EÖTVÖS LORÁND UNIVERSITY
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Examining collaborative problem-solving competence in an educational escape room environment

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1. Problem statement

Collaborative problem-solving is a key competence for everyday life, school learning and employability in the 21st century, and has therefore been identified as a key competence in the educational literature (Fiore et al., 2018) and in educational policy guidelines (e.g. Singapore Ministry of Education, 2009; European Centre for the Development of Vocational Training, 2015). In addition to the recognition of the importance of developing collaborative problem-solving competence as an educational goal, there is a growing need for legitimate measurement tools to assess the development of this competence (Tsang et al., 2019).

Collaborative problem-solving is one of the most common constructivist teaching strategies and can be linked to game-based learning (Cukurova et al., 2018). One such approach is a game called *escape room*, which can be defined as "an instructional method requiring learners to participate in collaborative playful activities explicitly designed for domain knowledge acquisition or skill development so that they can accomplish a specific goal (e.g., escape from a physical room or break into a box) by solving puzzles linked to unambiguous learning objectives in a limited amount of time" (Fotaris & Mastoras, 2019: 2). Escape rooms offer not only enjoyable activities, but also team-building exercises, opportunities for learning creative and group problem-solving, and are suitable for developing and testing problem-solving thinking, and communication and collaboration skills (Pan et al., 2017).

Workplaces increasingly emphasize teamwork and collaboration between different professionals, during which solving complex problems often requires a joint effort (OECD, 2018; Rosen & Rimor, 2016). Employers are looking for employees who can communicate effectively, collaborate with others, and adapt flexibly to changing circumstances. As a result, the development and assessment of collaborative problem-solving competence is crucial in the education of future employees (Griffin et al., 2012). Methods based on practical problem-solving in a real environment used by educational institutions, such as the escape room game, contribute to the systematic development of these competencies. These methods strengthen not only individual but also collaborative problem-solving competencies, thus helping students to be more prepared for the challenges of the labor market.

2. Theoretical background

The purpose of this chapter is to present the various interpretations of the relevant concepts, and to review and synthesize the literature related to collaboration, problem-solving and escape rooms.

Our research is based on constructivist and socio-constructivist foundations, which emphasize the active and creative nature of knowledge acquisition. According to constructivist pedagogy, knowledge is not merely transferred, but is the result of individual interpretation and integration into the system of previously acquired knowledge. According to this, as Fridrich (2021) and Nahalka (1998) highlight, during learning, the individual actively processes new information from his environment, using and further expanding his existing knowledge.

According to the constructivist approach, knowledge is not a static given, but is formed, developed, and shaped dynamically, through the continuous influence of social interactions and environmental influences. Thus, learning is not only an individual, but also a collective process, which is most accurately described by the socio-constructivist theory. This approach emphasizes the construction of knowledge through interpersonal interactions, as seen in the work of Gergen (2014) and Vygotsky (2000). In pedagogical practice, this means that learning processes must be shaped in a social context, with active participation and joint problem-solving, where the main goal is the collaboration of students and the development of critical thinking.

2.1. Problem-solving competence

Problem-solving competence is a high-level complex individual characteristic that is indispensable for the effective resolution of complex situations that arise in many areas of life. This competence includes the individual's ability to recognize and understand problematic situations, to be able to think creatively and critically, and to generate solutions by applying existing knowledge in new and innovative ways (Mayer & Wittrock, 2006). Problem-solving competence is crucial to personal and professional success, as it enables an individual to respond adaptively to environmental challenges and to effectively deal with difficulties. According to this, problem-solving requires not only the analysis of situations and the implementation of solutions, but also the

integration of all relevant cognitive, motivational and emotional resources, which as a whole contribute to its successful management (OECD, 2017; Funke, 2010).

Problem-solving competence has received intensive attention in the field of education and psychology in the past century, and is accompanied by an exceptionally rich literature (e.g. Funke, 2010; Funke & Frensch, 2007; Greiff et al., 2014; Lénárd, 1984; Mayer & Wittrock, 2006; Pólya, 2004; Soden, 2013). Following the work of Karl Duncker (1945), who defined the concept of a problem as the relationship between a goal and the uncertainty of achieving it, research covers a wide spectrum. In the 1970s, Newell and Simon created "*the General Problem Solver - GPS*", a computer program that models human problem-solving. With this, they set a new direction for the development of cognitive sciences and artificial intelligence, so problem-solving extended to other scientific fields. In recent decades, the focus has shifted more and more to the complexity of problem-solving and collaborative and creative forms of problem-solving, and within the framework of OECD and other international researches, classroom and national level measurements have come to the fore (OECD, 2017b).

Research directions range from the relationship between decision-making abilities and intelligence to analytical and creative problem-solving, discussing many specific problem-solving strategies. In recent decades, the role of problem-solving in education and in the development of expert systems has also been examined, while the influence of affective and motivational factors has been increasingly emphasized in research (Goleman, 2008; Vollmeyer & Rheinberg, 2000).

Researcher(s)	Year	Main research areas
Karl Duncker	1945	Defining the concept of a problem: the relationship between the goal and the way to reach it.
Newell & Simon	1972	General Problem-Solver: problem-solving strategies and artificial intelligence.
Funke and Frensch	1995	Complex problem-solving. The role of knowledge in problem-solving: a comparison of expert and novice approaches.
OECD	2003, 2014, 2017b	International measurements: focused on complex, creative and collaborative problem-solving.
Graesser et al.; Hesse et al.; Pásztor-Kovács et al.; Rosen & Rimor	2018; 2015; 2018; 2016	Collaborative problem-solving: the effect of group dynamics and cooperation on problem solving.

Table 1: Main research areas of problem-solving

Source: own editing

These researches clearly point to the complexity and multidisciplinary nature of problem-solving competence, supporting its importance in both academic and practical spheres.

2.2. Collaborative competence

The concept of collaboration is closely related to the theory of socio-constructive learning, which is based on collaboration and knowledge sharing. During collaboration, participants work together on a task, creating an opportunity to learn from each other and achieve joint results. This process not only promotes a deeper understanding of knowledge, but it can also create novel, innovative solutions by exploiting the synergy of the group (Bada & Olusegun, 2015). The essence of collaboration is common goals, continuous communication, and interactivity, where group members are mutually dependent (Lai, 2011). According to Roschelle and Teasley (1995), collaboration involves a shared understanding and solution of a problem in a coordinated, synchronized activity where participants work together in a "common problem space" that integrates goal interpretations and possible strategies. The fundamental difference between collaborative work and cooperative work is that the participants' cognitive processes are intertwined during problem solving (Dillenbourg et al., 1996). Collaboration is therefore a dynamic interaction process that promotes knowledge sharing and joint learning between participants, thereby strengthening the group's performance and innovative capacity.

2.3. Collaborative problem-solving competence

Collaborative problem solving is one of the defining 21st century key competencies that employees of modern societies must possess (Pásztor-Kovács, 2015). It forms an organic unit with social and cognitive competencies. Thus, the primary difference between individual problem-solving and problem-solving based on collaboration is the social dimension. The cognitive components of individual problem-solving include understanding the problem content, using problem-solving strategies, and using self-regulation and metacognitive processes to monitor progress toward the goal (Funke, 2010). However, the involvement of individuals in collaboration requires additional

cognitive and social competencies in order to enable understanding, knowledge and information flow, the creation and understanding of appropriate group organization, and the implementation of coordinated activities to solve the problem (Fiore et al., 2018) .

Collaborative problem-solving combines problem-solving thinking, communication and collaboration (Griffin & Care, 2015). We have only a few structured frameworks for assessing collaborative problem-solving competence (Mughal & Shaikh, 2018). Most theoretical frameworks have two overarching components: (1) a collaborative, communicative, or social component coupled with (2) cognitive problem-solving elements. The ATC21S framework (Griffin et al., 2012) is a theoretical system suitable for examining collaborative problem-solving competence, and is capable of studying both the problem-solving and the collaborative components in sufficient detail. The framework includes a monitoring entity and an entity that monitors and evaluates the development of competence (Appendix 1).

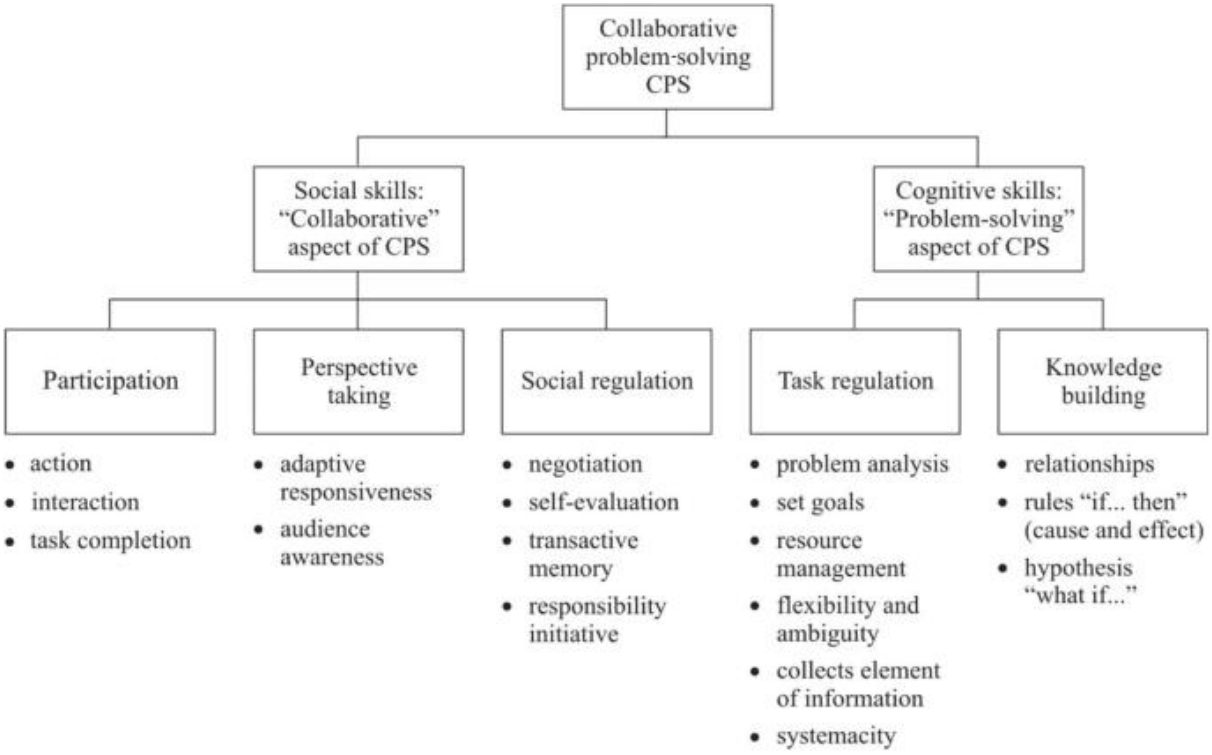

Figure 1: The ATC21S framework describing collaborative problem-solving competences

Source: own editing based on Hesse et al., 2015: 41-52

In this research, this collaborative problem-solving competence assessment system was adapted, as it allows for manual coding. The framework was used to assess the level of collaborative problem-solving competence of individuals and groups in an educational escape room, based on the data recorded through observation and video recordings. The framework helps to evaluate the activities of the students observed in the educational escape room and to quantify the data collected during the observation. The purpose of the criteria is to assess individual and group performance indicators of collaborative problem-solving competence in collaborative situations in the educational escape room environment.

2.4. Conditions of the examination: The escape room

The escape room is a real-life, group-based game in which participants search for clues, solve puzzles and achieve a specific goal by solving sub-problems in one or more rooms within a limited time (Nicholson, 2015). This form can be applied effectively in education, both in formal and informal settings, and represents a new direction in the field of serious games (Botturi & Babazadeh, 2020).

From a pedagogical aspect, the escape rooms are based on a socio-constructivist approach (Rugelj & Rugelj, 2021). Learners build their own knowledge based on real-time experiences while facing a range of challenges in the escape room, as they are often confronted with new and complex problems that they can solve by interacting with their peers and relying on support from the instructors (Fotaris & Mastoras, 2019).

Traditional education should also accommodate approaches that allow the integration of educational content in a game-based environment (Fotaris & Mastoras, 2019). An educationally oriented escape room environment has several features that both offer opportunities for active participation and follow a socio-constructivist approach to learning, emphasizing the importance of collaboration among students (Burns & Shumack, 2017).

3. Empirical research methodology

3.1. Objectives of the research

This doctoral research aimed to investigate the level of development of collaborative problem-solving competence among teacher-candidate students in the Carpathian Basin in an educational escape room setting.

The main objective of the research is:

- ***Examining the collaborative problem-solving competence of teacher-candidate students in educationally oriented escape room problem situations.*** The aim is not to develop competence but to map the students' competence level in the given moment.

The overall objectives of the research are:

- To map the key competences required by the 21st century labor market and within that to ***examine the development of collaborative problem-solving competences in an educational escape room environment***.
- ***Development and implementation of educational escape room principles*** for observing and evaluating collaborative problem-solving.
- ***Selection, development and adaptation of measurement tools for the assessment of collaborative problem-solving competence***.
- ***An empirical study among teacher-candidate students in higher education in Komárom, Budapest and Szabadka.***
- ***Evaluate the results of the research and make recommendations for the development of collaborative problem-solving competence***.

Our research was structured in a **development** and **research** phase. For the **first phase,** two objectives were defined:

Development objective 1: To **establish development, observation and assessment criteria** from a methodological perspective, taking the range of key competences to be observed into account, using escape room frameworks such as EscapED (Clarke et al., 2017), the Snyder escape room Framework - SERF (Snyder, 2018) and the ATC21S (Hesse et al., 2015).

Development objective 2: To develop logic puzzles and tasks that require the key competences to be measured and observed. Subsequently, **to create a prototype of an education escape room as a subject-independent learning platform.**

Four objectives have been identified for the **second phase:**

Research objective 1: To **observe and evaluate** students' **collaborative problem-solving activities** based on the functions of the framework elements (social and cognitive processes).

Research objective 2: **To identify and assess key competences**.

Research objective 3: **Evaluate the usage of the escape room for educational purposes**.

Research aim 4: To **formulate methodological recommendations** for the mapping and development of collaborative problem-solving competence.

The literature on key competences for employment, including collaborative problem-solving, is abundant, but there is a *lack of empirical research on the theoretical background for Hungary, Južného Slovenska (Slovakia) and Vojvodina (Serbia)*. Consequently, the present research is exploratory in nature and inductive in logic. To this end, research questions and hypotheses have been formulated, which have made it possible to explore the context and background factors relevant to the topic.

3.2. Research questions, hypotheses, methods and tools

The main research question is:

How can the escape room be used to measure collaborative problem-solving competence? What characterises the collaborative problem-solving competences of teacher-candidate students?

Based on the theoretical framework presented and the main research question above, the following questions and sub-questions and hypotheses were formulated:

Main question	Sub questions
Q1 What individual and group factors influence collaboration in the escape room experiment?	**Q1.1** Which key competences determine the success of the groups participating in the research? **Q1.2** How does the size and composition of the group influence the success of the groups participating in the research? **Q1.3** What is the relationship between the time taken to complete the game and the number of assists received during the game, and can it predict the level of collaborative problem-solving competence of the group? **Q1.4** What is the relationship between the individual's personal characteristics and collaborative problem solving? **Q1.5** Is there a significant difference in the average age of members of successful and less successful groups?
Q2 What is the relationship between logical reasoning and collaborative problem-solving competence?	**Q2.1** Can a correlation be shown between the scores on the Scrambled Adaptive Matrices (SAM) test and the time needed to get out of the escape room? Is there a correlation between the time required for problem-solving and the development of thinking? **Q2.2** Is there a significant difference in the scores on the problem-solving thinking test between the institutions and the disciplines involved in the research? **Q2.3** Is there a correlation between the score on the problem-solving test and personality characteristics?
Q3 What relationships can be identified between intra- and interpersonal competences in collaborative problem-solving?	**Q3.1** How do the results of the teamwork questionnaire relate to collaborative problem-solving? **Q3.2** What is the relationship between the Tóth creativity scale scores and collaborative problem-solving? **Q3.3** Is there a significant difference in the creativity questionnaire scores between the participating education institutions?

Hypotheses

H1 Complex problem situations in the escape room encourage students to collaborate and solve problems (e.g. Benassi, 2019; Escribano, 2018; Fotaris & Mastoras, 2019; Ho, 2018; Pan et al., 2017; Zhang et al., 2018).

H2 High levels of collaborative competence, communication skills, problem-solving and lateral thinking are the key to the effectiveness of the research teams (e.g. Binkley et al., 2012; Nicholson, 2016).

H3 Group composition strongly influences performance (Webb et al., 1998). Heterogeneous groups cooperate more effectively (e.g. Cohen, 1994; Webb et al., 1998).

H4 There is no significant difference in successful resolution by group size (groups of three, four and five) (Enu et al., 2015).

Hypotheses
H5 Group performance does not necessarily reflect individual performance, especially for students with less developed collaborative problem-solving skills (Wilczenski et al., 2001).
H6 Individual personal characteristics and problem-solving competence are significantly related to collaborative problem-solving. There is a positive correlation between collaborative problem-solving competence scores for openness and agreeableness , but no significant correlation with emotional stability and conscientiousness (Herborn, 2018; Piedmont et al., 1992).
H7 Improved logical reasoning leads to better results for the group in an educational escape room environment.
H8 Development of intra- and interpersonal competences improves group performance (Sailah, 2008).

Table 2: Research questions and hypotheses
Source: own editing

The following methods were used in this research:

(1) a structured method of observation to ensure objectivity, i.e. the events to be observed were predetermined. Both uncoding and coding techniques were used. Observations were made during the escape room game. The observed behaviour was quantified using the observation criteria developed by the ATC21S project (Annex 1). The aim of adapting and applying this framework was to assess the current level of development of the collaborative problem-solving competence of the participating students.

(2) semi-structured interview, for which the main groups of questions were identified.

(3) content analysis, which was achieved through video and audio analysis using a systematic coding technique. The events in the escape room were video recorded, while the focus group interviews ware audio and video recorded. The student behaviour observed through the video was coded according to the observation criteria, thus transformed into data and classified into specific classes and categories.

(4) Four questionnaires: a *background questionnaire,* a *personality* questionnaire, a *group work skills* questionnaire, a *creativity* questionnaire and a *test to assess* the students' level of logical thinking were used.

Measurement area	Measuring device
Demographic, cognitive and socio-economic status	Self-developed **background questionnaire** - 18 items
Thinking skills - logical and creative thinking	**Adaptive fluid intelligence test - problem solving test** (Scrambled Adaptive Matrices - SAM) (Klein et al., 2018) **Tóth Creativity Rating Scale (TKBS)** (Tóth & Király, 2006)

Measurement area	Measuring device
Measuring collaborative competence - interpersonal skills	**Big Five questionnaire** (Caprara et al., 1993) - extroversion, agreeableness and openness dimensions **Teamwork Skills Questionnaire - TSQ** (O'Neil et al., 1999) - interpersonal skills dimension
Measuring problem-solving competence - intrapersonal ability	**Big Five questionnaire** (Caprara et al., 1993) - conscientiousness and emotional stability dimensions **Teamwork Skills Questionnaire - TSQ** (O'Neil et al., 1999) - adaptability dimension
Evaluation of the escape room	**Escape room game** **Focus group interview**

Table 3: Measurement areas and instruments

Source: own editing

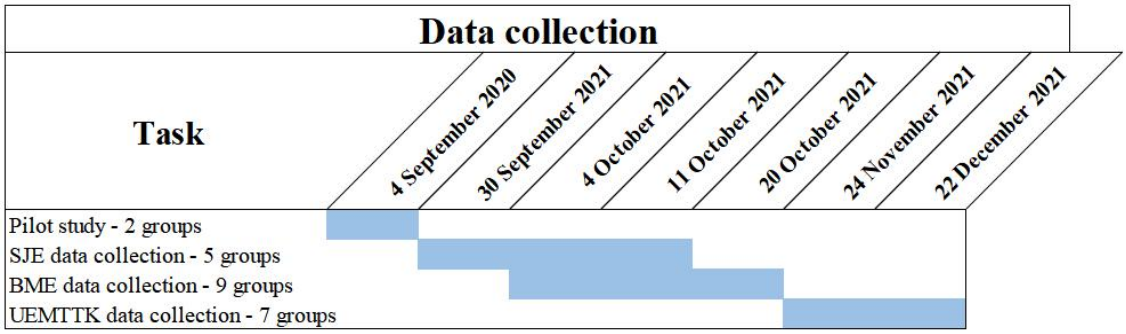

Figure 2: Flowchart of data collection

Source: own editing

Different methods were used to process the results. A Cronbach's α index was calculated to estimate the internal reliability of the scales. In order to check the normal distribution assumption of parametric statistical procedures, the distribution of continuous variables was examined in three ways: by performing the Kolmogorov-Smirnov and Shapiro-Wilk tests, by examining QQ graphs, and by simply visual inspection of the distribution of variables (using histograms). One-point analysis of variance was used to test whether there were differences between groups of different variables in terms of collaborative problem-solving. In addition, a one-tailed t-test was used to compare the groups. Linear regression was used to estimate the prediction of each outcome. The correlation between variables was tested using Pearson's correlation.

The video data was analysed using *Dedoose* software, which supports the mixed-methods approach. Analyses were performed using the statistical software package *SPSS Statistics 29.*

3.2.1. Own framework

Building on elements from two frameworks (Clarke et al., 2017; Snyder, 2018), the aim was to *develop a new, more comprehensive framework of principles* that designers and educators can use when designing educationally focused breakout rooms and evaluating collaborative problem-solving activities. These *frameworks provided a methodological basis for the design of a prototype of an educational escape room* (Figure 3) and interactive game solutions that can be used to observe behaviour and evaluate collaborative problem-solving activities individually and in groups.

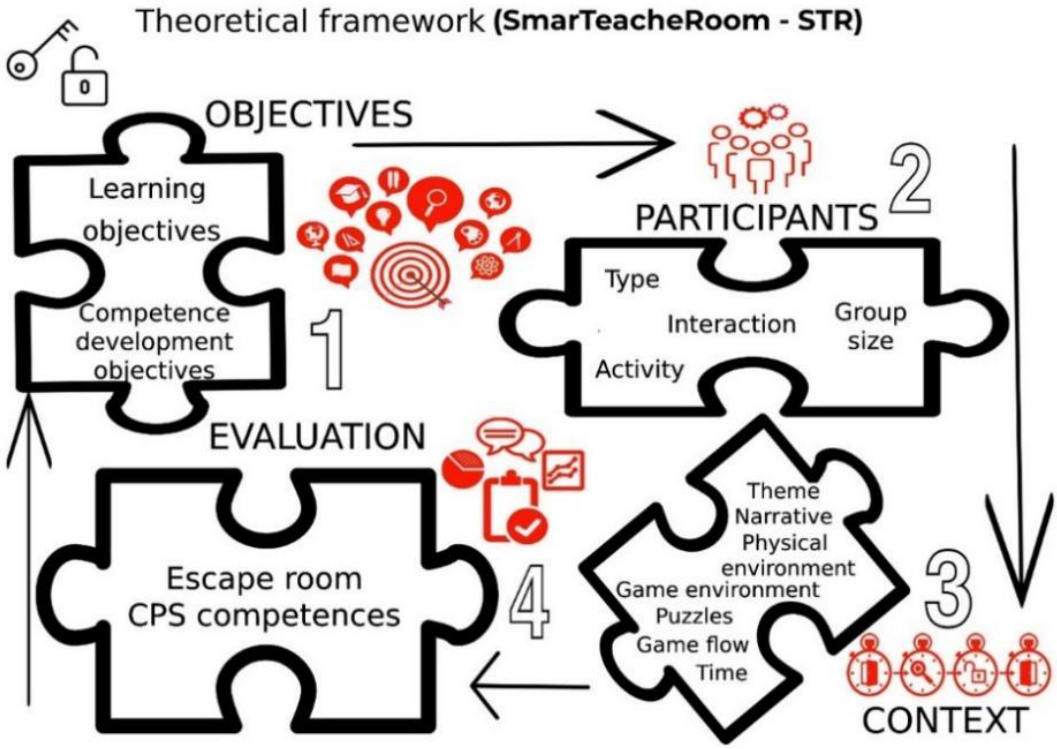

Figure 3: Theoretical framework (SmarTeacheRoom - STR)

Source: own editing

Figure 4 shows the design of the self-developed escape room game, detailing each puzzle and illustrating the "flow" of the room based on the order of the puzzles.

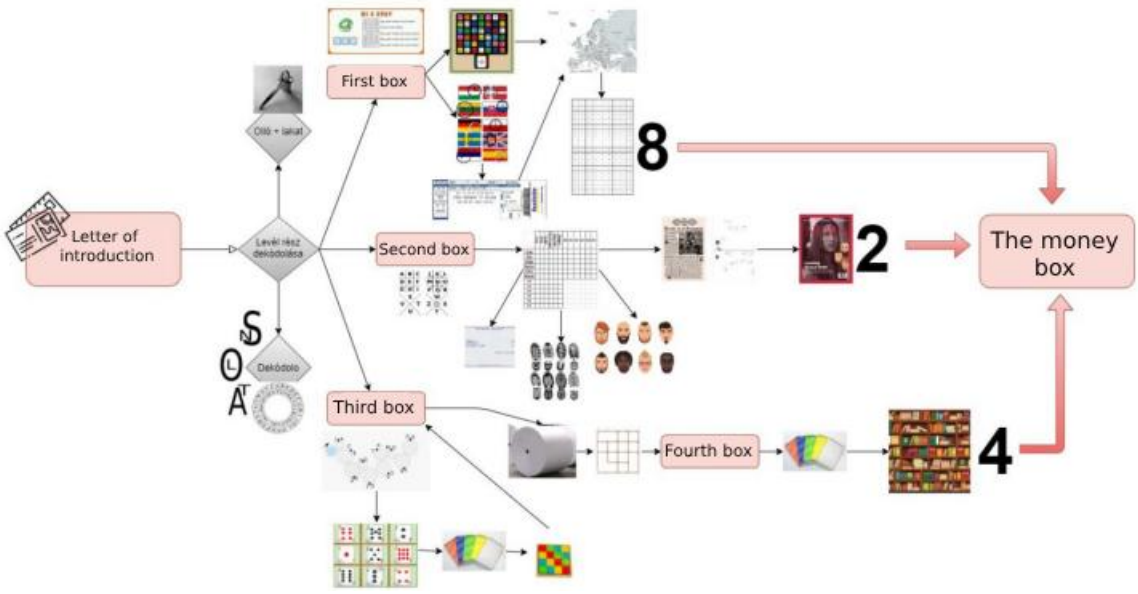

Figure 4: The game plan

Source: own editing

3.2. Target population and sampling

In this research, the sample consists of teacher-candidate students. The institutions were selected using an access sampling procedure. The target population was students in higher education in Komárom (*J. Selye University, Faculty of Education [SJE]*), Budapest (the *Budapest University of Technology and Economics, Department of Technical Education [BME]*) and in Szabadka (*University of Novi Sad, Hungarian Language Teacher Training Faculty [ÚE MTTK]*) (Table 4).

A total of 101 students (21 groups) participated in the escape room game, but only 98 students completed the post-game test and questionnaires, so we wanted to use their data to shed light on how the escape room game can be used to practice and measure soft skills in education.

Institute	Female		Male		Total							
	N	%	N	%	N	%		N	%	Age group	N	%
BME	27	39.1%	15	51.7%	42	42.9%	economics-teacher	21	50.0%	24 - 30	8	19.05%
							engineer-teacher	12	28.6%	31 - 40	12	28.57%
							vocational teacher	9	21.4%	42 - 57	22	52.38%
SJE	16	23.2%	8	27.6%	24	24.5%	pedagogy and public education	9	37.5%	19 - 21	13	54.17%
							german-computer science teacher	1	4.2%			
							english-german teacher	1	4.2%			
							english-biology teacher	1	4.2%			
							biology-history teacher	1	4.2%	22 - 24	8	33.33%
							mathematics-history teacher	1	4.2%			
							hungarian language and literature - english language and literature	1	4.2%			
							biology-hungarian teacher	1	4.2%			
							history-hungarian teacher	1	4.2%	25 - 41	3	12.50%
							hungarian language and literature - history	1	4.2%			
							pre-school and elementary pedagogy	5	20.8%			
							biology-german teacher	1	4.2%			
ÚE MTTK	26	37.7%	6	20.7%	32	32.7%	certified teacher	14	43.8%	18	6	18.75%
							educator	3	9.4%	19	15	46.88%
							certified kindergarten teacher	11	34.4%	20	10	31.25%
							communicator	4	12.5%	21	1	3.13%

Table 4: Characteristics of the sample

Source: own editing

In this research, we used the *convergent parallel design model*[1], which has its roots in the 1970s. Convergent parallel design aims to better understand a given social phenomenon by using two approaches. The results from both quantitative and qualitative methods can be used to illustrate and support each other, as well as for comparison (Teddlie & Tashakkori, 2006: 20-21).

In order to summarise the literature review, a model (Figure 5) was set up to outline the main concepts and pedagogical theories of the research that we drew on and considered relevant to our research in order to achieve our objectives. The model incorporates the main frameworks supporting the development (environment) and research (competences) stages.

[1] Sántha (2013) (convergent parallel design model, interpretive sequential design model, exploratory sequential design model). In other papers, the cohesive parallel design model appears (Zsuzsanna et al., 2014).

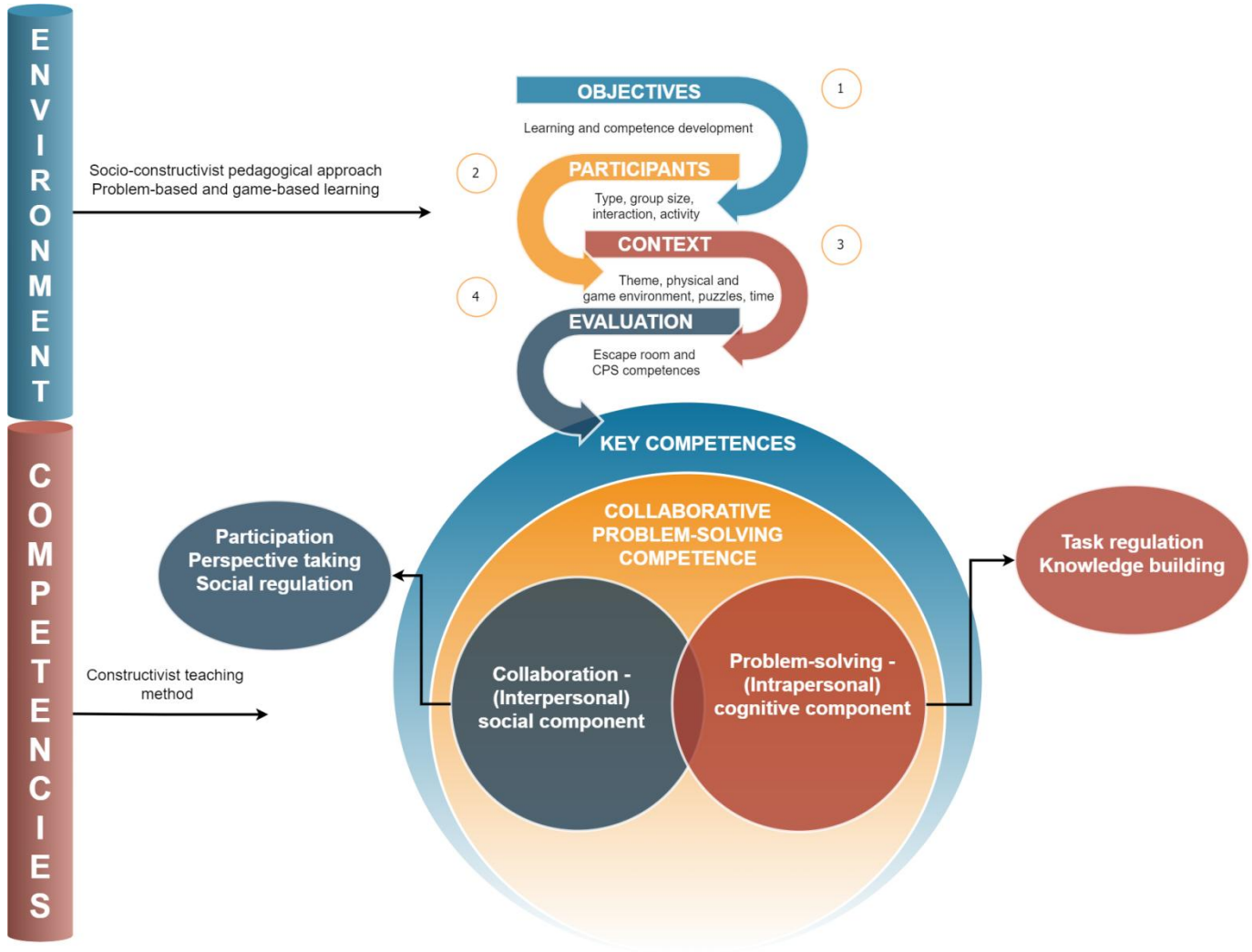

Figure 5: Research model

Source: own editing

4. Results of the research

The main question of the research was to explore the potential of the escape room to measure collaborative problem-solving competence. Furthermore, the hypothesis (**H1)** regarding the characteristics of this competence construct of teacher-candidate students hypothesized that the complex problem situations in the escape room would stimulate students to collaborate and solve problems.

Our results show that the educational escape room can be used to assess the level of collaborative problem-solving competence, as the student behaviour during the game can be used to identify and assess the sub-competences of the observational aspect.

Research has shown that in the escape room game, participants are forced to collaborate and communicate in order to successfully solve problems (Benassi, 2019; Escribano, 2018; Fotaris & Mastoras, 2019; Ho, 2018; Pan et al., 2017; Zhang et al., 2018). Based on the observation of student behaviour and their feedback, it can be stated that the escape room game stimulates collaborative problem-solving among student groups. In solving a number of real-life situations, students also needed group-based creative problem solving.

Already during the data collection, it was clear that the game requires all the competences that were classified in the structured assessment framework. The ATC21S framework proved to be ideal for mapping student competency levels. Apart from self-evaluation and peer evaluation sub-competencies, could all be observed and evaluated during the game. This should be seen as a prerequisite for a well thought out, designed and developed game. The framework supporting the self-developed game was key during the development phase.

The results therefore confirm that the escape room can indeed be an effective tool for measuring collaborative problem-solving competence. The environment stimulates students to collaborate and problem-solve, which contributes to the development of collaborative skills and abilities.

The **first question** asked which individual and group factors influence the effectiveness of collaboration. The influence of individual and group factors on collaboration effectiveness was investigated in the escape room experiment by analysing the results of participants with the highest and lowest levels of collaborative problem-solving

competence on personality traits, collaborative competence, creativity and logical thinking. Furthermore, the composition of the groups was also analysed as a factor that may influence the behaviour and success rate observed during the game. During the course of the research, it was identified that in the teams showing outstanding performance, the group collaborative problem-solving competence scores were higher than the individual scores. This suggests that the group performed better together than its members individually. The reverse was true for weak teams, which may suggest that the right combination of group composition and individual collaborative competence may be key to successful collaboration. Our results suggest that group composition can have a significant impact on the success of collaboration.

It is important to note that, in addition to personality traits, competences and individual skills, other factors such as communication, leadership and group dynamics also play a role in successful collaboration. These factors were referred to by the student groups during the interviews.

The success of the groups in the study was the result of a combination of social and cognitive competences (**K1.1**). Goal setting, hypothesis formation, relationship recognition and problem analysis were the cognitive sub-competences that were only observed in the top seven groups at an advanced level. The group results were organised into Guttman charts, which can be used to easily analyse which key competences need improvement for individuals and groups of students.

GROUP LEVEL

Group code		4.3 Resource menagement	3.1 Negotation	1.3 Task completion	2.2 Audience awareness	2.1 Adaptiv responsiveness	1.2 Interaction	4.5 Collect elemnt of information	1.1 Action	4.4 Flexibility	4.1 Problem analysis	5.1 Relationships	4.6 Systemacity	5.2 Cause and efects	3.4 Responsibility/initiative	5.3 Hypothesis	4.2 Set goals	3.2 Self-evulation	3.3 Transactive memory
		39.6	38.5	38.1	37.0	36.7	32.8	30.7	27.6	23.7	22.7	21.6	20.8	20.1	18.0	10.0	7.0	0.0	0.0
BME7	29.7	2	2	2	2	2	2	1.67	2	2	2	2	2	2	2	2	0	0	0
BME1	28.4	1.8	1.6	2	2	2	1.8	1.8	1.8	1.4	1.67	1.5	1.4	1.6	2	2	2	0	0
BME9	28.0	2	2	2	2	2	2	2	1.6	1.8	1.75	1.6	1.6	1.6	2	2	0	0	0
MTTK3	25.4	2	2	2	2	2	1.91	1.8	1.45	1.2	2	1.67	1.6	1.75	0	0	2	0	0
BME3	24.9	2	2	2	2	2	2	1.83	1	1.6	1.5	1.33	1.5	1.17	2	1	0	0	0
BME8	24.8	2	2	1.75	1.75	1.75	1.75	2	1.5	1.25	1.25	1.25	1.25	1.25	2	2	0	0	0
MTTK7	24.7	2	2	2	2	2	1.83	1.4	1.83	1.33	2	1.5	1.33	1.5	2	0	0	0	0
BME4	24.6	2	2	2	2	2	1.83	2	1.33	1.5	1.25	1.4	1	1.33	2	1	0	0	0
MTTK2	22.8	1.75	1.83	1.92	2	2	1.92	1.44	1.5	1	1.75	1.11	1.6	1	0	0	2	0	0
SJ5	22.8	2	2	2	2	2	1.5	1.5	1.33	1.5	1.33	1.33	1	1.33	1	0	1	0	0
BME5	22.4	2	2	2	2	2	2	2	1.25	1.5	1.5	1.67	1.5	1	0	0	0	0	0
SJ4	18.5	2	2	2	2	1.5	1	1.5	1	1.5	1	1	1	1	0	0	0	0	0
BME6	17.8	2	1.6	1.8	1.6	1.6	1.8	1.6	1	1.2	1	1	0.6	1	0	0	0	0	0
MTTK4	16.2	2	1.82	1.75	1.77	1.77	1.77	1.14	1.15	0.75	1	0.57	0.25	0.43	0	0	0	0	0
SJ2	15.5	2	1.67	1.67	1.5	1.5	1.5	1	1.5	0.83	0	0.67	1	0.67	0	0	0	0	0
SJ1	15.0	1.83	1.83	1.83	1.5	1.67	1.17	1.17	1	0.83	0	0.5	0.5	0.17	1	0	0	0	0
SJ3	14.6	1.83	2	1.67	1.67	1.5	0.83	1.17	1.17	0.83	0.67	0.33	0.8	0.17	0	0	0	0	0
MTTK1	14.4	1.6	1.8	1.4	1.6	1.6	1	1	1	0.4	1	0	0	0	2	0	0	0	0
MTTK5	12.6	1.8	1.83	1.83	1.5	1.5	1.17	0.33	1.17	0.4	0	0.33	0.4	0.33	0	0	0	0	0
BME2	12.3	1.67	1.17	1.33	1.33	1.33	1.17	1.33	1	0.67	0	0.5	0.33	0.5	0	0	0	0	0
MTTK6	9.5	1.33	1.33	1.17	0.8	1	0.83	1	1	0.2	0	0.33	0.17	0.33	0	0	0	0	0

Figure 6: Guttman diagram of the group results

Source: own editing

Collaborative competence covers the *Participation* and *Perspective taking* elements of the ATC21S framework, communication skills cover *Social regulation*, while problem-solving and lateral thinking cover the *Task regulation* sub-competences. **H2** is confirmed as Guttman's charts show that the most successful groups have high levels of each of the listed sub-competences.

(**K1.2**) Our research involved groups of 3-6 people. Groups were mixed by gender (heterogeneous) and female-only (homogeneous). (**H3**) In the study, we compared homogeneous and heterogeneous groups and found no significant difference in their collaborative problem-solving competence. Within heterogeneous groups, there was no significant difference in collaborative problem-solving competence regardless of gender composition.

ANOVA analysis showed no significant difference in mean competence levels by group size, which was confirmed by the F-test. It was confirmed that size had no effect on group performance (**H4**).

Most of the best groups scored better as a group, while the weaker groups had a higher composite of individual scores. This may suggest that the low-performing groups could have achieved an outstanding result in a different composition (this will be investigated in a future study), while in the more successful groups (e.g. BME8) a low-performing student pulled down the group average considerably. For this reason, individual assessment alone is not sufficient, group assessment is inevitable. Our hypothesis (**H5**) that group performance does not necessarily reflect aggregate individual performance is confirmed.

Our results show that the time required to complete the game and the number of assists received during the game are strongly negatively correlated with the group's collaborative problem-solving competence level (**K1.3**). The results suggest that groups that took less time to solve the puzzles and at the same time required less assistance during the game achieved superior results.

Extraversion and openness are personality traits that affect the success of problem-solving (**K1.4**). These two personality traits have a significant impact on the interaction between individuals and on problem-solving within the group. Extraversion includes energy, sociability, and emotional expression. Extraverted individuals often seek out social interactions, which can facilitate communication processes and the dynamics of

idea exchange in groups. They are characterized by higher social activity, frequent expression of positive emotions and more effective leadership skills. Extroverted individuals often take on leadership roles, which can help to manage the group and coordinate tasks. Individuals with this personality trait tend to communicate better and are more active in group interactions, which has a positive impact on teamwork and problem-solving skills.

Openness refers to receptiveness to new things and a willingness to depart from tradition. Open-minded individuals are often more creative and innovative, which can be key to approaching problems in new ways. They are characterised by creativity, an ability to adapt more easily to new situations and to take risks in unfamiliar areas, and an interest in arts and culture. Open-minded individuals are more adaptable to new ideas and perspectives, which promotes innovation and problem-solving within the group.

These qualities contribute to the success of group work in a complex way, especially in environments where creative solutions and effective communication are paramount, such as the escape room game.

(**H6**) Our results show that there is a significant relationship between competence level and extraversion and openness personality traits. Both are moderately positively correlated with the collaborative problem-solving competence level. No significant relationship was found for the other personality traits.

The average age of participants divided into two groups was compared (**K1.5**). Using an independent samples t-test, it was found that the average age of the high performing groups was significantly higher than the low performers. The average age of the highest performing students was 39.2 years, while the average age of the lowest performing students was 26.27 years. This statistically significant difference suggests that age alone, rather than life and work experience as a factor, may play a significant role in the success of the groups. A rich pool of experience can contribute to more effective management of problems and better use of group dynamics, which is more likely to lead to outstanding group performance.

Life and work experience, as an influencing factor, plays a key role in many areas, especially in activities in a collaborative environment. These experiences provide a deeper understanding and a broad range of competences that can contribute to the

effectiveness and success of teams. Life experience contributes to an individual's emotional maturity and social intelligence. Older individuals often have a broader perspective and better conflict management skills, which can be an advantage in group work (Goleman, 2008). Work experience is directly related to professional skills and knowledge. Individuals with more work experience are often more aware of the details of their field and the specific requirements of group work. Work experience has the advantages of expertise and the ability to adapt to new situations and changes, which is essential in a dynamic working environment (Northouse, 2021).

These experiential factors can have a significant impact on a group's performance, especially in tasks where complex problem-solving thinking is key. Life and work experience not only enriches immediate skills and knowledge, but also improves communication and collaboration between individuals, thereby enhancing group performance and coherence (Goldberg, 2006).

The **second question** aimed to explore the relationship between logical thinking and collaborative problem-solving competence. According to the related hypothesis (**H7),** more developed logical thinking will lead the group to better results in the educationally oriented escape room environment.

The results of the research confirm that the development of logical thinking has a significant impact on collaborative problem-solving competence. Improved problem-solving thinking not only leads to a faster exit from the escape room, but is also related to the openness dimension of personality, which may be a key factor in dealing with new and unexpected situations that arise during group work. The results of the logical reasoning test indicate that individuals with higher collaborative problem-solving competence also scored higher on the problem-solving test, i.e. the hypothesis was fulfilled.

The results show several significant associations between logical thinking and collaborative problem-solving competence.

There was a significantly weak negative correlation between the problem-solving thinking SAM test score and the time to get out of the escape room (**K2.1**). The participants in the study were classified into three categories in terms of the time required to complete the problem-solving test: high, average and low. The results showed a significant difference in problem-solving test scores between the three groups.

Those who took more time to complete the test scored higher, so more time spent solving the problem led to a better score. In the adaptive test, the better the student performs, the harder the problem is. More difficult problems take more time to solve and take longer to solve, regardless of whether they are solved by individuals with more advanced skills.

Based on our results, a significant weak negative correlation between test completion time and the time needed to play the escape room was found. This indicates that the more successful groups took more time to complete the problem-solving test, thus achieving higher scores.

There were significant differences in problem-solving test scores between students from different institutions participating in the study, with BME students scoring significantly better than students from other institutions (**K2.2**). Based on our previous results, we suggest that this may be due to the higher age and work experience of the participants. There is no significant difference in the test scores across the different disciplines within institutions.

An examination of the relationship between problem-solving test scores and personality traits (**K2.3**) showed a relationship with problem-solving test scores only for the personality trait openness. Our results suggest that openness may predict high levels of logical thinking. This factor indicates how imaginative and curious an individual is and whether he or she is open to new experiences.

The **third question** aimed to identify the relationship between intra- and interpersonal competences during collaborative problem-solving. The analysis of these relationships led to a number of important findings.

The related hypothesis (**H8**), that the development of intra- and interpersonal competences will improve group performance, was fulfilled. Intrapersonal and interpersonal competencies are defined as the social and cognitive sub-competencies of the ATC21S framework. Scores on these sub-competencies were compared between low and high performing groups. The results showed a strong positive correlation between the two groups of competencies, indicating that individuals with highly developed intrapersonal competencies are also likely to have highly developed interpersonal competencies. Higher levels of competence are also associated with better outcomes among research participants. Thus, our hypothesis that a high level of

development of intra- and interpersonal competences improves group performance is confirmed.

No significant correlation was found between teamwork questionnaire scores and collaborative problem-solving competence level (**K3.1**). There is a positive but weak relationship between the two scores. The teamwork test is used to assess the existence of collaborative competence. It is a self-report questionnaire, and it can be suspected that because the students were involved in a collaborative process prior to completing the questionnaire, they answered the questions in a way that would produce a result that meets the expectations of the research. Another problem with self-report questionnaires is that people are often not able to evaluate themselves objectively. Self-evaluation can be distorted by personal bias, low levels of self-confidence or the influence of social expectations. People often tend to paint a more positive picture of themselves or, conversely, underestimate their own abilities and characteristics. The cognitive elements, which were not measured by the teamwork skills questionnaire, accounted for 50% of the results for the collaborative problem-solving competence level, so the results are not surprising for us.

There is a medium positive relationship between scores on the Tóth creativity scale and collaborative problem-solving performance, especially on the subscales of complexity preference, autonomy of thought and energy (**K3.2**). These categories encompass novel, complex, difficult problems, interest in play and stimuli, exploring new paths without the help of external support and motivation to find novel solutions. This suggests that creative personality traits can foster group problem-solving skills.

There were significant differences in the creativity questionnaire scores between the higher education institutions participating in the research (**K3.3**). The results showed a significant difference between the scores of BME and SJE and BME and UE MTTK, but no significant difference in the creativity test scores between SJE and UE MTTK. Also in this test, BME students in the vocational teacher training programme scored higher.

The level of intra- and interpersonal competences has a significant impact on the level of collaborative problem-solving thinking. Interpersonal skills, such as teamwork and communication, did not show a strong direct correlation with collaborative problem-solving success, but creativity and logical thinking, as intrapersonal skills, were

strongly related to group problem-solving success. This suggests that creative and logical thinking can facilitate effective teamwork and innovative problem-solving.

5. Summary

This doctoral dissertation aimed was to comprehensively examine the development of students' collaborative problem-solving competence in an educational escape room environment. The main objectives of the research were (1) to construct a prototype of a subject-independent educational escape room, to develop observation and evaluation criteria, (2) to develop logic puzzles and tasks to measure and observe collaborative problem-solving competencies, and (3) to observe and evaluate students' collaborative problem-solving activities based on the functions of the framework elements.

As a practical implementation of socio-constructivist theory, the educational escape room is an attractive and interactive learning environment that promotes collaboration, problem-solving, learning and application of new knowledge. Students are encouraged to be active participants in their own learning, making the link between new information and their previous knowledge and experience. Collaborative problem-solving and socio-constructivist theory are closely linked.

Our research has focused on understanding social interactions and collaborative learning processes. In group settings, individuals solved complex problems, shared ideas and discussed possible solutions. This process not only enabled knowledge sharing, but also promoted deeper understanding and reflection among group members.

Through educational escape room play, we provided a dynamic learning experience that required collaboration, problem-solving, communication skills, creativity and lateral thinking. Students were not only passive recipients, but also active participants in shaping their perceptions of the world around them. Thus, it can be said that the objectives of the doctoral dissertation have been successfully met in the following areas:

(1) During the development phase, a prototype of an escape room game for educational purposes was created. This was preceded by the development of a proprietary framework that incorporates the methodological elements of educational escape rooms and provides a basis and guide from the game design to the play phase. During the development of the prototype, particular attention was paid to the fundamental aim of

the game, to create an environment for observing and measuring collaborative problem-solving competence, which also aligns with the observation and assessment criteria in the ATC21S framework. This included analysing the dynamics of group work, assessing the quality of communication and monitoring problem-solving strategies. For our research purposes, the escape room was constructed from subject-independent logic puzzles. Our main objective was to assess the development of collaborative problem-solving competence, but prior knowledge (or lack thereof) was assumed to have a large impact on the assessment of cognitive competence. In the development phase, a game system was designed to convey any learning content. By integrating the specific learning content, it is also hypothesised that there would have been a greater difference in the collaborative problem-solving performance of students studying at the three universities. We plan to investigate this in a future study.

(2) We have developed a series of logic puzzles and tasks to enhance, measure and observe collaborative problem-solving skills. These tasks enabled collaboration between participants, analysis of problems and the development of innovative solutions. The problems we developed allowed us to measure and observe collaborative problem-solving competences. There was a huge emphasis on the narrative of the game and that the problems in it were closely related to it, thus ensuring a flow experience during the game.

(3) During the research, we carried out observations and evaluations of students' collaborative problem-solving activities based on the functions of the elements of the adapted framework. Participants' group work and individual performance were observed and evaluated in terms of collaborative problem-solving competencies. Data analysis helped us to understand the students' development in this area.

The research involved empirical data collection among teacher-candidate students in higher education in Komárom, Budapest and Szabadka between 2021 and 2022. A total of 101 students, divided into 21 groups, participated in the escape room game. The game was followed by a focus group interview and the completion of a test (*Adaptive Fluid Intelligence Test*) and four questionnaires (*Tóth Creativity Rating Scale, Big Five Questionnaire, Teamwork Skills Questionnaire and Background Questionnaire*). Data analysis aimed to identify and assess key competencies and to evaluate the educationally oriented escape room.

5.1. Results, conclusions

5.1.1. Answers to the questions

Question	Answer
(HEAD)Q	The escape room's complex problem-solving situations encourage students to collaborate and problem-solve. The escape room game forces participants to work together and communicate to successfully solve the challenges they face. The escape room can be a truly effective tool for measuring collaborative problem-solving competence. The environment stimulates students to collaborate and problem solve, which contributes to the development of collaborative skills and abilities.
Q1	In addition to group composition, personality traits, intra- and interpersonal competences and individual skills, other factors such as communication, leadership and group dynamics also play a role in successful collaboration.
Q1.1	The effectiveness of the groups in the study was the result of a combination of social and cognitive competences.
Q1.2	In the study, we compared homogeneous and heterogeneous groups and found no significant difference in their collaborative problem-solving competence. Group size also had no effect on group performance.
Q1.3	The time taken to complete the game and the number of assists received during the game show a strong negative correlation with the group's collaborative problem-solving competence level.
Q1.4	Extraversion and openness are the personal characteristics that have the greatest impact on problem-solving performance.
Q1.5	The average age of the high performing groups was significantly higher than the average age of the low performing groups. Age alone, rather than life and work experience, can be a significant factor influencing the success of groups.
Q2	There is a significant relationship of medium direct proportionality between logical reasoning and collaborative problem-solving competence.
Q2.1	There was a significant weak negative correlation between the SAM test score and the time to escape from the escape room.
Q2.2	There were significant differences in problem-solving test scores between students at the different institutions participating in the research, with BME students performing better.
Q2.3	Only the personality trait of openness showed a significant correlation with problem-solving test scores. Our results suggest that openness may predict high levels of logical thinking.
Q3	Interpersonal skills, such as teamwork and communication, did not show a strong direct correlation with success in collaborative problem-solving, but creativity and logical thinking, as intrapersonal skills, were strongly associated with group problem-solving success. This suggests that creative and logical thinking can facilitate effective teamwork and innovative problem-solving.
Q3.1	No significant correlation was found between teamwork questionnaire scores and collaborative problem-solving competence levels.

Q3.2	There is a medium positive relationship between scores on the Tóth creativity scale and collaborative problem-solving success, especially on the subscales of complexity preference, autonomy of thought and energy.
Q3.3	Significant differences were found between the creativity questionnaire scores of the participating higher education institutions. BME students scored significantly higher than students from other institutions.

Theses

Thesis 1: Complex problem situations in the escape room encourage students to collaborate and solve problems.

Thesis 2: The effectiveness of the research groups will be driven by high levels of collaborative competence, communication skills, problem-solving and lateral thinking.

Thesis 3: There is no significant difference in success rates between group sizes (groups of three, four and five).

Thesis 4: Group performance does not necessarily reflect individual performance, especially for students with less developed problem-solving skills.

Thesis 5: More developed logical thinking leads to better group outcomes in educational escape room environments.

Thesis 6: The development of intra- and interpersonal competences improves group performance.

Table 5: Answers to the research questions and theses of the research
Source: own editing

5.2. Limitations and further research directions

Although the escape room game and the adapted ATC21S framework offer definite advantages in the development and assessment of collaborative problem-solving competence, several limitations were identified that affected the outcome, validity and generalizability of the research.

(1) Our research examined the use of the escape room game in a higher education setting. The generalisability of the results to other contexts (e.g. students in other courses, other age groups) requires further investigation. Sample size and composition do not ensure representativeness.

(2) Measuring self-assessments, attitudes or emotions may be subjective and individual differences in interpretation may affect the results. In our research, this was observed in the results of the Teamwork Skills Questionnaire.

(3) The elements of the escape room game are paper-based. More technology and tools are needed for a better play experience and immersion. Educational technologies such as AR (Augmented *Reality*) and VR (*Virtual Reality*) would serve to enrich the learning experience and further develop collaborative problem-solving competencies. Limited budgets have constrained this.

Further research directions:

(1) *Repeating the research with a new game, but with the students who participated in the first survey in different group settings*. This would give a more accurate picture of whether individual contribution or group composition is the decisive factor for collaborative problem-solving competence scores.

(2) Future work will include *the validation of a self-developed framework*. The framework has been developed with the aim of providing an overview of the elements to be considered when designing an educational escape room. In the validation of the model, we would focus on internal validation based on *Instructional Design,* i.e. we would consider the formal characteristics and use of the model (Richey, 2005). Our validation would address the clarity and completeness of the model and, in terms of its use, would include both its perceived usefulness and its actual use.

(3) A next development is a digital game solution that would implement *automatic monitoring of* the *escape room for educational purposes*. The goal is to create an adaptive escape game that can automatically provide hints, monitor student needs based on experience, and change the activity based on their performance.

(4) *Integrating Artificial Intelligence (AI) into the educational escape room* to adaptively design individual learning pathways. AI can analyse students' progress and reactions in real time and offer personalised learning challenges (problems), optimising the learning experience for all participants. The use of AI in the design of escape room games could save teachers a lot of time. The logic and puzzles of the game could be dynamically adapted to the competence level of the players. This could include automatically setting difficulty levels and modifying the gameplay to provide challenge and learning opportunities for all students.

5.3. Formulation of recommendations for teacher training

We are constantly looking for innovative ways to promote more active and deeper learning for our students. In this context, the escape room game, as an interactive, problem-solving activity, offers an outstanding opportunity, both in the learning process and in the assessment and development of collaborative problem-solving competences.

Teacher training should give priority to the integration of gamification elements, with a particular focus on games in the escape room. These educational games are not only innovative and enjoyable methodological tools, but also complex environments that allow for the practical development of collaborative problem-solving competences. The use of these methods has a direct impact on the learning process, promotes active participation of learners and supports the development of self-regulated learning skills.

The widespread introduction of gamified learning environments such as escape rooms in teacher training programmes has been proposed. This type of learning model focuses not only on the acquisition of knowledge, but also on creative thinking, analytical skills and teamwork. Escape room games are particularly well suited to helping students develop real-life problem-solving skills, which are critical to meeting the needs of the modern labor market.

In the light of the above, teacher training institutions should integrate game-based learning into their curricula so that future teachers can experience and learn how to use these innovative and effective methods during their training. The benefits of this type of practice include the provision of real-time feedback to learners, which can contribute to a deeper understanding of learning processes and to the enhancement of knowledge that teacher candidates can later apply.

Gamification, in particular the use of escape room games, offers an excellent opportunity to renew teacher education, enabling teacher candidates to acquire the competences necessary to face the challenges of modern education and work while they are still in training. It also provides an opportunity for institutions to develop innovative teaching strategies tailored to the needs of students, which support the development of students' active and autonomous problem-solving skills.

Learning in an interactive and motivating environment increases the active participation of learners and the quality of the results achieved. The need for interactive,

collaborative problem-solving in modern education systems draws attention to the pedagogical potential of escape room games.

The aim of education is not only to acquire knowledge, but also to develop competences that will help students to solve problems effectively and creatively in real life. The framework of the adapted ATC21S project fits perfectly into the assessment of this complex competence construct, including all the indicators that can be developed during the game. The framework allows for manual coding so that teachers can monitor the development of their students' collaborative problem-solving competence levels. From the first observation and assessment, the sub-competences that a student or group needs to develop are highlighted. The adapted framework provides an opportunity to gain an in-depth understanding of learners' collaborative and problem-solving competences, thus contributing to the development of competence in the educational environment.

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Appendix 1 - The ATC21S framework

Element	Indicator	Low	Middle	High
Participation				
Action	Activity within environment	No or very little activity	Activity in familiar contexts	Activity in familiar and unfamiliar contexts
Interaction	Interacting with, prompting and responding to the contributions of others	Acknowledges communication directly or indirectly	Responds to cues in communication	Initiates and promotes interaction or activity
Task completion/ perseverance	Undertaking and completing a task or part of a task individually	Maintains presence only	Identifies and attempts the task	Perseveres in task as indicated by repeated attempts or multiple strategies
Perspective taking				
Adaptive responsiveness	Ignoring, accepting or adapting contributions of others	Contributions or prompts from others are taken into account	Contributions or prompts of others are adapted and incorporated	Contributions or prompts of others are used to suggest possible solution paths
Audience awareness (Mutual modelling)	Awareness of how to adapt behaviour to increase suitability for others	Contributions are not tailored to participants	Contributions are modified for recipient understanding in the light of deliberate feedback	Contributions are tailored to recipients based on interpretation of recipients' understanding
Social regulation				
Negotiation	Achieving a resolution or reaching compromise	Comments on differences	Attempts to reach a common understanding	Achieves resolution of differences
Self evaluation (Metamemory)	Recognising own strengths and weaknesses	Notes own performance	Comments on own performance in terms of appropriateness or adequacy	Infers a level of capability based on own performance
Transactive memory	Recognising strengths and weaknesses of others	Notes performance of others	Comments on performance of others in terms of appropriateness or adequacy	Comments on expertise available based on performance history
Responsibility initiative	Assuming responsibility for ensuring parts of task are completed by the group	Undertakes activities largely independently of others	Completes activities and reports to others	Assumes group responsibility as indicated by use of first person plural

Figure 7: Social skills in collaborative problem-solving
Source: Hesse et al. 2015: 43

Element	Indicator	Low 0	Middle 1	High 2
Task regulation				
Organises (problem analysis)	Analyses and describes a problem in familiar language	Problem is stated as presented	Problem is divided into subtasks	Identifies necessary sequence of subtasks
Sets goals	Sets a clear goal for a task	Sets general goal such as task completion	Sets goals for subtasks	Sets goals that recognise relationships between subtasks
Resource management	Manages resources or people to complete a task	Uses/Identifies resources (or directs people) without consultation	Allocates people or resources to a task	Suggests that people or resources be used
Flexibility and ambiguity	Accepts ambiguous situations	Inaction in ambiguous situations	Notes ambiguity and suggests options	Explores options
Collects elements of information	Explores and understands elements of the task	Identifies the need for information related to immediate activity	Identifies the nature of the information needed for immediate activity	Identifies need for information related to current, alternative, and future activity
Systematicity	Implements possible solutions to a problem and monitors progress	Trial and error actions	Purposeful sequence of actions	Systematically exhausts possible solutions
Learning and knowledge building				
Relationships (Represents and formulates)	Identifies connections and patterns between and among elements of knowledge	Focused on isolated pieces of information	Links elements of information	Formulates patterns among multiple pieces of information
Rules: "If … then"	Uses understanding of cause and effect to develop a plan	Activity is undertaken with little or no understanding of consequence of action	Identifies short sequences of cause and effect	Uses understanding of cause and effect to plan or execute a sequence of actions
				Plans a strategy based on a generalised understanding of cause and effect
Hypothesis "what if…" (Reflects and monitors)	Adapts reasoning or course of action as information or circumstances change	Maintains a single line of approach	Tries additional options in light of new information or lack of progress	Reconstructs and reorganises understanding of the problem in search of new solutions

Figure 8: Cognitive skills in collaborative problem-solving
Source: Hesse et al. 2015: 43