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ABSTARCT OF THE PH.D. THESIS

THE ROLE OF GAMIFICATION IN SELF-REGULATED LEARNING AND GAME EXPERIENCE DURING MATHEMATICAL PROBLEM-SOLVING AMONG PRESERVICE PRESCHOOL AND PRIMARY SCHOOL TEACHERS

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INTRODUCTION

The present dissertation examines the role of gamification in relation to self-regulated learning (SRL) and game experience in the context of mathematical problem-solving among pre-service preschool and primary school teachers. The research is situated within the broader transformation of educational paradigms that increasingly emphasize learner autonomy, active engagement, and the development of higher-order thinking skills.

In contemporary educational research, growing attention has been directed toward understanding how learners actively regulate their own learning processes. This shift reflects a move away from traditional teacher-centered instruction toward approaches that highlight the agency of the learner. Within this context, self-regulated learning (SRL) has emerged as a central construct, describing the cognitive, motivational, and behavioral processes through which learners plan, monitor, and evaluate their learning (Panadero, 2017; Zimmerman, 2000). SRL is widely recognized as a key factor in academic achievement, persistence, and adaptability, particularly in contexts that require sustained reasoning, problem-solving, and emotional regulation.

Parallel to these developments, rapid advances in digital technologies have contributed to the emergence of innovative instructional approaches designed to increase learner engagement and participation. Among these, gamification—defined as the use of game design elements in non-game contexts (Deterding et al., 2011)—has gained considerable attention in recent years. Gamified learning environments typically incorporate elements such as points, levels, feedback, and narrative structures, which can make learning more interactive, engaging, and emotionally meaningful. While early research on gamification focused primarily on its motivational effects (Hamari et al., 2014), more recent studies suggest that gamification may also influence deeper learning processes, including metacognition, emotional regulation, and aspects of self-regulated learning (Sailer & Homner, 2020).

These developments are particularly relevant in the domain of mathematics education. Mathematics is often perceived as a challenging subject, where learners frequently experience anxiety, low confidence, and negative attitudes (Ashcraft & Krause, 2007; Ramirez et al., 2018). Mathematical problem-solving requires not only procedural knowledge but also strategic thinking, persistence, and the ability to regulate both cognitive and emotional processes. As a result, self-regulated learning plays a particularly important role in this domain. However, many learners—including pre-service teachers—face difficulties in planning, monitoring, and regulating their learning during mathematical tasks.

Teacher education represents a critical context for examining these issues. Pre-service preschool and primary school teachers often enter training programs with fragile mathematical identities, limited confidence, and inconsistent self-regulation skills (Hodgen & Askew, 2007). These factors can influence not only their academic performance but also their future teaching practices, shaping how they present mathematics to young learners. Consequently, there is a strong need for pedagogical approaches that support both cognitive development and positive emotional experiences in mathematics.

In this context, gamification has been proposed as a promising approach for creating more engaging and supportive learning environments. By incorporating elements such as feedback, progression systems, and narrative contexts, gamification may enhance motivation, reduce anxiety, and encourage persistence. However, despite increasing interest in gamified learning, its role in supporting self-regulated learning processes remains insufficiently understood, particularly in mathematics-related contexts and within teacher education programs.

At the same time, recent research highlights the importance of learners' subjective experiences in shaping learning processes. Concepts such as enjoyment, flow, tension, and perceived competence are increasingly recognized as critical components of engagement and performance (IJsselsteijn et al., 2013). In gamified environments, these game-related experiences may influence how learners approach tasks, regulate their learning, and respond to challenges. Nevertheless, the role of game experience in mathematical problem-solving contexts has received limited attention.

Although there is a growing body of research on self-regulated learning, gamification, and mathematics education, these fields are often examined separately. Few studies have explored how these dimensions appear together within authentic learning environments, particularly in teacher education contexts. Furthermore, domain-specific instruments for measuring SRL in mathematics are relatively scarce, limiting the precision with which learning processes can be examined.

To address these gaps, the present dissertation adopts a multi-study research design structured into two main phases: preliminary research (Studies 1–3) and experimental research (Studies 4–6). The preliminary phase focuses on establishing conceptual and methodological foundations, including the exploration of pre-service teachers' perceptions of gamification, the examination of gamified problem-solving activities, and the development of a domain-specific instrument for measuring self-regulated learning in mathematics. The experimental phase builds on these foundations by investigating how gamified learning environments influence engagement, learning processes, and subjective experiences during mathematical problem-solving.

Overall, the dissertation aims to provide a comprehensive and empirically grounded understanding of how gamification functions in mathematics education, with particular attention to self-regulated learning processes and learners' game experiences. By examining these aspects within the context of teacher education, the research contributes to the development of pedagogical approaches that support active, reflective, and emotionally meaningful learning.

CHAPTER I. THEORETICAL FRAMEWORK

1.1 Self-Regulated Learning

Self-regulated learning (SRL) is a central construct in contemporary educational psychology, referring to the processes through which learners actively plan, monitor, and evaluate their cognition, motivation, and behavior during learning (Zimmerman, 2000; Panadero, 2017). SRL emphasizes learners' active role in controlling and directing their learning processes, as well as their ability to adapt strategies based on feedback and learning goals.

Theoretical models of SRL highlight its multidimensional nature. Zimmerman's cyclical model conceptualizes SRL as a process involving phases of forethought, performance, and self-reflection, while other frameworks emphasize the interaction of cognitive, motivational, and contextual factors (Pintrich, 2000). Across these perspectives, SRL is understood as a dynamic and adaptive process involving metacognitive monitoring, motivation regulation, and strategic behavior.

In mathematics education, SRL plays a particularly important role. Mathematical problem-solving requires planning, monitoring, and evaluating strategies, as well as persistence and emotional regulation. Learners frequently encounter difficulties in regulating these processes, especially when dealing with complex or non-routine problems (Ashcraft & Krause, 2007; Schoenfeld, 2016).

1.2 Gamification

Gamification refers to the use of game design elements in non-game contexts with the aim of enhancing motivation and engagement in learning environments (Deterding et al., 2011). Typical elements include points, feedback, levels, and narrative structures, which can contribute to more interactive and engaging learning experiences.

The effectiveness of gamification can be explained through motivational theories such as Self-Determination Theory, which emphasizes the importance of autonomy, competence, and relatedness in fostering intrinsic motivation (Ryan & Deci, 2000b). Gamified environments can support these needs by providing meaningful challenges, structured progression, and opportunities for interaction.

Recent research suggests that gamification may influence not only motivation but also learning processes. By offering clear goals, feedback, and progression, gamification can support key aspects of self-regulated learning, such as goal setting, monitoring, and reflection (Sailer & Homner, 2020).

1.3 Gamification and Self-Regulated Learning

Gamification and self-regulated learning share several structural similarities. Game elements such as goals, progress indicators, and feedback mechanisms align closely with the phases of SRL, supporting learners' planning, monitoring, and reflection processes.

Research indicates that gamified environments can make self-regulatory processes more visible and accessible, particularly through external scaffolding mechanisms (Azevedo et al., 2020). These features may support learners who experience difficulties in independently regulating their learning.

At the same time, the effectiveness of gamification in supporting SRL depends on its design. While well-designed gamification can enhance motivation and strategic engagement, an overreliance on extrinsic rewards may limit deeper learning processes (Deci et al., 1999). Therefore, gamification should be carefully aligned with pedagogical goals and learner needs.

1.4 Gamification in Mathematics Education

Mathematics is a domain in which learners frequently experience anxiety, low confidence, and negative attitudes, which may hinder engagement and performance (Ashcraft & Krause, 2007; Ramirez et al., 2018). In this context, gamification has been proposed as an approach for creating more engaging and supportive learning environments (Hamari et al., 2014; Sailer & Homner, 2020).

Gamified mathematics tasks can increase engagement, provide immediate feedback, and encourage persistence. They also have the potential to support conceptual understanding by embedding mathematical problems in meaningful and interactive contexts. However, their effectiveness depends on achieving a balance between challenge and support, as well as on ensuring alignment with learning objectives.

1.5 Game Experience

In gamified learning environments, learners' subjective experiences represent a key component of the learning process. Game experience includes dimensions such as enjoyment, flow, tension, and perceived competence (IJsselsteijn et al., 2013).

These experiences influence how learners engage with tasks and regulate their learning. Positive experiences, such as enjoyment and flow, are associated with increased persistence, motivation, and deeper engagement. In contrast, negative experiences, such as excessive tension or frustration, may reduce motivation and hinder learning (Pekrun et al., 2017).

1.6 Rationale, Objectives, and Research Framework

The increasing complexity of contemporary education and the rapid development of digital technologies highlight the need for learning environments that support learners' cognitive, motivational, and emotional development. These challenges are particularly evident in mathematics education and teacher preparation, where learners often struggle with confidence, engagement, and self-regulated learning (Panadero, 2017; Zimmerman, 2000).

The present research project addresses these issues by examining the role of gamification in mathematics-related learning contexts. Although SRL and gamification have both been widely studied, their combined application, particularly in teacher education, remains insufficiently explored (Sailer & Homner, 2020).

The main aim of the dissertation is to investigate how gamified learning environments function in relation to self-regulated learning and learners' subjective experiences. The research focuses on pre-service preschool and primary school teachers, for whom both mathematical competence and pedagogical innovation are essential.

The study is structured into six interrelated investigations organized into two phases. The preliminary phase (Studies 1–3) focuses on conceptual and methodological foundations, including the exploration of pre-service teachers' perceptions and the development of a domain-specific SRL measurement instrument. The experimental phase (Studies 4–6) examines learning processes in gamified environments, with particular attention to engagement, self-regulation, and game experience.

The overall research framework, including the relationship between identified research gaps and the contributions of the dissertation, is illustrated in Figure 1. The structure of the research project and the organization of the six studies are presented in Figure 2

Figure 1

Mapping of Research Gaps and Dissertation Contributions

DOMAIN	RESEARCH GAP	DISSERTATION CONTRIBUTION
Self-Regulated Learning (SRL)	SRL has rarely been examined in gamified mathematical contexts; no	Development and validation of the SRMPS scale (Study 3); SRL examined in gamified

	mathematical problem solving related SRL scale existed.	mathematical problem solving (Studies 2, 4, 5, 6).
Gamification	The effects of gamification on SRL processes remain unclear; most studies rely on short-term, one-shot interventions.	Long-term (5–10 week) gamified interventions (Studies 4–6); analysis of SRL, motivation, and strategy use over time.
Pre-service Teachers	Limited research on pre-service preschool and primary teachers; misconceptions about gamification.	Study 1 documents misconceptions and training needs; Studies 2–6 provide a comprehensive profile of SRL, motivation, emotions, and game experience.

Figure 2

The Structure of The Current Research Project

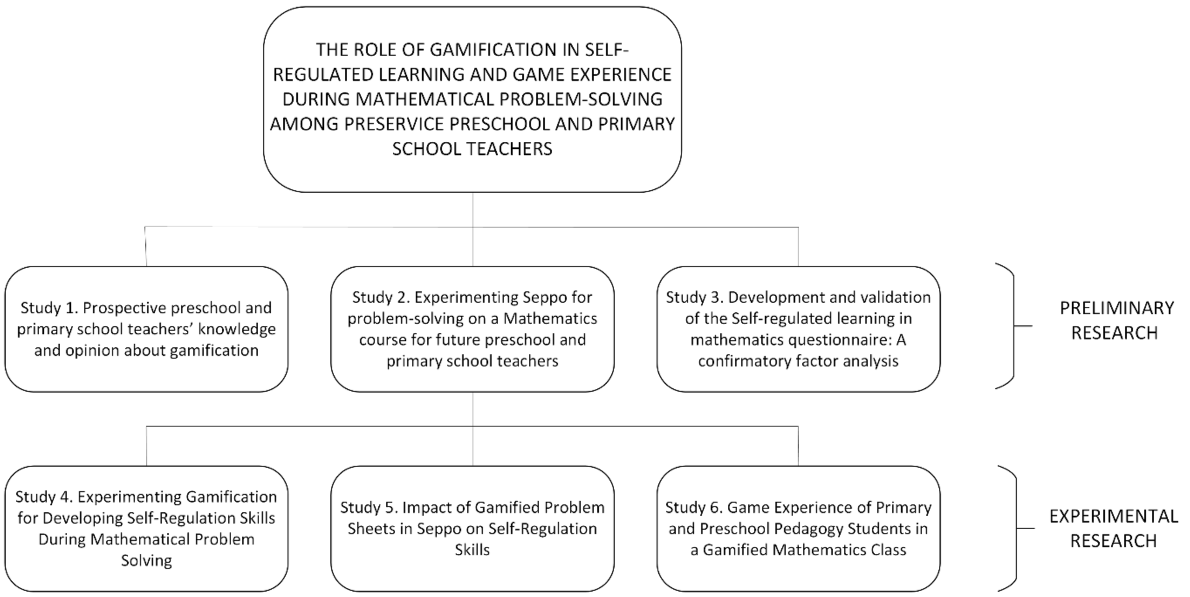


Figure 2 presents the overall structure of the dissertation, including the sequence and interrelation of the six studies.

CHAPTER II. PRELIMINARY RESEARCH: PRE-SERVICE TEACHERS' GAMIFICATION PERCEPTIONS AND THE DEVELOPMENT OF THE SRMPS SCALE

This chapter presents the preliminary phase of the research project, which consisted of three studies designed to explore pre-service teachers' existing conceptions, self-regulated learning processes, and emotional–motivational responses in mathematical problem-solving contexts. The aim of this phase was to establish the empirical and methodological foundations necessary for the subsequent experimental investigations. The findings of Studies 1–3 informed the development of the measurement tools and intervention principles applied in the later stages of the dissertation.

2.1 Study 1. Prospective Preschool and Primary School Teachers' Knowledge and Opinion about Gamification[1]

2.1.1. Introduction

In recent years, educational innovation has increasingly emphasized approaches that enhance learner engagement and support the development of key competencies. Among these approaches, gamification has gained attention as a method that can make learning activities more motivating and interactive. However, the effective use of gamification depends on teachers' familiarity with the concept and their ability to integrate game elements meaningfully into instruction.

Although gamification has been discussed widely in educational research, its classroom implementation remains limited, particularly in pre-university settings. Previous studies in the Romanian–Hungarian context show that only a minority of primary school teachers have encountered the term, and even those who have often confuse it with game-based learning (Hari & Zsoldos-Marchis, 2020). Such misconceptions highlight the need to examine how pre-service teachers understand gamification before expecting them to apply it in practice.

Because pre-service preschool and primary school teachers will soon be responsible for designing learning environments for young children, it is important to understand their existing knowledge, perceptions, and expectations regarding gamification. This study therefore

[1] T*his study has been published.*
Opriș, E.-T., Bálint-Svella, É., & Zsoldos-Marchis, I. (2021). Prospective preschool and primary school teachers' knowledge and opinion about gamification. *Acta Didactica Napocensia, 14*(1), 104–114. https://doi.org/10.24193/adn.14.1.8

investigates how pre-service teachers conceptualize gamification, what benefits and challenges they associate with it, and how familiar they are with its pedagogical applications.

2.1.2. Methodology

The study was conducted in February–March 2020 at Babeș-Bolyai University and involved 81 pre-service preschool and primary school teachers.

Data were collected using a structured questionnaire consisting of 18 items, including both closed-ended (Likert-scale and multiple-choice) and open-ended questions. The instrument was designed to assess participants' knowledge of gamification, their attitudes toward its use, and their perceptions of its benefits, limitations, and implementation.

First-year students received an introductory presentation on gamification, while second-year students also gained practical experience through gamified activities on the Seppo platform.

The data were analyzed using descriptive statistics for quantitative responses and qualitative content analysis for open-ended answers.

2.1.3. Results and Discussions

2.1.3.1. Students' Knowledge about Gamification

More than half of the participants (56.5%) were able to correctly define gamification as the use of game elements in non-game contexts. However, many students described gamification through its perceived benefits rather than its conceptual definition, emphasizing motivation, engagement, and interactive learning.

Conceptual confusion was also evident: 46.9% of participants did not distinguish between gamification and game-based learning. Students with prior experience demonstrated a more accurate understanding and emphasized intrinsic motivational aspects (Ryan & Deci, 2000a; Sailer et al., 2017).

2.1.3.2. Students' Opinion about the Benefits and Role of Gamification in Education

Participants reported highly positive attitudes toward gamification, with a mean perceived usefulness score of 4.69 (Martí-Parreño et al., 2016).

The perceived benefits were grouped into four categories: improved learning experience, increased learning effectiveness, enhanced motivation and engagement, and the development of social skills. Motivation and active participation emerged as the most prominent aspects, confirming previous research (Fromann, 2017; Song & Burton, 2018).

Participants also highlighted key roles of gamification, particularly its ability to diversify the learning process, increase student activation, and sustain motivation. Additional roles included supporting pedagogical goals, creating a relaxed classroom atmosphere, and promoting personal development.

2.1.3.3. Students' Opinion about the Disadvantages and Obstacles of Integrating Gamification in Education

Participants identified two main disadvantages: the time required for implementation and the potential shift of focus from learning content to gameplay. Some participants expressed concerns that excessive emphasis on rewards may reduce intrinsic motivation (Werbach & Hunter, 2012).

The most frequently mentioned issues were related to teachers' attitudes and preparedness. Participants emphasized that educators often perceive gamification as time-consuming and may lack the methodological knowledge required for effective implementation.

In addition, curricular constraints, particularly limited time, were identified as factors restricting the use of gamification in educational practice.

2.1.3.4. Students' Opinion about Methodology of Integrating Gamification in Education

Most participants (72.84%) preferred combining digital and non-digital gamification approaches. Classroom tasks were identified as the easiest elements to gamify, while more complex applications, such as full-course gamification, were perceived as less feasible.

Overall, participants considered gamification most suitable for supporting practice-oriented classroom activities and increasing student engagement, particularly in tasks requiring active participation.

2.1.4. Conclusions

The findings indicate that pre-service teachers hold positive attitudes toward gamification but often lack a clear conceptual understanding. While they recognize its motivational benefits, they also perceive practical challenges related to implementation.

The results highlight the importance of developing both theoretical knowledge and practical competencies in gamification within teacher education programs, thereby supporting its effective integration into educational practice.

2.2 Study 2. Experimenting Seppo for Problem-Solving on a Mathematics Course for Future Preschool and Primary School Teachers[2]

2.2.1 Introduction

Online mathematics instruction presented challenges for maintaining student engagement, particularly in collaborative problem-solving activities. While face-to-face learning supports interaction and immediate feedback, online environments often limit communication and active participation (Uz-Bilgin & Gül, 2019).

Gamification offers a potential solution by integrating game elements such as feedback, progression, and narrative into learning environments (Deterding et al., 2011; Kapp, 2012). Previous research highlights its benefits, including increased motivation, participation, and improved learning outcomes (Barata et al., 2017; Zsoldos-Marchis, 2020).

This study aimed to examine how pre-service teachers perceive gamified mathematical problem-solving activities implemented via the Seppo platform, with a focus on both individual and group-based formats.

2.2.2 Methodology

The study was conducted in February–March 2021 at Babeș-Bolyai University.

A total of 41 second-year pre-service preschool and primary school teachers participated, of whom 38 completed both individual and group gamified activities. All participants were female, aged between 19 and 21.

Data were collected using a questionnaire consisting of 21 items (demographic, closed-ended, and open-ended questions), focusing on students' experiences with gamified problem-solving and their perceptions of individual versus group work.

Two gamified activities were designed using the Seppo platform:

- Game 1 (individual): narrative-based, using real-life problems (Figure 3)
- Game 2 (group): more abstract mathematical tasks (Figure 4)

Both games incorporated multiple-choice items, feedback mechanisms, and optional solution uploads.

[2] Findings from this study have been published in the following articles.
Zsoldos-Marchis, I., & Opriș, E.-T. (2021). Experimenting Seppo for problem-solving on a mathematics course for future preschool and primary school teachers. In R. Jugureanu, G. Albeanu, D. M. Popovici, O. Istrate, & A. Adăscăliței (Eds.), *Proceedings of the 16th International Conference on Virtual Learning* (pp. 215–222).
Opriș, E.-T. (2021). A diákok véleménye az egyéni illetve a csoportos játékosított feladatmegoldásról [Students' opinions on individual and group gamified problem-solving]. In I. Lőrincz (Ed.), *A Kárpát-medencei magyar tannyelvű pedagógusképzés és neveléstudományi kutatás aktuális és történeti tárházának értékei* (pp. 395–402). Pécsi Tudományegyetem Bölcsészet- és Társadalomtudományi Kar Neveléstudományi Intézet.

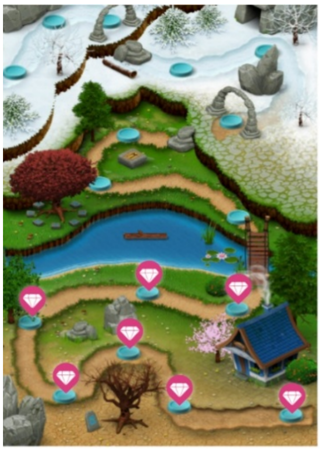
Quantitative data were analyzed using descriptive statistics and t-tests, while qualitative responses were analyzed through categorical content analysis.

Figure 4

Map of the Individual Game

Figure 5

Map of the Group Game



2.2.3 Results and Discussion

2.2.3.1 Comparison of Problem-Solving with Problems Given on a Problem-Sheet to Problems Integrated in a Game

Compared to traditional problem-sheet-based activities, gamification increased students' engagement and motivation. Participants reported higher levels of involvement and immersion during problem solving, while the game elements did not appear to reduce concentration or compromise the quality of their solutions.

2.2.3.2 Comparison of the Two Experimental Games

Both games received positive evaluations from the participants, with an identical mean score of 4.02 (SD = 0.97 for Game 1 and SD = 0.92 for Game 2). Although the overall evaluation of the two games was similar, students expressed different preferences regarding specific game elements. The story, the mathematical problems, and the feedback were more frequently preferred in Game 2, whereas the board design was rated more positively in Game 1. Interestingly, despite Game 1 incorporating everyday-life problems requiring mathematical reasoning, students showed a stronger preference for the purely mathematical problems featured in Game 2. These findings suggest that different design elements contributed to students' positive experiences, even though both games were perceived as equally enjoyable overall.

2.2.3.3 Impact of Different Game Elements and Rules on Students' Motivation

The most motivating aspects of the gamified environment were the possibility of choosing the order of task completion and revisiting previously solved tasks (both M = 4.41), followed by continuous progress monitoring (M = 4.09). By comparison, the narrative framework (M = 3.19) and points (M = 2.75) played a less prominent role in supporting motivation.

2.2.3.4 Emotions Experienced During the Games

Students reported a high level of immersion during the game (M = 4.12, SD = 1.12). They also frequently experienced a sense that time passed more quickly than usual (M = 3.97, SD = 1.17) and reported temporarily forgetting their everyday concerns (M = 3.70, SD = 1.34). Feelings of competitiveness were present at a moderate level (M = 3.63, SD = 1.29), while concerns about personal performance were less pronounced (M = 2.92, SD = 1.38). Overall, the results suggest that the game successfully captured students' attention and encouraged immersion without generating excessive performance-related anxiety.

2.2.3.5 Impact of Gamification on Students' Achievement

Students generally perceived gamification as having a positive impact on their achievement. The scoreboard emerged as the most influential element (M = 4.02, SD = 1.10), while participants also reported that the gamified environment supported their learning performance and increased their motivation to achieve academic goals (both M = 3.73, SD = 1.11).

2.2.3.6 Students' Opinion about Gamification in Seppo

Students evaluated the Seppo platform positively, with a mean score of 4.26 (SD = 0.50), indicating a high level of satisfaction with the gamified learning environment. Although 41.5% of the participants had previous experience with other gamification platforms, such as Wordwall, Kahoot, LearningApps, and Minecraft, no statistically significant differences were found between students with and without prior gamification experience in their evaluation of Seppo.

2.2.3.7 Students' Opinions on Individual and Group Gamified Problem-Solving

Students reported highly positive experiences with teamwork during the group-based game. Cooperation among team members received the highest ratings (M = 4.63, SD = 0.59), followed by active participation of all group members (M = 4.36, SD = 0.94) and smooth collaboration (M = 4.26, SD = 1.06). Task distribution within groups was less common (M = 3.21, SD = 1.51), while feelings of competition among teammates remained relatively low (M = 2.26, SD = 1.45), suggesting that most groups approached the tasks collaboratively rather than competitively.

When comparing individual and group-based gamified problem solving, students generally favored the group format. More participants reported higher motivation, lower stress levels, and a more positive overall experience during the group game. In contrast, individual gameplay was more often associated with greater effort to solve tasks correctly, deeper reflection on solutions, and stronger competitive feelings. These findings suggest that group-based gamification primarily supports engagement and emotional comfort, whereas individual gameplay may encourage deeper cognitive involvement and personal challenge.

2.2.4 Conclusions

The findings indicate that gamified problem-solving activities can significantly enhance students' engagement and motivation compared to traditional methods. Gamification supported immersion and active participation without reducing concentration on mathematical content.

Group-based gamification proved particularly effective in promoting motivation, cooperation, and emotional comfort, while individual work supported deeper reflection and accuracy. Additionally, game design elements such as autonomy, feedback, and progress tracking played a key role in influencing motivation.

Overall, the results suggest that gamification, when thoughtfully designed, can support diverse learning needs and improve mathematical problem-solving experiences in teacher education.

2.3 Study 3. Development and Validation of Self-Regulation During Mathematical Problem-Solving Scale: A Confirmatory Factor Analysis

2.3.1 Introduction

Self-regulated learning (SRL) plays a key role in mathematics education, where problem solving requires not only cognitive strategies but also motivation, persistence, and reflective thinking (Pintrich, 2000; Zimmerman, 2000). Due to the domain-specific nature of mathematical problem solving, there is a need for instruments that capture SRL processes specifically in mathematical contexts.

This study addresses this gap by developing and validating the Self-Regulation During Mathematical Problem-Solving Scale (SRMPS), a 30-item instrument integrating metacognitive, motivational, and volitional components of SRL. The scale is based on established instruments (e.g., Bacsa, 2012; Lim & Chapman, 2013; Yoong & Qian, 2012) and includes newly developed items to ensure domain relevance.

The SRMPS consists of six dimensions:

- Check / Self-Control
- Confidence / Self-Efficacy
- Multiple Solution Strategies
- Value / Usefulness
- Intrinsic and Extrinsic Goal Orientation
- Self-Regulation of Motivation

2.3.2. Methodology

The study involved 526 undergraduate students enrolled in the Preschool and Primary Pedagogy program at Babeș-Bolyai University. All participants were female, aged between 18 and 56 years.

Data were collected online in 2021 through a 30-item Likert-scale questionnaire (SRMPS). Participation was voluntary and anonymous.

The instrument was constructed by adapting and integrating items from validated SRL scales and refining them to reflect the demands of mathematical problem solving. Data analysis included descriptive statistics and confirmatory factor analysis (CFA) using the WLSMV estimator, appropriate for ordinal data (Finney & DiStefano, 2013).

2.3.3 Statistical Analysis

As a preliminary step, the univariate normality of all observed variables was assessed. For each item, descriptive statistics were computed, including means and standard deviations, as well as skewness and kurtosis indices to evaluate the distribution of the data.

We used confirmatory factor analysis (CFA) with Weighted Least Squares Mean and Variance adjusted estimator (WLSMV) to test the six-factor structure of the Self-Regulation During Mathematical Problem-Solving Scale. The WLSMV estimator is particularly appropriate for ordinal data and is robust to violations of multivariate normality, providing more accurate parameter estimates and standard errors under such conditions (Finney & DiStefano, 2013). Model fit was evaluated with the following indices and their respective cut-off values: Comparative Fit Index (CFI; >0.90 adequate fit, >0.95 good fit), Tucker-Lewis Index (TLI; >0.90 adequate fit, >0.95 good fit), and the Root Mean Square Error of Approximation (RMSEA; <0.08 adequate fit, <0.05 good fit) (Hu & Bentler, 1999).

2.3.4 Results and Discussion

3.2.4.1 Descriptive Statistics

Descriptive statistics including means, standard deviations, skewness, and kurtosis are presented in Table 1. The results indicated that several items exhibited moderate to substantial deviations from normality. Skewness values ranged from –2.004 to +0.528, while kurtosis values ranged from –0.924 to +3.551. Given these findings and the ordinal nature of the scale, in subsequent CFA analyses the WLSMV estimator was employed.

Table 1

Overview and Descriptive Statistics for Items.

No.	Item	Source	Mean (SD)	Skewness (SE)	Kurtosis (SE)
1.	When I know I have made a mistake in solving a problem, I will try to find out why.	Yoong & Qian, 2012 Tanner & Jones, 2003	4.11 (.901)	-.928 (.106)	.687 (.213)
2.	After I have solved a problem, I will go through the solution again and check if I have made any mistakes.	Yoong & Qian, 2012	4.00 (1.021)	-.838	-.051
3.	After I have solved a problem, I will ask myself if the answer makes sense to the given problem.	Yoong & Qian, 2012	3.28 (1.159)	-.295	-.665

4.	After I've solved a problem, I ask if I have learnt something new.	Marchis, 2012	3.31 (1.210)	-.219	-.870
5.	After I have solved a problem, I reflect on the learning experience.	Annemieke & Egbert, 2012	3.34 (1.187)	-.305	-.799
6.	I am good at using mathematics to solve real-life problems.	Yoong & Qian, 2012	2.98 (1.119)	-.029	-.697
7.	I am good in solving mathematics problems.	Yoong & Qian, 2012 Banks, 2014	3.05 (1.110)	-.064	-.610
8.	Usually, I can help my classmates, when they ask me for help in problem-solving.	Nicolaidou & Philippou, 2004	3.26 (1.119)	-.256	-.649
9.	After I solve a problem, I know if I've solved it correctly or not.	Marchis, 2012	3.02 (1.018)	-.027	-.554
10.	I am able to solve mathematics problems without too much difficulty.	Lim & Chapman, 2013 Banks, 2014	2.98 (1.094)	.072	-.545
11.	When I start solving a mathematical problem, I usually feel that I would not manage to give a solution.	Nicolaidou & Philippou, 2004	3.47 (1.191)	-.478	-.649
12.	I do not feel sure about myself in problem-solving.	Nicolaidou & Philippou, 2004	3.31 (1.224)	-.304	-.832
13.	I am not good at giving reasons in mathematics.	Yoong & Qian, 2012	3.11 (1.187)	-.159	-.831
14.	I do not like to think of other ways to solve the same problem.	Yoong & Qian, 2012	3.40 (1.206)	-.406	-.712
15.	I often figure out different ways to solve mathematics problems.	Yoong & Qian, 2012	3.13 (1.131)	-.038	-.841

16.	I try to understand the different solutions given by my classmates.	Yoong & Qian, 2012	3.71 (.979)	-.535	-.093
17.	After I have solved a problem, I will look for other methods to solve it.	Yoong & Qian, 2012 Marchis, 2012	2.35 (1.073)	.528	-.331
18.	Mathematical problem solving helps to develop the mind and teaches a person to think.	Lim & Chapman, 2013, modified	4.27 (.906)	-1.140	.788
19.	I believe solving mathematical problems helps me with problem solving in other areas.	Lim & Chapman, 2013, Banks, 2014, modified	3.98 (1.007)	-.768	-.152
20.	Problem solving competence is important in everyday life.	newly developed	4.61 (.739)	-2.004	3.551 (213)
21.	Problem solving competence is important in many careers.	newly developed	4.58 (.759)	-1.951	3.769
22.	I complete the assigned tasks because I believe they are important for my future.	Bacsa, 2012 Vandevelde & Van Keer, 2011	3.78 (1.099)	-.596	-.456
23.	I complete the assigned tasks because I find them useful.	Bacsa, 2012 Vandevelde & Van Keer, 2011	3.71 (1.059)	-.453	-.528
24.	I complete the assigned tasks because I find them interesting.	Bacsa, 2012 Vandevelde & Van Keer, 2011	3.20 (1.109)	-.164	-.613
25.	I complete the assigned tasks because I enjoy them.	Bacsa, 2012 Vandevelde & Van Keer, 2011	3.00 (1.173)	.028	-.815
26.	I complete the assigned tasks because they help me develop my problem-solving skills.	Bacsa, 2012 Vandevelde & Van Keer, 2011	3.87 (1.034)	-.680	-.177
27.	While working on tasks, I encourage myself to keep going.	Bacsa, 2012 Vandevelde & Van Keer, 2011	3.77 (1.059)	-.549	-.424

28.	Even when I would rather do something else, I make myself work on the tasks.	Bacsa, 2012 Vandevelde & Van Keer, 2011	3.32 (1.218)	-.202	-.924
29.	When I feel like giving up, I remind myself why it is important to complete the assigned task.	Bacsa, 2012 Vandevelde & Van Keer, 2011	3.47 (1.169)	-.383	-.771
30.	While working on tasks, I encourage myself not to give up.	Bacsa, 2012	3.90 (1.082)	-.737	-.254

Note: All items were rated on a five-point Likert scale ranging from 1 (“It doesn’t characterize me at all”) to 5 (“It totally characterize me”). Items 2-6, 8-10, 12-17 are shown in their original English versions. Items 1, 7, 11, 18, 19 are shown in their original English versions with modifications made for clarity. Items 22-30 was translated into English. Items 20 and 21 are new items, developed based on statements. *p < .05

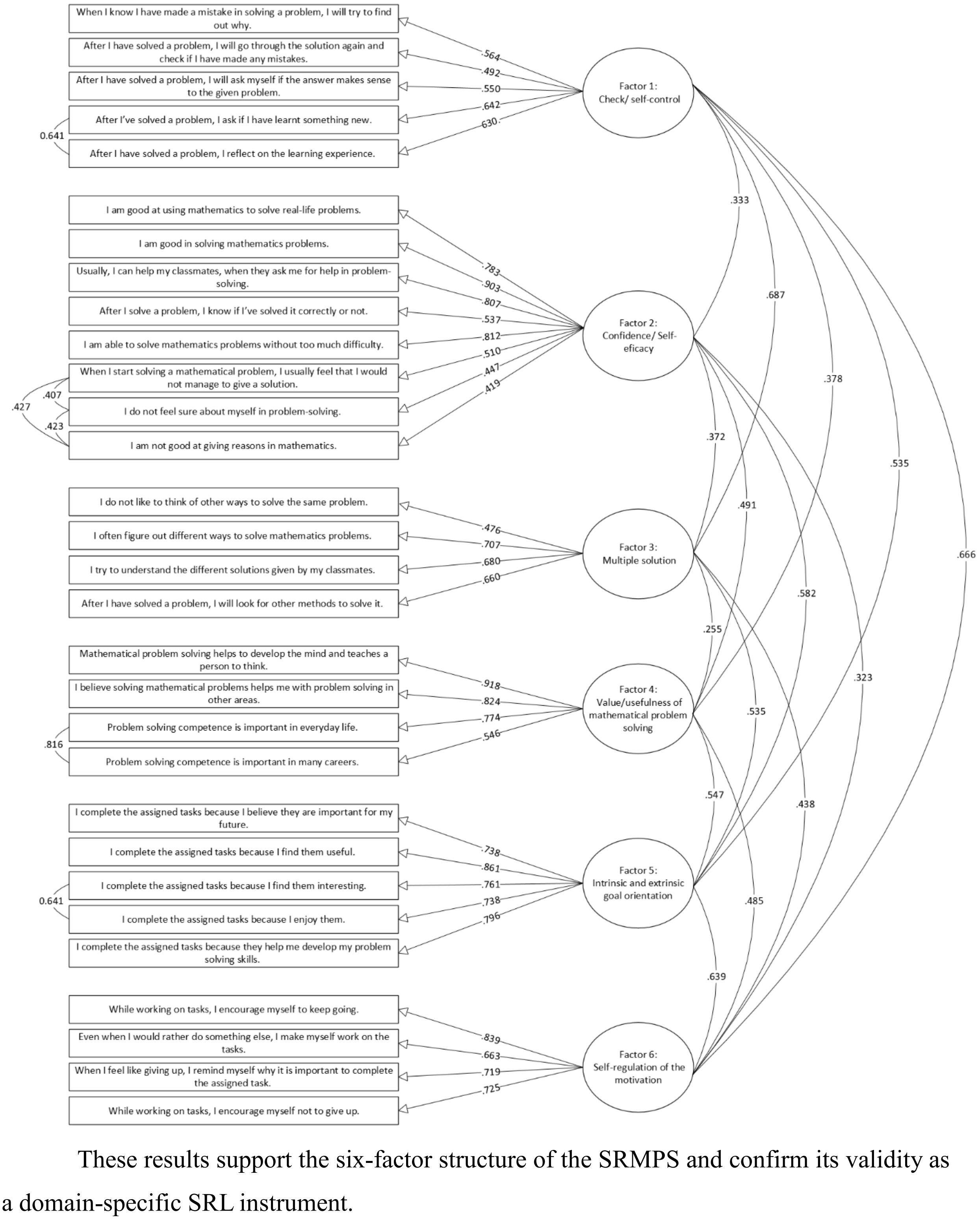
3.2.4.2 Confirmatory Factor Analysis

The initial confirmatory factor analysis indicated inadequate model fit χ^2 (390) = 1673.270, $p < 0.001$, CFI = 0.909, TLI = 0.889, RMSEA = 0.080. High residual covariances were observed between several items, reflecting conceptual overlap among items derived from similar theoretical constructs (e.g., value, goal orientation, confidence, self-control).

After allowing theoretically justified residual covariances, the model achieved acceptable model fit CFI = .946, TLI = 939, RMSEA = .064 (see Figure 5).

Figure 6

Adequate Model Fit



These results support the six-factor structure of the SRMPS and confirm its validity as a domain-specific SRL instrument.

2.3.5 Conclusion

The study successfully developed and validated the SRMPS, a 30-item scale measuring self-regulated learning in mathematical problem solving.

The final model demonstrated adequate fit, confirming that the six-factor structure provides a coherent and theoretically grounded representation of SRL. The instrument captures both cognitive and motivational dimensions and can support research and educational practice by identifying strengths and weaknesses in students' self-regulation.

2.3.6 Limitations and Future Directions

Several limitations should be noted. The sample consisted only of female students from one program, limiting generalizability. The use of self-report data may also introduce biases.

Although the model achieved adequate fit, residual covariances suggest some conceptual overlap between items. Future research could refine the instrument, test measurement invariance, and validate the scale in different populations.

The SRMPS may also be used in future studies to examine the relationship between SRL and instructional approaches, such as gamification, in mathematics education.

2.4 Conclusion of the Preliminary Research

The findings of the preliminary studies (Studies 1–3) provided a coherent empirical foundation for the subsequent experimental phase of this dissertation. Study 1 revealed that pre-service preschool and primary teachers often hold misconceptions about gamification, highlighting the need for targeted pedagogical support. Study 2 demonstrated that learners' self-regulated learning processes in mathematical contexts are frequently inconsistent and fragile, underscoring the importance of examining SRL in more complex and dynamic learning environments. Study 3 addressed a major methodological gap by developing and validating the Self-Regulated Learning in Mathematics Problem Solving Scale (SRMPS), offering a domain-specific instrument capable of capturing cognitive, motivational, and emotional regulatory processes.

Taken together, these studies confirmed that pre-service teachers represent a population for whom the integration of gamification and SRL-focused instructional design is both necessary and underexplored. They also established the conceptual, empirical, and methodological groundwork required for investigating how learners regulate their behaviour, experience game elements, and respond emotionally during extended gamified mathematical activities. These insights directly informed the design of the experimental studies (Studies 4–6), which aimed to examine SRL, motivation, strategy use, and game experience within long-term gamified interventions.

Building on the insights gained from the preliminary studies, the next phase of the dissertation focuses on examining how these cognitive, motivational, and emotional patterns unfold within long-term gamified mathematical learning environments. The following experimental studies (Studies 4–6) were therefore designed to investigate these processes in more dynamic and sustained instructional contexts.

CHAPTER III. EXPERIMENTAL RESEARCH: GAMIFICATION FOR DEVELOPING SRL SKILLS AND STUDYING GAME EXPERIENCE

3.1 Study 4. Experimenting Gamification for Developing Self-Regulation Skills During Mathematical Problem Solving[3]

3.1.1 Introduction

Mathematical problem solving requires not only cognitive strategies but also the ability to plan, monitor, and regulate one's thinking. However, research shows that pre-service teachers often struggle with non-routine problems and self-regulation processes (Asman & Markovits, 2009; Zsoldos-Marchis, 2014).

Since self-regulation plays a key role in effective problem solving (Auliya & Usman, 2019), developing these skills is essential in teacher education. This study examines whether gamified problem sheets can support the development of self-regulated learning (SRL) during mathematical problem solving.

3.1.2 Methodology

The study was conducted during the second semester of the 2020/2021 academic year.

The sample consisted of 54 second-year pre-service teachers, divided into:

- experimental group (n = 27)
- control group (n = 27)

Self-regulation was measured using the SRMPS scale (Study 3), encompassing six dimensions: check/self-control, confidence/self-efficacy, multiple solutions, value/usefulness, goal orientation, and motivation regulation.

3.1.2.1 Intervention

The intervention was implemented over five weeks within the course Mathematics in Primary and Preschool Education. Both the experimental and control groups solved the same mathematical problems in teams, but the experimental group used gamified problem sheets on the Seppo platform, while the control group worked in Schoology. The activities also included prompts designed to encourage reflection on cognitive and emotional processes during problem solving.

[3] *Parts of this study have been published.*
Egri, E., Opriş, E.-T., & Zsoldos-Marchis, I. (2022). Experimenting gamification for developing self-regulation skills during mathematical problem solving. In *INTED2022 Proceedings* (pp. 10155–10162). https://doi.org/10.21125/inted.2022.2671

The gamified worksheets were embedded in a travel-themed narrative in which students explored European locations and earned badges by successfully completing mathematical tasks. As illustrated in Figure 6, progression was represented through a map-based structure that allowed students to choose the order of task completion. In addition to mathematical problems, the activities included self-regulatory prompts and narrative elements intended to support engagement and reflection.

Figure 7

The Map for the Gamified Problem Sheets

3.1.3 Results

To examine the effects of the intervention, mixed-design ANOVAs were conducted with Time (pretest vs. posttest) as a within-subjects factor and Group (experimental vs. control) as a between-subjects factor. Most self-regulated learning dimensions remained stable across time and groups. A significant Time × Group interaction emerged only for multiple solution strategies, $F(1, 52) = 6.54$, $p = .014$, reflecting a slight increase in the control group (from $M = 2.71$ to $M = 2.85$) and a decrease in the experimental group (from $M = 3.07$ to $M = 2.70$). Furthermore, a significant group effect was found for motivation regulation, $F(1, 52) = 4.77$, $p = .034$. No significant effects were observed for self-control, confidence, value/usefulness, or goal orientation. These findings indicate that the intervention produced only limited changes in students' self-regulated problem-solving processes.

3.1.4 Discussion and Conclusions

The findings indicate that the intervention had only limited effects on self-regulated learning. A significant effect was observed solely for multiple solution strategies, suggesting that gamification may support greater flexibility in problem solving, a finding consistent with previous research (Deterding et al., 2011; Hamari et al., 2014). In contrast, no significant effects were found for self-control, confidence, value beliefs, or goal orientation. These results suggest that, although gamification may enhance specific aspects of problem solving, the development of self-regulated learning likely requires longer interventions and explicit instructional support (Bandura, 1997; Pintrich, 2000; Zimmerman, 2002). Consequently, gamification appears to be most effective when integrated into a broader pedagogical framework that includes self-regulation strategies and guided reflection.

3.2 Study 5. Impact of Gamified Problem Sheets in Seppo on Self-Regulation Skills[4]

3.2.1 Introduction

Problem-solving skills are essential in mathematics education and strongly connected to self-regulated learning (SRL), including goal setting, monitoring, and motivation (Bandura, 1991; Zimmerman, 2002). However, pre-service teachers often show only moderate levels of SRL and need further development (Zsoldos-Marchis, 2014).

Gamification has been suggested as a potential tool for supporting SRL, particularly by enhancing motivation and engagement (K. Li et al., 2022). Building on previous findings, where group-based gamification showed limited or negative effects (Egri et al., 2022), this study examines an individual gamified intervention, incorporating flexible task selection and explicit SRL prompts.

3.2.2 Methodology

The study was conducted during the first semester of the 2021/2022 academic year.

Participants included 118 second-year pre-service teachers:

- experimental group: 82 students
- control group: 36 students

Additionally, 9 students from the experimental group participated in semi-structured interviews.

3.2.2.1 Instrument

Self-regulation was measured using the SRMPS scale (30 items, Likert-scale), covering: check/self-control, confidence/self-efficacy, multiple solutions, value/usefulness, goal orientation, motivation regulation.

[4] *Parts of this study have been published.*
Opriș, E.-T., Zsoldos-Marchis, I., & Egri, E. (2024). Impact of gamified problem sheets in Seppo on self-regulation skills. *Open Education Studies, 6*, 20240024. https://doi.org/10.1515/edu-2024-0024

Interviews were conducted to explain quantitative findings and explore students' experiences in depth.

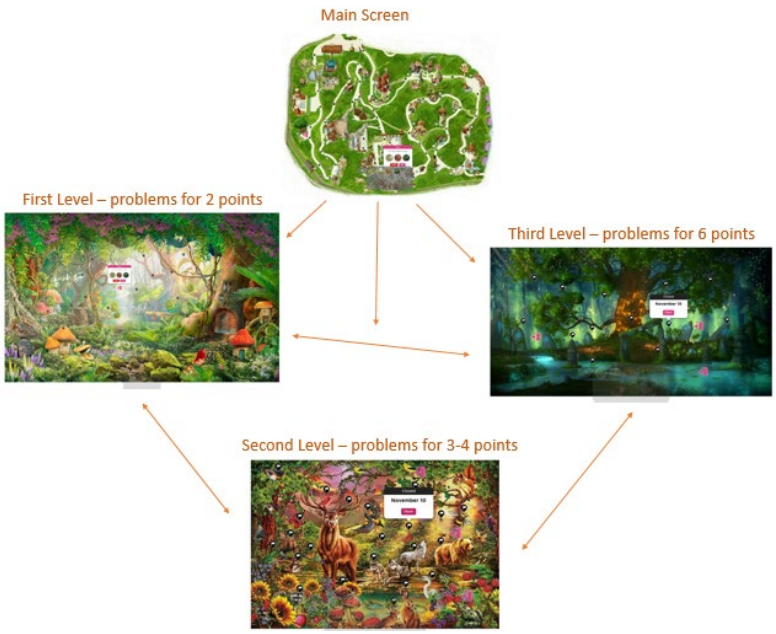
3.2.2.2 Intervention

The experimental group participated in a six-week intervention consisting of weekly two-hour seminars. Students solved gamified mathematical problem sheets on the Seppo platform, individually rather than in teams, based on the findings of a previous study (Egri et al., 2022). The game was embedded in a fairy-tale narrative and organized into three difficulty levels, allowing students to freely choose both the level and the order of the tasks (Figure 7).

The activities covered the main topics of the mathematics course and incorporated self-regulation prompts encouraging students to reflect on their strategies, emotions, task difficulty, and solution checking. The gamified environment integrated several motivational elements identified by Huang and Hew (2018), including goals, choice, immediate feedback, and challenges. Students earned points through task completion and could monitor their performance on a leaderboard, while automatic feedback supported continuous monitoring of their work.

Figure 8

The Map for the Gamified Problem Sheets.



3.2.3 Results

3.2.3.1 Results Based on the Self-Regulated Problem-Solving Scale

Mixed-design ANOVAs revealed limited effects of the intervention on self-regulated problem solving. Significant Time × Group interactions were observed for check/self-control, $F(1, 116) = 4.62$, $p = .034$, and motivation regulation, $F(1, 116) = 4.23$, $p = .042$, while confidence/self-efficacy showed a significant decline over time, $F(1, 116) = 5.56$, $p = .020$. Significant group differences were found for value/usefulness of mathematical problem solving, $F(1, 116) = 13.89$, $p < .001$, and motivation regulation, $F(1, 116) = 59.61$, $p < .001$. No significant effects were observed for multiple solution strategies or goal orientation, indicating that the overall impact of the intervention on self-regulated problem-solving processes was limited.

3.2.3.2 Results of the Interviews

To complement the quantitative findings, semi-structured interviews were conducted with nine students and analyzed qualitatively using MAXQDA. Three main themes emerged from the analysis: level selection, goal orientation, and motivation.

Students evaluated positively the possibility of freely moving between difficulty levels. Most participants started with easier tasks and gradually progressed to more difficult ones, using successful completion of simpler tasks to build confidence. Several students reported that the freedom to choose levels enhanced their sense of control and supported strategic decision-making during problem solving.

Regarding the goal of collecting a minimum number of points, most students continued solving tasks even after achieving the required score, reflecting a tendency to approach the gamified worksheets similarly to traditional problem sheets. However, some participants experienced frustration due to time constraints and the large number of available tasks.

Motivation emerged as the most prominent theme. Seven of the nine interviewed students reported that the gamified worksheets were more motivating than traditional problem sheets. Both intrinsic and extrinsic motivational factors were identified. Students frequently mentioned the story, visual design, immediate feedback, points, and leaderboard as sources of motivation, while others emphasized the satisfaction of solving problems successfully and personal skill development. Some participants also reported a gradual shift from extrinsic to intrinsic motivation over the course of the intervention.

In addition, most students indicated that the gamified environment helped them maintain motivation more easily than traditional worksheets and reduced the need for deliberate self-encouragement during task completion.

3.2.4 Discussion and Conclusions

The findings indicate that the gamified intervention had mixed effects on students' self-regulated learning. While gamification appeared to support engagement and motivation, its impact varied across the different SRL dimensions. Significant effects were observed for motivation regulation, perceived value, self-efficacy, and self-control, whereas no significant changes were found for goal orientation or problem-solving flexibility.

Interview data suggest that game elements such as the narrative framework, visual design, immediate feedback, and the freedom to choose task difficulty contributed to students' motivation and sustained engagement. However, the decline observed in self-efficacy and self-control indicates that gamification alone may not be sufficient to foster more complex self-regulatory processes. Consistent with previous research, these processes develop gradually and typically require explicit instructional support, metacognitive guidance, and extended practice (Bandura, 1991; Pintrich, 2000; Zimmerman, 2002).

Overall, the results suggest that gamification can make problem-solving activities more engaging and enjoyable, but its effects on self-regulated learning are not uniformly positive. The findings highlight the importance of integrating gamification within a broader pedagogical framework that includes self-regulation strategies and guided reflection (K. Li et al., 2022).

Several limitations should be acknowledged. The relatively short duration of the intervention may have limited the development of self-regulated learning processes (Hanus & Fox, 2015). In addition, the study relied primarily on self-report measures, although qualitative interviews were used to complement and contextualize the quantitative findings.

3.3 Study 6. Game Experience and Self-Regulated Problem Solving of Primary and Preschool Pedagogy Students in a Gamified Mathematics Class[5]

3.3.1 Introduction

Developing problem-solving competence is a key goal of mathematics education, yet pre-service teachers often struggle with non-routine tasks and show limited confidence (Marchiș, 2013b; Näveri et al., 2011). Since emotional factors and motivation strongly influence engagement in mathematical problem solving, gamification has been proposed as a way to create more engaging learning environments (Deterding et al., 2011).

[5] *Parts of this study have been published.*
Zsoldos-Marchiș, I., Opriș, E.-T., & Illyés, M. (2023). Game experience of primary and preschool pedagogy students in a gamified mathematics class. *Journal of Research in Higher Education, 7*, 67–89. https://doi.org/10.24193/JRHE.2023.2.3

This study examines a 10-week gamified mathematics intervention implemented in Seppo, focusing on students' game experience, motivation, perceived stress, and their relationship with self-regulated problem solving.

3.3.2 Methodology

The quasi-experimental study was conducted during the 2022–2023 academic year with 32 second-year pre-service teachers (mostly female).

3.3.2.1 Intervention

A team-based Seppo game was developed to integrate mathematical problem-solving and travel-planning activities within a fairy-tale narrative. The intervention lasted ten weeks, with one two-hour session per week. Students worked in teams and completed mathematical and real-life tasks embedded in a storyline in which fairy-tale characters had to be rescued and books republished.

The first and final stages were played in the university building using a location-based gameboard, while the remaining stages were implemented on virtual maps in Seppo. As illustrated in Figure 8 and Figure 9, the game combined physical and virtual exploration with mathematical problem-solving tasks. Students progressed through different levels, sometimes freely and sometimes by fulfilling advancement requirements. Throughout the game, teams managed virtual financial resources and made collective decisions while completing the tasks.

Figure 8

Board (Map) of the Game in the Building

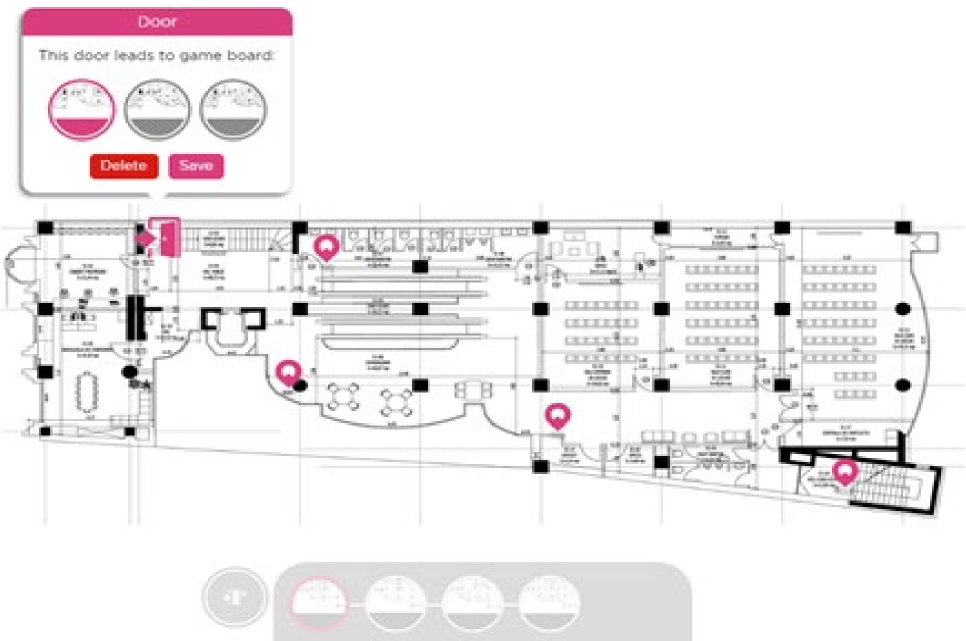
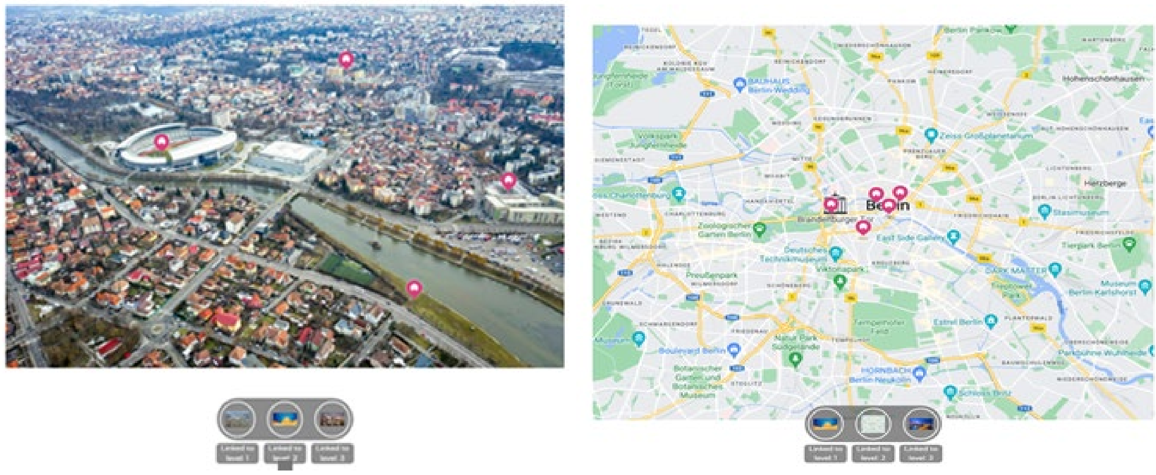


Figure 9

Boards (Maps) of the Games



A B

3.3.2.2 Instruments

Following the intervention, students completed the GAMEX (Eppmann et al., 2018), a researcher-developed Game Experience Questionnaire, and the SRMPS (Study 3). Data were collected online after the 10-week intervention and analyzed using descriptive statistics, paired-samples t-tests, ANOVA, correlations, and qualitative content analysis with MAXQDA.

3.3.3 Results and Discussion

3.3.3.1 Game Experience Measured with the GAMEX Scale

Students reported high levels of enjoyment ($M = 3.91$, $SD = 0.77$) and creative thinking ($M = 3.52$, $SD = 0.95$), while lower scores were observed for absorption, activation, and dominance. Significant positive correlations were found between creative thinking, absorption, and activation, suggesting that students who perceived the game as more creative also reported higher engagement and immersion.

3.3.3.2 Motivation and its Change During the Game

Teamwork emerged as the most motivating element of the game (71.88%), followed by collecting money (56.25%), progressing through levels (37.50%), and the narrative framework (31.25%). Most students reported a combination of intrinsic and extrinsic motivation, while purely intrinsic motivation was less common. However, no significant differences were found between motivational profiles and game experience dimensions. Consistent with previous findings, motivation tended to increase at the beginning of the intervention and decrease toward the end for a substantial proportion of students (Hanus & Fox, 2015).

3.3.3.3 Students' Opinion About the Seppo Game

Students expressed a clear preference for the version involving physical movement within the university building, which they rated significantly higher than the virtual-map version ($z = 3.014$, $p = .002$). The story ($M = 4.41$, $SD = 0.91$) and teamwork ($M = 4.31$, $SD = 0.96$) were the most highly valued aspects of the game. In addition, travel-planning tasks were rated significantly more positively than mathematical tasks and self-regulation questions ($F(2) = 3.976$, $p = .024$). Students particularly appreciated the variety of tasks, the narrative framework, and opportunities for collaboration.

3.3.3.4 Students' Perceived Stress and Stress Factors During the Seppo Game

Students reported relatively low levels of stress during the game ($M = 2.22$, $SD = 0.98$). Perceived stress showed a significant negative correlation with enjoyment ($r = -0.482$, $p = .005$). The most frequently reported sources of stress were task difficulty, lack of time, competition between teams, and difficulties related to students' competencies.

3.3.3.5 Impact of the Seppo Game on the Students Self-Regulated Problem Solving

Paired-samples t-tests revealed no statistically significant changes between pretest and posttest scores on the dimensions of self-regulated problem solving. Although a tendency toward increased self-control ($p = .076$) and small descriptive increases in problem-solving flexibility and goal orientation were observed, these effects did not reach statistical significance. Overall, the results suggest that the 10-week gamified intervention enhanced students' game experience and motivation but had only limited short-term effects on self-regulated problem-solving processes.

3.3.4 Conclusions

The results indicate that the gamified intervention generated high levels of enjoyment and creativity, while effectively supporting students' engagement with mathematical tasks and maintaining relatively low levels of perceived stress. At the same time, however, motivation tended to decrease over time for a proportion of participants, and self-regulated problem-solving processes remained largely stable throughout the intervention.

These findings suggest that gamification can be an effective tool for enhancing learners' experience and engagement, but it does not automatically lead to short-term improvements in self-regulated learning. Overall, the results highlight that game experience and self-regulated learning are closely related yet distinct constructs, and that the development of self-regulation likely requires longer interventions as well as explicit and well-structured pedagogical support.

3.4 Conclusion of the Experimental Research

The experimental studies (Studies 4–6) provided comprehensive evidence on how pre-service preschool and primary teachers regulate their learning, experience game elements, and respond emotionally during extended gamified mathematical activities. Across the three studies, the long-term interventions revealed that gamification can support the development of more stable and adaptive SRL processes, particularly when learners engage with meaningful challenges, receive continuous feedback, and experience a sense of progression. The findings also demonstrated that motivational and emotional responses, such as enjoyment, absorption, and tension, confirming the relevance of integrating game-experience frameworks into mathematics education.

Furthermore, the experimental phase showed that pre-service teachers' strategy use, persistence, and confidence can improve over time when gamified tasks are embedded in authentic problem-solving contexts. The combined use of the SRMPS, GAMEX, and GEQ instruments enabled a multidimensional analysis of cognitive, motivational, and affective processes, offering a more nuanced understanding of how learners navigate gamified mathematical environments. These results directly addressed the gaps identified in the theoretical background and preliminary studies, demonstrating that gamification, when designed as a sustained, pedagogically grounded intervention, can meaningfully influence SRL, motivation, and emotional engagement.

Taken together, the experimental studies contributed to a deeper understanding of the mechanisms through which gamification affects learning in mathematics and provided empirical support for the integration of SRL-focused, game-informed instructional design in teacher education.

Together, the findings of the experimental studies provide a comprehensive picture of how gamification shapes self-regulated learning, motivation, and emotional engagement in mathematics education. These results, combined with the insights from the preliminary phase, form the basis for the broader theoretical, practical, and methodological implications discussed in the final chapter.

CHAPTER IV. GENERAL CONCLUSIONS AND IMPLICATIONS

4.1 Theoretical and Methodological Advance

This dissertation investigated the relationship between gamification, self-regulated learning (SRL), and mathematics education in the context of pre-service preschool and primary school teacher education. The findings contribute to a more integrated understanding of how gamified learning environments influence learners' cognitive, motivational, emotional, and behavioral processes.

A key theoretical contribution is the integration of SRL and gamification research. The results suggest that gamification influences learning not only through increased motivation and engagement but also through its potential to support planning, monitoring, reflection, and motivational regulation. Game elements such as feedback, progression systems, narrative structures, and collaboration may function as external scaffolds for self-regulation when aligned with meaningful learning objectives.

The dissertation also contributes to mathematics education research by highlighting the importance of motivational and emotional factors in mathematical problem solving. The findings confirm that self-efficacy, persistence, and emotional regulation play a central role in learners' engagement with mathematical tasks (Ashcraft & Krause, 2007; Ramirez et al., 2018; Schoenfeld, 2016).

From a methodological perspective, an important contribution is the development and validation of the Self-Regulation During Mathematical Problem-Solving Scale (SRMPS), which provides a domain-specific instrument for investigating SRL processes in mathematical contexts. The combination of quantitative and qualitative methods across six interrelated studies further enabled a comprehensive examination of learners' perceptions, experiences, and regulatory processes.

4.2 Practical Implications

The findings suggest that gamification can be an effective pedagogical approach when it is meaningfully aligned with educational objectives. Gamified activities promoted engagement, participation, and positive learning experiences, particularly in mathematics-related contexts.

The results emphasize the importance of designing gamified environments that support self-regulated learning through clear goals, immediate feedback, progressive challenges, opportunities for reflection, and collaboration. The studies also demonstrate the potential of digital and location-based environments, such as Seppo, to create active and engaging learning experiences.

Furthermore, the findings highlight the need to strengthen SRL skills, emotional regulation, and pedagogical knowledge related to gamification within teacher education programs. Future teachers should be provided with opportunities not only to experience but also to critically analyze and design gamified learning activities.

4.3 Limitations and Future Directions

Several limitations should be acknowledged. The studies were conducted within a specific teacher education context, limiting the generalizability of the findings. In addition, much of the data relied on self-report measures, and several interventions were relatively short in duration.

Future research should investigate the long-term effects of gamification, examine different gamification designs and game elements, and explore emotional regulation processes in greater depth. Further studies should also investigate how pre-service teachers transfer their experiences with gamified learning into their future classroom practice.

4.4 Summary of General Conclusions

The dissertation demonstrates that gamification can support engagement, motivation, positive learning experiences, and selected aspects of self-regulated learning in mathematics education. At the same time, the findings indicate that gamification does not automatically lead to improvements in all dimensions of SRL and that its effectiveness depends on thoughtful pedagogical design.

Overall, the results support an integrated view of learning in which cognitive, motivational, emotional, and contextual factors interact dynamically. By combining perspectives from SRL, gamification, mathematics education, and game experience research, the dissertation contributes both theoretical and practical insights for the design of meaningful learning environments in teacher education.

REFERENCES

Annemieke, E. J., & Egbert, G. H. (2012). *Towards efficient measurement of metacognition in mathematical problem solving. Metacognition and Learning, 7*(2), 133–149. https://doi.org/10.1007/s11409-012-9088-x

Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review, 14*(2), 243–248. https://doi.org/10.3758/BF03194059

Asman, D., & Markovits, Z. (2009). Elementary school teachers' knowledge and beliefs regarding non-routine problems. *Asia Pacific Journal of Education, 29*(2), 229–249.

Auliya, V., & Usman, O. (2019). Influence of self-regulation, attitude, creativity, and critical thinking skills on problem-solving in the millennial generation. *SSRN*. https://ssrn.com/abstract=3415371

Azevedo, R., Taub, M., & Mudrick, N. (2020). Understanding and reasoning about real-time cognitive, affective, and metacognitive processes to foster self-regulated learning with advanced learning technologies. *Educational Psychologist, 55*(4), 210–230. https://doi.org/10.1080/00461520.2020.1824477

Bacsa, É. (2012). *Általános iskolások önszabályozott tanulását mérő kérdőív adaptálása. Alkalmazott Pszichológia, 12*(4), 53–80.

Bandura, A. (1991). Social cognitive theory of self-regulation. *Organizational Behavior and Human Decision Processes, 50*(2), 248–287. https://doi.org/10.1016/0749-5978(91)90022-L

Bandura, A. (1997). *Self-efficacy: The exercise of control*. W. H. Freeman.

Banks, A. D. (2014). *Effects of embedded study-skills instruction on high school students' attitudes toward mathematics* (Doctoral dissertation, Walden University). https://scholarworks.waldenu.edu/dissertations/50

Barata, G., Gama, S., Jorge, J., & Gonçalves, D. (2017). Studying student differentiation in gamified education: A long-term study. *Computers in Human Behavior, 71*, 550–585.

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin, 125*(6), 627–668. https://doi.org/10.1037/0033-2909.125.6.627

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining gamification. In *Proceedings of the 15th International Academic MindTrek Conference* (pp. 9–15). ACM. https://doi.org/10.1145/2181037.2181040

Egri, E., Opriș, E.-T., & Zsoldos-Marchis, I. (2022). Experimenting gamification for developing self-regulation skills during mathematical problem solving. In *INTED2022 Proceedings* (pp. 10155–10162). https://doi.org/10.21125/inted.2022.2671

Eppmann, R., Bekk, M., & Klein, K. (2018). Gameful experience in gamification: Construction and validation of a gameful experience scale (GAMEX). *Journal of Interactive Marketing, 43*(1), 98–115. https://doi.org/10.1016/j.intmar.2018.03.002

Finney, S. J., & DiStefano, C. (2013). *Nonnormal and categorical data in structural equation modeling*. In G. R. Hancock & R. O. Mueller (Eds.), *Structural equation modeling: A second course* (2nd ed., pp. 439–492). Information Age Publishing.

Fromann, R. (2017). Gamification – épülőben a Homo Ludens társadalma? http://jatekoslet.hu/letoltes/publikaciok-gamification.pdf

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification. *In Proceedings of the 47th Hawaii International Conference on System Sciences* (pp. 3025–3034). https://doi.org/10.1109/HICSS.2014.377

Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education, 80*, 152–161. https://doi.org/10.1016/j.compedu.2014.08.019

Hari, T., & Zsoldos-Marchis, I. (2020). Primary school teachers' knowledge and opinion about gamification. In *Proceedings of the 13th Annual International Conference of Education, Research and Innovation* (pp. 9281–9287).

Hodgen, J., & Askew, M. (2007). Emotion, identity and teacher learning: Becoming a primary mathematics teacher. *Oxford Review of Education, 33*(4), 469–487. https://doi.org/10.1080/03054980701451090

Hu, L., & Bentler, P. M. (1999). *Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Huang, B., & Hew, K. F. (2018). Implementing a theory-driven gamification model in higher education flipped courses: Effects on out-of-class activity completion and quality of artifacts. *Computers & Education, 125*, 254–272. https://doi.org/10.1016/j.compedu.2018.06.018

IJsselsteijn, W., Poels, K., & de Kort, Y. (2013). *The game experience questionnaire*. Technische Universiteit Eindhoven.

Kapp, K. M. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education*. John Wiley & Sons.

Li, K., Xia, Z., Chu, S. K. W., & Yang, X. (2022). Gamification and self-regulated learning in education: A systematic review. *Educational Psychology Review, 34*(1), 249–284. https://doi.org/10.1007/s10648-021-09622-1

Lim, S. Y., & Chapman, E. (2013). Development of a short form of the attitudes toward mathematics inventory. *Educational Studies in Mathematics, 82*(1), 145–164. https://doi.org/10.1007/s10649-012-9414-x

Marchis, I. (2012). Self-regulated learning and mathematical problem solving. *The New Educational Review, 27*(1), 195–208.

Marchiş, I. (2013). Future primary and preschool pedagogy specialization students' mathematical problem-solving competency. *Acta Didactica Napocensia*, 6(2), 33–38.

Martí-Parreño, J., Seguí-Mas, D., & Seguí-Mas, E. (2016). Teachers' attitude towards and actual use of gamification. *Procedia - Social and Behavioral Sciences, 228*, 682–688.

Näveri, L., Pehkonen, E., Ahtee, M., Hannula, M. S., Laine, A., & Heinilä, L. (2011). Finnish elementary teachers' espoused beliefs on mathematical problem-solving. In *Proceedings of the MAVI-17 Conference* (pp. 161–171).

Nicolaidou, M., & Philippou, G. (2004). Attitudes towards mathematics, self-efficacy and achievement in problem solving. In M. A. Mariotti (Ed.), *European research in mathematics education III* (pp. 1–11). University of Pisa.

Opriș, E.-T. (2021). A diákok véleménye az egyéni illetve a csoportos játékosított feladatmegoldásról [Students' opinions on individual and group gamified problem-solving]. In I. Lőrincz (Ed.), *A Kárpát-medencei magyar tannyelvű pedagógusképzés és neveléstudományi kutatás aktuális és történeti tárházának értékei* (pp. 395–402). Pécsi Tudományegyetem Bölcsészet- és Társadalomtudományi Kar Neveléstudományi Intézet.

Opriș, E.-T., Bálint-Svella, É., & Zsoldos-Marchis, I. (2021). Prospective preschool and primary school teachers' knowledge and opinion about gamification. *Acta Didactica Napocensia, 14*(1), 104–114. https://doi.org/10.24193/adn.14.1.8

Opriș, E.-T., Zsoldos-Marchis, I., & Egri, E. (2024). *Impact of gamified problem sheets in Seppo on self-regulation skills. Open Education Studies,* 5(1), 1–15.

Panadero, E. (2017). A review of self-regulated learning: Six models and four directions for research. *Frontiers in Psychology, 8*, Article 422. https://doi.org/10.3389/fpsyg.2017.00422

Pekrun, R., Lichtenfeld, S., Marsh, H. W., Murayama, K., & Goetz, T. (2017). Achievement emotions and academic performance: Longitudinal models of reciprocal effects. *Child Development, 88*(5), 1653–1670. https://doi.org/10.1111/cdev.12704

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 451–502). Academic Press.

Ramirez, G., Shaw, S. T., & Maloney, E. A. (2018). Math anxiety: Past research, promising interventions, and a new interpretation framework. *Educational Psychologist, 53*(3), 145–164. https://doi.org/10.1080/00461520.2018.1447384

Ryan, R. M., & Deci, E. L. (2000a). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*(1), 54–67.

Ryan, R. M., & Deci, E. L. (2000b). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review, 32*(1), 77–112. https://doi.org/10.1007/s10648-019-09498-w

Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior, 69*, 371–380. https://doi.org/10.1016/j.chb.2016.12.033

Schoenfeld, A. H. (2016). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. *Journal of Education, 196*(2), 1–38. https://doi.org/10.1177/002205741619600203

Song, K., & Burton, L. (2018). *Gamification in learning and education*. Springer Nature.

Tanner, H., & Jones, S. (2003). Self-efficacy in mathematics and students' use of self-regulated learning strategies during assessment events. In *Proceedings of the 27th International Conference for the Psychology of Mathematics Education* (Vol. 4, pp. 275–282).

Uz-Bilgin, C., & Gül, A. (2019). Investigating the effectiveness of gamification on group cohesion, attitude, and academic achievement in collaborative learning environments. *TechTrends, 64*, 1–11. https://doi.org/10.1007/s11528-019-00442-x

Vandevelde, S., & Van Keer, H. (2011). *Studying primary school children's self-regulated learning.* Paper presented at the ORD Conference, Maastricht, the Netherlands.

Werbach, K., & Hunter, D. (2012). *For the win: How game thinking can revolutionize your business*. Wharton School Press.

Yoong, W. K., & Qian, C. (2012). Nature of an attitudes toward learning mathematics questionnaire. In *Proceedings of the 35th Annual Conference of the Mathematics Education Research Group of Australasia (MERGA 2012): Mathematics education—Expanding horizons*. Singapore.

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–39). Academic Press.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory Into Practice, 41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2

Zsoldos-Marchis, I. (2014). 10–11 year old pupils' self-regulated learning and problem-solving skills. *Review of Science, Mathematics and ICT Education, 8*(1), 33–42.

Zsoldos-Marchis, I. (2020). Gamification of the mathematics course for pre-service preschool and primary school teachers. In L. Gómez Chova, A. López Martínez, & I. Candel Torres (Eds.), *EDULEARN16 Proceedings* (pp. 6787–6794). IATED Academy. https://doi.org/10.21125/edulearn.2020.1765

Zsoldos-Marchis, I., & Opriș, E.-T. (2021). Experimenting Seppo for problem-solving on a mathematics course for future preschool and primary school teachers. In R. Jugureanu, G. Albeanu, D. M. Popovici, O. Istrate, & A. Adăscăliței (Eds.), *Proceedings of the 16th International Conference on Virtual Learning* (pp. 215–222).

Zsoldos-Marchiș, I., Opriș, E.-T., & Illyés, M. (2023). Game Experience of Primary and Preschool Pedagogy Students in a Gamified Mathematics Class. Journal of Research in Higher Education, 7(2), 67-89. http://dx.doi.org/10.24193/JRHE.2023.2.3