Furman et al., 2019).

At the same time, the learning of various learning objects, such as mathematics, is enhanced through the didactic use of smart mobile devices (Zaranis et al., 2013). Many researchers have found that the interactive environment created in kindergarten by using tablets attracts children’s interest, encouraging them to participate more closely and effectively in mathematical activities (Papadakis et al., 2018).

Teachers use technology in various forms in education depending on their educational program and goals (Ramsey, 2018). Gamification through smart mobile devices in education has been proved to be a successful learning approach because of its positive impacts on students’ enjoyment and motivation (Metwally et al., 2021). However, not only students but also teachers benefit from the gamification process. In contradistinction to designing complicated games, which require a large amount of money or time (Dicheva et al., 2015), gamification uses game elements to existing systems (Sanmugam et al., 2015) through various software forms, such as apps or simulation games (Peixoto & Silva, 2017). Teachers need to choose their gamified content carefully, as in this way, technology can be used effectively in education. One of the main goals of teachers who utilize the digital tools of gamification in educational practice is to attract the interest of their students. Teachers need to pay attention to every detail in a gamified app to make this possible, starting from its mechanism. The mechanism of an app is fundamental, as it includes the rules of a game, the algorithms and what the player does (Putra & Yasin, 2021).

Gamification can be implemented through smart mobile devices, such as puzzles, strategy games or simulation (Zakaria et al., 2020), Sudarmilah & Arbain (2019), using video games, concluded that gamification has positive results in the cognitive ability of preschool children. At the same time, Matchacheep, Chookew & Nilsuk (2019) showed that digital storytelling through gamification positively affects children’s learning and teamwork skills.

The effectiveness of gamification in preschool education is found in many studies in the literature, such as that of Parra-González et al. (2021), in which scholars compared the application of gamification and flipped classrooms on the subject of Physical Education in kindergartens in Spain and found that gamification achieved better results in the autonomy of preschool children. Furthermore, applications of gamification, which have been made in educational practice, have shown that students’ attention is improved (Setiawan & Soeharto, 2020), while the enthusiasm and interaction between learners are increased (Umboh et al., 2021).
In addition, the various difficulty levels offered through the gamified apps provide opportunities for all students regardless of their learning level (Bovermann & Bastiaens, 2020). The score can be adjusted depending on the purpose of the game being created. In general, the game’s purpose and direction are influenced by the predetermined learning goals that the teacher will set during the design (Putra & Yasin, 2021). These can be achieved through interactive tools, such as Microsoft Office embedded tools, which do not require programming skills (Bovermann & Bastiaens, 2020).

5 Gamification in preschool science education

The issue of critical teaching-learning science subjects, such as mathematics and natural sciences, often tend to be characterized by students as tricky, difficult to understand or too bored (Setiawa & Soeharto, 2020). For this reason, teachers are looking for ways to motivate their students by teaching the lessons in a fun way.

Teaching science subjects is extremely important in preschool, where children’s curiosity about exploring the world around them can be nurtured and lay the foundation for their later learning in these areas (National Science Teachers Association, 2014; Fragkiadaki & Ravanis, 2021). Preschoolers develop positive attitudes toward science (Gomes & Fleer, 2019), by learning about specific scientific concepts (Akerson et al., 2015) and by understanding the world around them (Larimore, 2020). At the same time, they develop their vocabulary with scientific terms (Eshach & Fried, 2005). In particular, activities where students are asked to describe phenomena (Fragkiadaki & Ravanis, 2021), explain their ideas and seek information in informative texts (Guo et al., 2016) support their language development and literacy.

Therefore, educators need to look for ways to encourage preschoolers to develop their scientific thinking and their emerging science concepts (Bose & Seetso, 2016) while working in the light of a holistic approach, as physical, socio-emotional and cognitive development are priorities in preschool education (Schwarz et al., 2017). More generally, preschool education’s influences from Piaget’s constructivist theory and Vygotsky’s theory of cognitive development emphasize the importance of social interactions and external stimuli in preschool (Copple & Bredekamp, 2009).

As argued by many researchers (Nayfeld et al., 2013; Kalogiannakis et al., 2018), sciences support the socio-emotional development of preschool children. More specifically, through collaborative learning (Ampartzaki & Kalogiannakis, 2016), students organize research and solve problems, and as a result, they are enhancing their executive function. On the other hand, teachers can enhance students’ learning by following various educational practices, such as linking to children’s pre-existing knowledge about the phenomena they are examining or highlighting events during the observation of a phenomenon (Andersson & Gullberg, 2014).

Regarding teaching subjects from the field of Natural Sciences, preschool children develop respect for the natural environment through opportunities to explore natural phenomena (Larimore, 2020). However, many educators express difficulties in teaching Natural Sciences, as it is a field of science that needs an exceptional conceptual understanding. In educational reality, kindergarten teachers spend less time teaching Natural Sciences than any other field (Edwards, 2011). This lack of time may be due to teachers’ lack of knowledge or interest (Garbett, 2003) in teaching Natural Sciences. As a result, preschoolers lose meaningful experiences with sciences and gain knowledge gaps (Larimore, 2020). It is no coincidence that although preschoolers’ performance at the beginning of the school year is similar in Mathematics, Natural Sciences and Literacy, at the end of the school year, it falls markedly lower (Greenfield et al., 2009). Therefore, it is essential to offer open-ended experiences to preschool students, including content and practices from science (National Science Teachers Association, 2014).

In combination with the materials provided to learners, the environment in which learning takes place is critical (Fleer et al., 2014). In particular, digital tools, such as smart mobile devices, give students different learning styles (Kalogiannakis et al., 2018) and different skills (Sezgin et al., 2018) to participate in the educational process. Regarding the integration of smart mobile devices in the teaching of Natural Sciences, it has been proven that these devices offer students a better visualization of phenomena related to the Natural Sciences and make it easier for them to understand better these concepts (Fokides & Zachristou, 2020).

Combined with the game elements and mechanisms, which gamification utilizes, if used in the right way, can increase the students’ enjoyment and achievements (Morris et al., 2013). Students are encouraged to try new things and repeat the exercises if they wish, minimizing the fear of failure. Adapting data, which motivate preschoolers to try again (Hunter & Werbach, 2012), enhance the willingness to participate in the process. In addition, the capability to correct a mistake involves students in a typical assessment process (Sánchez-Rivas et al., 2019).
Thus, preschool children can enter the role of scientists, experiment, and participate in learning through discovery (Tsai, 2018). Consequently, positive results are provided in motivation, commitment and social interaction (Kalogiannakis et al., 2021). However, in order to achieve the above, the role of the teacher is essential, as he/she is the one who plans the educational practice, evaluates the type of each student, chooses the materials, the pedagogical strategies and how students will receive feedback (Zourmpakis et al., 2022).

Preschool education lays the foundation for children’s future attitudes and perceptions around sciences. Children develop relationships between the real world, mathematical concepts and symbols (Gray et al., 2000). Learning mathematical concepts in preschool should involve children creatively, allowing them to learn problem-solving strategies (Seo & Ginsburg, 2004) through formal and informal learning processes (Gasteiger & Benz, 2018). Preschoolers can develop their math skills through daily activities, such as playing or cooking (Anthony & Walshaw, 2009). Similar results are provided by daily interaction with information and communication technologies and smart mobile devices (Papadakis et al., 2016a).

Several researchers have studied and documented the positive effects of smart mobile devices in teaching mathematical concepts in preschool education (Papadakis et al., 2016a; Papadakis et al., 2021; Outhwaite et al., 2019). The interaction of preschool children with interactive applications, which incorporate mathematical concepts into play-like activities (Hirsh-Pasek et al., 2015), enhances their participation (Papadakis et al., 2016b). In addition, the use of game elements in teaching mathematics is one of the methods that can help students learn mathematics with pleasure. Students find lessons through gamification more exciting and more active in their activities (Zsoldos-Marchis, 2020).

Examples of the application of gamification for the development of students’ mathematical skills in preschool education have shown that the gamification elements promote learning through experimentation, exploration, mistakes, comprehension and repetition (Lamrani & Abdelwahed, 2020). What is essential to consider when designing mathematical activities for preschoolers is that children of this age understand problems that refer to real-world situations (Papadakis et al., 2021). While in a gamification environment, preschool children are led to learning through a fun process and at the same time, their active participation is encouraged, resulting in the successful acquisition of basic mathematical concepts (Karademir & Akman, 2021). In addition, the level of children’s autonomous learning increases along with their interest in completing math tasks (Mowafi et al., 2019). Thus, every student gains emotional, cognitive and social benefits from the process of gamification (Karamert & Vardar, 2021).

However, there are some difficulties in the practical application of game elements and mechanisms when teaching mathematics, such as the extra time that the teacher should devote, the work for the educational mathematical content of the application and the careful selection of software (Bocconi et al., 2018). Considering the above-mentioned, several scholars using multimedia elements, such as text, images, sound, and animation, have created and implemented their interactive games, recording positive results in cultivating students’ mathematical ability (Udjaja et al., 2018).

In addition, various mobile applications, which are based on gamification features, such as formative assessment and feedback, have been tested by the research community, suggesting that students’ motivation and commitment can be enhanced while improving the learning process, even when students do not receive feedback from their teacher. However, they receive performance feedback directly from the system (Kickmeier-Rust et al., 2014).

Properly designing a digital application and adapting it to appropriate educational scenarios can introduce preschoolers to concepts long ago considered problematic for their age (Zaranis et al., 2013). From this point of view, it can be considered that gamification can contribute to understanding scientific concepts from chemistry at the preschool level. Although they show difficulties expressing scientific words and expressions, preschoolers can perceive mechanical processes from chemistry (Adbo & Carulla, 2019).

Similarly, students’ participation in mobile applications and gamification promotes their biology knowledge. In some cases, researchers select competitive gamified apps, such as the “Kahoot” application, to emphasize students’ commitment and motivation in the learning process of objects characterized as tricky, such as Biology (Jones et al., 2019). In this way, students expand their knowledge on health topics and begin adopting choices for a healthier lifestyle (Kostenius et al., 2018).

6 Limitations – Prospects for future research

There are some limitations considering gamification in education that should be addressed in this paper. Therefore, it is essential to look at some criticisms that have been formulated in the
past few years. As highlighted in various studies, game elements frequently repeated in different settings, such as rewards and scoreboards, can interfere with students’ intrinsic motivations (Perryer et al., 2016), paving the way for competition (Hamari et al., 2014).

Creating a competitive environment is controversial, and it is commonly used in science education to combat students’ negative emotions and experiences and increase learning outcomes (Kalogiannakis et al., 2021). Therefore, competition can be considered part of gamification and might cause social pressure to increase students’ involvement in the learning process (Sailer & Homner, 2020).

On the other hand, as argued in several studies, a gamification element, which positively affects one person’s performance, may not improve or may even worsen another person’s performance and motivation (García-Iruela & Hijón-Neira, 2020), or it may even worsen the performance for the whole group (Marlow et al., 2016). This is where adaptive gamification comes in to help overcome the many limitations and related difficulties in “conventional” gamification (Zourmpakis et al., 2022).

In addition, it is argued that it is common for students to be discriminated against based on their skill levels and grades, which they achieve during gamification activities. This can lead to a gradual loss of motivation and commitment of participants (Toda et al., 2017). At the same time, loss of productivity can be detected when game elements distract users from the activity’s primary purpose (Thiebes et al., 2014).

These challenges, which refer to creating a competitive environment through gamification in education, arise from the lack of appropriate methods and/or frameworks for the design and development of gamification in the context of learning and should be taken seriously by teachers when applying gamification in their classrooms. To avoid such problems and limitations, teachers should be careful when designing gamification teaching tools and take into account the needs of their students and their educational goals. In this way, gamification can enhance educational processes in science teaching in preschool, with promising results regarding students’ motivations.

Furthermore, teachers find it challenging to accept gamified environments, as they consider that they are not directly related to the content of their lessons (Markopoulos et al., 2015). Therefore, research findings on gamification in science teaching in preschool are limited. Our next steps in advancing these findings are to study, in the context of experimental research, how we can use gamification to teach science in different levels of formal education, depending on the needs of the students. In this way, it will also be explored whether the well-designed application of gamification in science teaching in preschool enhances preschool students’ motivation and thinking skills and whether and to what extent it enhances competition among preschool children.

7 Conclusions

A present literature review is an initial approach to the issue of utilizing gamification for the teaching of science subjects in preschool education. The literature review findings gave us information about the term of gamification in general and the forms in which we encounter it in various fields and, more specifically, in education.

The gamification elements and strategies were presented and their application by utilizing new technologies and smart mobile devices. In education, gamification positively affects the learning process and positively affects teaching subjects from science. Students are more confident to participate in the learning process, while the collaboration between peers is enhanced, creating appropriate fields for the implementation of collaborative learning. In addition, the feedback it provides can give teachers direct information about the learning level of their students.

The importance of play in preschool is emphasized from the beginning of the study. When play’s pedagogical strategies and elements are used in preschool education, preschool children become actively involved in learning and acquire knowledge through exploration and discovery. The present study aimed to describe the situation of gamification in preschool science education dominating the literature and the possibilities for teaching these subjects. However, the findings present some problems that future research should consider. In addition, limited studies have been conducted on the application of gamification in preschool science education, and as a result, we do not have a collective picture of the issue and the impact that gamification has on preschool education.

Therefore, more research is needed to study this subject, considering the limitations and problems mentioned, such as the mechanisms and elements used in conjunction with the learning strategies. Also, one of the most significant issues of gamification in education should be considered, which is the creation of competition between students and the elimination
of internal motivations. Future studies will help to clarify the actual effects on learners’ motivations. Finally, it is essential to consider the application of gamification to learning objects underrepresented by the research community in preschool education, such as Chemistry and Biology.

Conflicts of interest

The author declares that they have no conflict of interest.

References


Andersson, K., & Gullberg, A. (2014). What is science in preschool, and what do teachers have to know to empower children?. Cultural studies of science education, 9(2), 275-296. https://doi.org/10.1007/s11422-012-9439-6


https://doi.org/10.1007/978-3-319-33808-8_8

https://doi.org/10.1177/0306419015591324

https://doi.org/10.1016/j.chb.2015.09.028

https://doi.org/10.1145/3369199.3369211

https://doi.org/10.1016/j.ijer.2021.101832

https://doi.org/10.20469/wjhss.4.10003-1

https://doi.org/10.3389/fpsyg.2013.00607

https://doi.org/10.1007/978-3-030-27192-3_2


https://doi.org/10.1016/j.lindif.2013.04.011

https://doi.org/10.1037/edu0000286

https://doi.org/10.4018/978-1-7998-1486-3

https://doi.org/10.1080/17530873.2016.1268177

https://doi.org/10.1504/IJMLO.2016.077867

https://doi.org/10.1016/j.compedu.2017.09.007

https://doi.org/10.25082/AMLER.2021.01.002

https://doi.org/10.1057/palcomms.2017.65

https://doi.org/10.1145/3019612.3019752

https://doi.org/10.1016/j.ijme.2016.07.001


Sylva, K., Bruner, J. S., & Genova, P. (1976). The role of play in the problem-solving of children 3-5 years old. Play: Its role in development and evolution, 244-257.


