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Mathematics
EduLarp

MATHEMATICS EDULARP

Educational Live Action Role Playing Game in Mathematical Context

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Editorial

It is said that three forms of activity accompany a person throughout life: playing, learning, and working. At each stage of development, the game has different features and a different meaning. For young people, play is an entertaining activity, it is a specific way of learning about the world, during which they gain new knowledge not only about the world around them, but also about themselves.

This material, titled Mathematics EduLARP, aims to present the ideas and design of an original learning game, an EduLARP, which can be used to motivate students to study science subjects, in especially mathematics. Using the EduLARP method, mathematical concepts as well as intersubject relationships are applied to facilitate the development of knowledge but also skills, such as spatial orientation, communication in a small team, and problem solving. In the creation of mathematical EduLARPs, didactic knowledge in the field, experience in the field of game creation, research-oriented teaching and psychology have been connected.

The target categories of teaching mathematics for the 21st century are formulated with an emphasis on students' ability to analyse, reason, and communicate effectively as they formulate, solve, and interpret mathematical problems in contexts that often connect mathematical problems with authentic real-life situations. Appropriate teaching methods can improve students' level of understanding and help them adopt mathematical rules and procedures. Emphasis is placed on the type of mathematical tasks that are complex, non-routine, go beyond traditional ways of solving problems, and are better suited to preparing students for an authentic use of mathematics.

With these goals in mind, the developed game represents a connection of several areas that frontal teaching usually fails to saturate sufficiently. This is a combination of knowledge development and soft skills, followed by knowledge transfer training. Both are applied in the simulated reality of the game world. Game participants can immediately apply the acquired knowledge in practical situations, justifying the correctness of their applications. We want to contribute to the discussion with the help of a case study from the development of a unique approach to the development of an educational game, which connects the principles of digital and physical games, which participants enter in real time.

This material was written by members of the international team of the Mathematics EduLARP project from the VSB – Technical University of Ostrava, the University of Cantabria, and the University of Genoa.

Tereza Benešová, Mathematics EduLARP project head manager

Roots and Anchoring of EduLARPs

Josef Kundrát

When you refer to an interactive educational role-playing activity as EduLARP and frame it in the context of this relatively young approach to interactive education, you will often encounter responses that will compare EduLARPs to a number of other methods, activities or approaches in pedagogy. We can randomly mention various educational simulations, role-playing, theatre of the oppressed, psychodrama, digital educational games, a number of activation pedagogical methods or camp games. An EduLARP is connected to most of the mentioned activities to varying degrees, it would be beyond the scope of this monograph to describe the mutual influence or historical connection of the mentioned approaches and methods. In this chapter, we name the individual historical roots of EduLARPs, the most important related directions in interactive education, and we define an EduLARP as an independent and gradually more prominent direction with a unique history.

The English acronym EduLARP stands for educational live action role playing. The term EduLARP was created by adding the prefix "edu" to the existing term LARP, which has established itself as a distinct type of a wide spectrum of leisure activities, sharing several basic characteristics. Tychsen et al. (2006) state that the term LARP is generally accepted by the gaming community, today we could add that also by the public, due to the appearance of the term in the media (e.g. Czech Television, 2017). LARP is a type of participatory game in which players physically adopt roles, similar to improvisational theatre. LARPs take place in a fictional environment that is represented by physical space. Players have control over their character's behaviour and decision-making, as a rule they don't exactly follow the given scenario. Together, the players shape and develop a story that they play for themselves, LARPs are played, with exceptions, without an audience. Another essential characteristic of a LARP can be considered the consensus (contract) of all involved players over the rules and the idea of the fictitious game world (Tychsen et al., 2006). The shared and generally accepted fictional reality then defines the so-called magic circle, i.e. the mental membrane that separates the fictional world from the real one in the minds of the players involved (Linser & Ree-Lindstad, 2008). The magic circle of the game can also be defined by the physical boundaries of the game space (e.g. a LARP taking place in a single room defines a magic circle ending behind the walls of room.

Figure 1: MethanCity LARP (Jihlava, Czechia, 2015) set in a fictitious totalitarian state

Games that contain the essential elements of LARP (physical role-playing without spectators, game space, consensus over the rules and setting of the game, possibly the use of costumes) are often encountered outside the context of LARP, in the form of children's or camp games, which may precede the concept of LARP by decades. In Fig. 2, we illustrate with an example from the cartoon historical comic *The Fast Arrows* (Rychlé šípy, Foglar et al., 2012), in which the author depicted the experiences and games of his own leisure group through the stories of a (most likely) fictitious boys' club. Figure 2 is a strip from a comic book illustrating a battle game with the roles of Indians and soldiers. The players use simple costumes, the game takes place in a defined area and a simple game mechanics is presented: lives that players lose when hit by a cone. In the comic from 1948, the author gives a brief overview of the rules and setting of the game, probably as an inspiration for the implementation by reading clubs.

Figure 2: Illustration of a battle camp game with a storyline, roles and rules

Harvianinen (in Duus Henriksen et al., 2011) distinguishes between the terms LARP and larping, by which he refers to playing a role in a certain context, which is not necessarily, unlike LARP, framed by a magic circle. In this context, we would consider larping, for instance, training or educational simulations with role-playing, psychodrama or the aforementioned camp games, which have a permeable magic circle (in the case of Foglar's game, the players went to the local news agent's for new lives, which can't have been part of the game's magic circle). A number of games that contain larping and can be regarded as the historical roots of this entertainment are described by Zapletal (in Veselý, 2010) and he mentions as one of the first examples Ernest Thompson Seton's games for the American youth association at the beginning of the 20th century.

The context in which the term LARP was established and which historically defines it is connected with so-called hero games or role-playing games (RPG for short). It is a group of games in which the player represents a character in a fictional setting. Through playing the character, the player experiences and develops a story that does not have a predetermined script. Role-playing games exist as a genre of digital games for different platforms in which the player controls one or more characters and moves through a predetermined, often non-linear story. Another form of RPG games, which can be understood as closely related to LARP, are tabletop role playing games (TRPG). The essence of this type of RPG is the group play of characters in a fictitious setting, which, however, is not simulated by a physical space, but takes place only in the imagination of the players. The name of this form of RPG implies that it mostly takes place at the table. The narrator, who describes to the players what is around them in the fictional world and what their characters perceive and experience, represents the central figure in this type of games. TRPGs are usually based on extensive rules that describe in detail various solutions to game situations, character abilities, descriptions of enemies, etc. In the Czech environment, the best-known TRPG is Dungeons and Dragons (Benda & Klíma, 2001), which is followed by a number of other systems, e.g. Dragon Watch (Ondrusz & Politzer, 2020). Dungeons and Dragons, which was introduced in the 1970s, is considered the most famous TRPG worldwide (Gygax et al., 2013). Tabletop RPGs share a number of similarities with LARPs, both forms of RPGs interact with each other. A frequent fictional setting for LARPs is a fantasy setting, the perception of which was strongly shaped by the aforementioned TRPGs (Live Action Role Playing (LARP) – Between Game and Art, b.r.).

Figure 3: A group playing a TRPG

The clear dividing line between improvisational theatre, role-playing games in a tabletop or digital form, simulations or psychodrama is rather blurred. All activities share similar elements, however, we can distinguish a LARP by the fact that it is primarily a game. Approaches to creating a LARP can be similar to digital or tabletop games. A LARP is usually created with regard to the game story, game mechanics, roles, etc. Processes from the creation of digital games are often applied in the creation of a LARP for entertainment as well as a deliberately created LARP with an educational purpose (Mochocki, 2013).

A LARP, played for fun, already implicitly contains a whole range of developing or educational elements, which we will now analyse step by step. In the following section, we will present the current literature that goes more in-depth in the description of these elements and relates them to established approaches or theories in education. Role-playing itself is considered an activity that has the potential to develop. Above all, he development of communication skills, empathy and imagination are emphasised (Meriläinen, 2012). When playing a LARP, it is necessary to get involved and interact socially, which can have a positive effect on the development of competences associated with understanding social situations, and therefore conflicts. Role-playing means that the participant adopts a different identity, explores it, experiments with new social positions and adapts to new circumstances. Unlike playing theatre, where the actors follow a given script, when playing a LARP, the participant is drawn into the action, moves inside the magic circle and, in interaction with others, organically and emergently reacts to the events around her, which places high demands on the correct reading of social situations, orientation in relationships and communication, quick adaptation and appropriate reactions. LARP stories often work with strong dramatic plots that can push players beyond their comfort zone and lead to learning. The fact that it is not predetermined how the story of the game will develop, or the participant of the game usually does not know its dramaturgy, playing a LARP is an opportunity to experience a large number of unknown situations.

Meriläinen also found that most players positively evaluate the effect of LARP on personal development in problem solving (2012). Situations in LARP games often put participants in conflicting or problematic situations that need to be solved creatively. LARPs are a participatory activity, and solving game problems (that is, those presented by the game world) often takes place in cooperation with others. Kundrát (2013) identified four areas in which LARP has the potential to develop participants in interviews with long-time LARP players. They are communication skills, self-awareness, increasing self-confidence, which is related to the development of the ability to solve issues and changing or deepening the attitudes and values of the participant. In the last mentioned area, LARPs can act through the author's intention to present the players with a story or an environment that approximates a certain historical era or opens up a socially important topic. As an example, we can cite the LARP Projekt Systém, which dealt with topics related to the totalitarian regime. Through the game experience, participants gain stimuli for shaping their attitudes, through mutual discussion, and are more personally motivated to further education on the topic. A documentary film was made about LARP (*5 Rules*, 2013).

Although most LARPs are created only for the entertainment of the participants, as studies by Meriläinen (2012) and Kundrát (2013) show, the potential of this type of games to develop and educate the players is perceived and reflected. Over the past three decades, when LARP has established itself as a unique genre, a number of LARP projects have been created in which the goal of the game was not only to entertain, but above all to educate in a certain area.

An EduLARP is defined as an educational role-playing game or exercise in which participants assume a new role for an extended period of time in a limited fictitious setting that "may or may not resemble everyday reality" (Bowman & Standiford, 2015). In a broader context, an EduLARP represents any application of a role-playing game with an educational or therapeutic purpose.

Mochocki (2013) presents EduLARP as a specific type of educational drama, i.e. an approach where role-playing elements known from the theatre context are used for educational purposes. It lists elements of EduLARP that are identical to edu-drama (Heathcote, 2002, in Mochocki, 2013). Both approaches use social collaboration, always involve a here-and-now element in which participants act in the first person (when playing a character), involve action and, focus and productive tension, always require some modification of behaviour for role-playing. Similar elements can already be found in the historical work of Comenius, who, as part of his game-based education, proposes an interactive teaching method that includes dramatic elements. Their motivational effect and the high level of the participant's own activity are emphasised (Comenius & Bötticher, 2017).

Comparing EduLARPs to other educational activities that use role-playing or other common elements is always quite difficult, given the broad definitions and overlapping boundaries in individual applications. Bowman dealt with a detailed review of the literature devoted to the educational benefits of EduLARPs and at the same time to a comparison with a number of related activities (Bowman, 2014). Based on the analysis of the literature, she divides the educational dimensions of EduLARPs into the categories of cognitive (including, for example, improving problem solving, increasing self-efficacy, developing creativity, etc.), affective (e.g. increasing empathy, social skills, improving understanding of the perspective of others) and behavioural dimensions (active involvement, development of cooperation, improvement of leadership skills).

As a defining difference between EduLARPs and related activities (edu-drama, role playing in teaching, psychodrama, teaching simulation, etc.) we perceive the high complexity of EduLARPs, which results from the game nature of the activity. The creation of a magic circle, a shared narrative by the participants, a set of rules and game mechanics, roles, a scenario and other elements in mutual cooperation often exceeds simpler approaches in complexity, such as the use of role-playing by a teacher in teaching. This allows the parallel application of multiple educational dimensions at the same time (Bowman, 2014).

Based on experience with the design of EduLARPs, we also add the possibility of different uses of EduLARPs for different pedagogical situations, which pushes the complexity of the method even further. In the timeline of the pedagogical process, we can apply EduLARP in many situations. Before acquiring knowledge, EduLARP enables to motivate, awaken interest in the topic, shape and deepen attitudes. Subsequently, it is possible to apply EduLARP as a tool for the adoption of a specific curriculum (Mochocki, 2013). Last but not least, EduLARP will find application as a knowledge validation tool. In the game context, participants use information that they have previously mastered.

References

5 Pravidel: Dokument o hře na totalitu. (2013, březen 28). Radio Wave. https://wave.rozhlas.cz/5-pravidel-dokument-o-hre-na-totalitu-5296977

Benda, M., & Klíma, M. (2001). *Dračí doupě: Fantasy hra na hrdiny : pravidla pro začátečníky : verze 1.6. [2], [2],*. Altar.

Bowman, S. (2014). *Educational Live Action Role-playing Games: A Secondary Literature Review* (s. 112–131).

Bowman, S., & Standiford, A. (2015). *Educational Larp in the Middle School Classroom: A Mixed Method Case Study*. 4–25.

Comenius, J. A., & Bötticher, W. (2017). *Des Johann Amos Comenius Schola Ludus Die Schule als Spiel*. https://nbn-resolving.org/urn:nbn:de:101:1-2019022301083304213097

Česká televize. (2017). *Planeťácká reportáž: Larp — Planeta YÓ*. https://www.ceskatelevize.cz/ivysilani/10315711050-planeta-yo/217543117370001/obsah/528456-planetacka-reportaz-larp

Duus Henriksen, T., Rollespilsakademiet (firma), & Knudepunkt (konference) (Ed.). (2011). *Think larp: Academic writings from KP2011*. Rollespilsakademiet.

Foglar, J., Fischer, J., & Nosek-Windy, V. (2012). *Rychlé šípy*. Olympia.

Gygax, G., Mearls, M., & Wizards of the Coast, I. (2013). *Dungeons & Dragons*.

Kundrát, J. (2013). Live action role playing jako prostředek osobnostního rozvoje. Univerzita Palackého v Olomouci, diplomová práce.

Linser, R., & Ree-Lindstad, N. (2008). *The Magic Circle—Game Design Principles and Online Role-play Simulations*. 8.

Live Action Role Playing (LARP) – Between Game and Art. (b.r.). MPIWeb. Získáno 16. červen 2021, z ~/blog

Meriläinen, M. (2012). *The self-perceived effects of the role-playing hobby on personal development-a survey report*.

Mochocki, M. (2013). Edu-Larp as Revision of Subject-Matter Knowledge. *International Journal of Role Playing*, 55–75.

Obrdlíková, K. (2021, květen 6). Online sezóna plná e-larpů. *Larpy.cz*. https://www.larpy.cz/online-sezona-plna-e-larpu/

Ondrusz, P., & Politzer, J. (2020). *Dračí hlídka: Hra na hrdiny*.

Tychsen, A., Hitchens, M., Brolund, T., & Kavakli, M. (2006). Live Action Role-Playing Games: Control, Communication, Storytelling, and MMORPG Similarities. *Games and Culture*, *1*(3), 252–275. https://doi.org/10.1177/1555412006290445

Veselý, L. (Ed.). (2010). *Rozlety: Sborník larpové konference Odraz 2010*. Tempus ludi.

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Metacognition and play

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The phenomenon of play as a natural activity through which a child gains experience and at the same time learns about herself is the subject of a number of important theories and research (e.g. H. Spencer, J. Piaget, etc.). In her overview study, Rachel White (2012) maps the influence of play on the overall development of a child and points to the positives of a wide range of games from pretend play, physical games, social games to didactic games. Through play, children naturally develop cognitive abilities, abstract thinking, learn to solve problems, develop motor skills, but also significantly develop social skills, the ability to cooperate and resolve conflicts.

Current research mainly points to the fact that play develops early metacognitive and self-regulatory abilities, independently of general intelligence (Veenman & Spaans, 2005). Veenman and Spaans (2005) draw attention to the importance of self-regulatory abilities, especially in the context of intentional learning, which requires effort and includes a number of metacognitive activities, such as planning, organisation, selection of appropriate cognitive strategies and their reflection.

In professional literature, **metacognition** is most often defined as knowledge about managing one's own cognitive activities during learning (Foltýnová, 2009) or as the ability to reflect on one's cognitive processes and at the same time to improve and develop these processes. Experts disagree on the exact definition of metacognition, mainly due to the overlap of related concepts that are closely related to metacognition, such as executive control, self-regulation, meta-memory, self-reflection, confidence in one's own self-efficacy, among others (Whitebread, Coltman, Jameson & Lander, 2009). The term metacognition is attributed to John H. Flavell, who in the early 1970s defined metacognition broadly as knowledge of one's own cognitive processes and divided it into two basic components: cognitive knowledge and cognitive regulation/monitoring. Knowledge of cognition includes established knowledge about personal characteristics, but also knowledge about the requirements of the task situation and knowledge about the used solution strategies. Cognition regulation then means the ability to monitor one's cognitive activities and can be divided into other subcategories, such as anticipation, planning, monitoring and evaluation (Chytrý, Pešout & Říčan, 2014). Other research on metacognition emphasises that it is a multidimensional construct that is related to a number of psychological concepts, such as motivation, critical thinking, problem solving, self-regulated learning and evaluation (Chytrý, Pešout & Říčan, 2014). Despite this obvious layering and different explanations, the individual definitions meet in emphasising the role of executive processes, especially the control and regulation of cognitive processes. These are cognitive mechanisms that help self-regulate one's own learning. It is the student's ability to effectively manage and reflect on her own learning process that is among the indisputable factors of academic success (Brown & Palinscar, 1989), and a similar causality is seen in the cause of school failure, behind which, on the contrary, lies a deficit in metacognitive ability.

In their concept of metacognitive knowledge, Borkowski, Milstead and Hale (1988) define a separate area, which they call metacognitive knowledge of relationships. This is an area of metacognition that can be strengthened by involving the individual in task situations, in which she practices assessing the adequacy of the strategy in relation to the task situation, but also to herself, and where she is exposed to the necessity of choosing from several possible solutions or creating complex solutions, which requires a higher degree of generalisation and abstraction from her.

For pedagogical practice, it is important to take into account that the optimisation of the learning process can only occur during the direct use of metacognitive strategies, i.e. only when the knowledge of the strategy is used in actual strategic action within the framework of three basic metacognitive processes: planning, monitoring and evaluation (Schraw, 1998).

Planning is already part of the initiation of the activity, within which the student must think about a suitable solution strategy in accordance with the goals. Monitoring is part of direct work on the task combined with metacognitive knowledge of one's own knowledge and experience. Evaluation is then a process of checking cognitive action with possible revision of goals, solution process and others. The evaluation reflects the quality of the monitoring process.

By consciously applying these metacognitive processes in the game, one can also contribute to intentional learning, practice problem solving and develop creativity. Targeted self-regulation of one's own learning through deliberate play was already pointed out by Vygotskij with the concept of the "zone of proximal development", i.e. the distance between the current performance level, the level of the child's ability to solve a certain task, and the potential developmental level that can be overcome in cooperation with a more experienced person (Vygotsky, 2017). In simple terms, the principle of the zone of proximal development consists of working with a support person, who can be a teacher, parent or peer, who guides the child through a problem, mentoring and leading a discussion with her (Vygotsky, 1979). This type of implementing and activating approach also meets the type of game called didactic game. A didactic game is an analogy of children's spontaneous activity, which, however, pursues predetermined didactic goals, not necessarily in an obvious way for the participants. The didactic game has defined rules, requires progress management and a final evaluation. A great advantage is the stimulating potential, the stimulation of creativity, spontaneity, cooperation and the natural involvement of skills and life experience (Průcha et al., 2003). The didactic game is thus one of the appropriate tools to support the development of metacognition and support a positive learning experience. At the same time, demands are placed on the didactic game, such as determining the cognitive and social goals, the necessary knowledge, skills, experience of the students, clarifying the rules of the game, defining the role of accompanying adults, determining the method of evaluation, ensuring suitable spaces for the game, preparing game aids, determining the time frame of the game and its variability (Maňák & Švec, 2003).

Metacognitive prerequisites for the development of mathematical skills

A number of studies draw attention to the important role of metacognition in mathematics as well as the connection with other psychological concepts, such as motivation (e.g. Tian, Fang & Li, 2018). A student's level of metacognition explains a substantial amount of individual differences in mathematics test scores. The predictive potential of metacognitive abilities in relation to school success is shown to be an alternative to standard ways of determining the level of intelligence (Veenman & Spaans, 2005). As early as the 1980s, researchers in the field of problem solving agreed that the low performance of students in solving problem situations, primarily in mathematics, is caused by not only a lack of adequate factual knowledge, but also the student's inability to organise, use and correctly evaluate what knowledge is available, to fully understand the assignment of the task and to be able to use a functional solution strategy appropriately, especially if it is a non-routine task (Garofalo & Lester, 1985).

Research shows a significant connection between executive functions and mathematical skills, especially the correlation between various aspects of metacognition and mathematical performance (e.g. Presentación et al., 2015), with the emphasis being mainly on the level of inhibition and working memory. From the point of view of observing metacognitive functions, inhibition as one of the core executive functions is responsible for an individual's ability to control attention, behaviour, and emotions in order to be able to successfully use functional solution strategies and divert distracting stimuli. Not only is inhibition closely related to the demands of the school environment, but the level of inhibition related to numerical stimuli highly reliably predicts the level of mathematical skills (Presentación et al., 2015). It can be assumed that if an individual has sufficiently developed metacognitive abilities, she has the potential to handle tasks in which the level of mathematical knowledge is insufficient. Her support here is the way of focusing on the problem situation and the ability to understand the necessary mental resources and solution strategies. According to some authors, an individual's metacognitive abilities are most manifested in specific areas of mathematics, such as logic, propositional logic, and the like. As part of the preparation and implementation of the mathematical game EduLARPU Starflyer (Erasmus + project, 2019-1-CZ01-KA201-061377), logical problems became a cohesive element of the mathematical content of the game, and the players acknowledged their inclusion as more functional than the inclusion of a purely mathematical problems. In the event of an unsuccessful solution to a mathematical problem, players faced various consequences. It was impossible to continue in some stations, or the game was blocked, but the players soon found out that most numerical failures could be solved constructively, e.g. by calling for repeated solutions to a mathematical problem, temporary replacement of members of different teams (e.g. pupils more skilled in a specific mathematical problem) etc. The participants perceived the possibility to intervene in the game and monitor the effects of their decisions as a positive element. The introduction of the metacognitive process (thinking about thinking) thus created a functional superstructure in the game that helped players overcome any factual ignorance in the assigned tasks. Within the framework of the game constructed in this way, mathematics itself became a means, not just a goal, and even students who did not regard mathematics as their favourite subject expressed that they did not mind the game and did not even perceive that they were dealing with the given subject.

Metacognition in connection with mathematics is more often investigated in older students, but already in the first grade it is appropriate to present metacognitive knowledge about mathematical strategies so that they are aware of why, when and how to apply strategies that will help them to reach solutions successfully. The development of the ability to think about one's own knowledge, to evaluate one's knowledge and competences is also a suitable tool for eliminating anxiety and a negative attitude towards mathematics, which often appears in the assessment of mathematics by pupils. At the same time, the personal and affective side, the students' motivation, affects the learning of mathematics more significantly than studying other subjects (Tian, Fang & Li, 2018).

Reflective processes

As mentioned above, an important area of the metacognitive process is evaluation, i.e. the process of checking cognitive action with possible revision of goals and the solving process. The inclusion of this area of the metacognitive process in the EduLARP game is an important tool of LARP dynamics. Larpers and educators who use LARP elements in teaching draw attention to the importance of non-game reflective activities connected to the game experience (Mochocki, 2013). In the LARP context, debriefing is often referred to as desirable to ensure the proper completion of the game process. The reflective process can take different forms within an (Edu)LARP; it can be a discussion, a debriefing or a detailed reflection of the game after its end. Duus Henriksen (2010) points out that reflective processes in edu-games can be anchored in the game plan in various ways, such as pre-reflection (briefing and preparatory activities), post-reflection (debriefing and other types of discussion), break-out from the game (the moment when the game pauses for a while) and reflection in action, which means embedding a reflective process in a given task, thereby continuously adapting to the development of the context or problem. This type of reflection was also incorporated into the EduLARP game StarFlyer. First of all, there were the roles of the so-called ushers: androids, which made it possible to be with all the players – members of the crew in continuous interaction, control their progress, help them and, if necessary, direct game situations. However, the ushers were not hierarchically superior to the crew, so that the democratic social dynamics of the game could be preserved and so that one of the didactic purposes of the game could be fulfilled, i.e. to develop communication and social competences, the skill of critical thinking and solving ethical questions. The ushers fulfilled the role of guides, but did not enter into decisions about human dilemmas. These decisions were in the hands of the players. The overall system of players' decisions about story and ethical dilemmas in the mathematical EduLARP Starflyer is based on the cooperation of players in small groups, in which they always make a choice based on group consensus from two or more alternatives. This reflection in action (Mochocki, 2013), that is, building a reflective element into the overall game mechanism using a shared perspective and goal, enabling group participation, opens up space for critical discussion and the search for group consensus within the game (Duus Henriksen, 2010). The core of the game is thus based on metacognitive processes of analysis, planning, monitoring and ongoing collective evaluation of goals.

In our opinion, the game design of the mathematical EduLARP Starflyer thus fulfils the central characteristics of an effective didactic procedure (as defined for example by Chytrý, Říčan and Živná, 2019), i.e. it develops critical thinking in students in the sense of predicting, planning, monitoring and evaluating their own steps so that the didactic process formed as many autonomous beings as possible with a high level of self-regulation.

References:

Brown, A., & Palinscar, A. (1989). *Coherence and causality in science readings*. In Annual meeting of the American Educational Research Association, San Francisco.

Borkowski, J. G., Milstead, M., & Hale, C. (1988). Components of children's metamemory: Implications for strategy generalization. *Memory development: Universal changes and individual differences*, 73-100.

Duus Henriksen, T. (2010). *Moving educational role-play beyond entertainment. Education in the Knowledge Society, 11*(3). DOI:10.14201/eks.7462

Foltýnová, D. (2009). Vliv metakognitivních strategií na rozvoj dovedností žáků autoregulovat své učení. *Pedagogická orientace, 19*(2), 72-88.

Garofalo, J., & Lester, F. K. (1985). Metacognition, cognitive monitoring, and mathematical performance. *Journal for research in mathematics education, 16*(3), 163-176.

Chytrý, V., Pešout, O., & Říčan, J. (2014). *Preference metakognitivních strategií na pozadí úkolových situací v matematice u žáků druhého stupně ZŠ*. Univerzita JE Purkyně v Ústí nad Labem.

Chytrý, V., Říčan, J., & Živná, D. (2019). Matematická výkonnost a metakognice žáků základních škol běžných, základních škol Montessori a žáků vyučovaných podle Hejného metody. *Studia Paedagogica, 24*, 107-133.

Maňák, J., & Švec, V. (2003). *Výukové metody*. Paido.

Miranda, A., Colomer, C., Mercader, J., Fernández, M. I., & Presentación, M. J. (2015). Performance-based tests versus behavioral ratings in the assessment of executive functioning in preschoolers: associations with ADHD symptoms and reading achievement. *Frontiers in psychology, 6*, 545.

Mochocki, M. (2013). Edu-larp as revision of subject-matter knowledge. *International Journal of Role-Playing, 4*, 55-75.

Průcha, J., Walterová, E., & Mareš, J. (2003). *Pedagogický slovník*. 4. vyd. Praha: Portál.

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional science, 26*(1), 113-125.

Tian, Y., Fang, Y., & Li, J. (2018). The effect of metacognitive knowledge on mathematics performance in self-regulated learning framework—multiple mediation of self-efficacy and motivation. *Frontiers in psychology, 9*, 2518.

Veenman, M. V. J., & Spaans, M. (2005). *Relation between Intellectual and Metacognitive Skills: Age and Task Differences. Learning and Individual Differences, 15*, 159-176.

Vygotsky, L. S. (2017). The Problem of Teaching and Mental Development at School Age [Problema obuchenija i umstvennogo razvitija v shkol'nom vozraste]. *Changing English, 24*(4), 359-371.

White, R. E. (2012). *The power of play: A research summary on play and learning*. http://www.mcm.org/uploads/MCMResearchSummary.pdf.

Whitebread, D., Coltman, P., Jameson, H., & Lander, R. (2009). Play, cognition and self-regulation: What exactly are children learning when they learn through play?. *Educational and Child Psychology, 26*(2), 40.

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Games and education

Simona Oľhová

In this chapter, we will look at two words that we all encounter throughout our lives and that are often seen as opposites – game and education. Let us try to look at games differently than through the lens of aimless entertainment or undirected leisure activity. Also, we will try to look at education differently from traditional face-to-face teaching, students‘ passive sitting and notebooks full of notes.

Education is defined as the process of mastering knowledge and activities, acquiring knowledge and skills, and developing the intellectual side of the personality (Průcha et al., 2009). By contrast, playing as such is often defined as an activity different from work or learning that one engages in for entertainment. Educational games offer a unique structure to **complement** traditional teaching strategies and energise teaching, stimulate innovative thinking and provide variety in teaching methods (Boyle, 2011). During an educational game, the traditional teaching method is replaced, and learning takes place during the game through a better understanding or awareness of the issue being discussed. Learning through play must have pre-defined learning outcomes that it delivers – so it is key to think about the balance between the subject-matter coverage and the students‘ desire to prefer playing.

From a broad point of view, it is possible to say that the use of games in the teaching process allows students to look at educational topics in a different way, thus helping to reduce the monotony of teaching or to motivate them to concentrate. However, not every game is suitable for teaching and can be labeled as an educational game in the true sense of the word. Many commercial games have educational elements, but the companies that develop them are largely motivated by profit. This leads to the entertainment and marketability value of the games taking precedence over the educational value. This can lead to a loss of the game‘s educational potential. Therefore, identifying appropriate games and using them for the right school audience is an important part of the challenging task of teaching staff.

What to consider when using educational games

Educational games in the school context often start with the simple idea that games motivate and that their motivational power can be used to sweeten the pill of the bitter content of learning (Scanlon et al., 2005). However, it is not easy to work with a suitable method for the teacher and the class, which can be included in the educational process of, for example, one lesson.

The key to any game is teacher's preparation. Teacher must firstly know what group of participants she will be working with – how to capture their interest, what knowledge and experience they already have – and at the same time know the premises in which the activity will take place in order to know the possibilities and limitations. Furthermore, her internal setting and ability to work with group dynamics are important. Games can reveal topics that would remain untouched in the standard teaching process. The physical preparation of materials and the time available to the teacher must not be neglected.

It is also advisable to think about the possibility of oversaturating the participants. It is therefore appropriate to combine various forms of acquiring knowledge and experience in the educational process. The importance of discussion, evaluation and reflection should not be neglected either. During the game and after its completion, it is possible to approach topics that would otherwise receive no attention. Games often act as learning triggers that spark lively discussion of learning concepts among students after playing (Boyle, 2011). At the same time, the game allows the participants to realise their own view of the matter and at the same time to understand the other's perspective. The game often does not need a single truth or a universally valid rule – on the contrary, it can point to a different experience. Part of the discussion after the activity can be, for example, a summary of the course of the activity, emotional experience during the activity, retrospective evaluation of discoveries that the participants have made about themselves or the game.

Types of educational games

There are an infinite number of divisions of educational games (according to the age and number of participants, the necessary space and equipment…). In this subsection, we will look at two selected types: games in the "real" world and games in the digital world (computer games). Bednařík et al. (1998) distinguish the following types in the case of real games:

- Cognitive approaches
  - for example: discussion, text analysis, fact searching

- Roleplay
  - for example: simulations, psychological drama, social drama

- Practise-based learning
  - for example: direct actions, strategic planning, attendance of a court proceedings

- Experience-based games
  - for example: focus on collaboration, decision-making, empathy enhancement, elements of art

In the case of real-world games, these are often games that teachers have already encountered in their profession. On the other hand, digital games are a relatively new concept that is sometimes misunderstood. This is due to the perception of all computer games as intended only for entertainment – that is, something that does not primarily belong in school. Nowadays, it is impossible to separate technology from education – it is necessary to make them allies, not adversaries. In addition, by using the Internet, digital technologies or social media, we create a natural and attractive environment for students, where they can navigate without problems. Scanlon (2011) comments on the natural enthusiasm and talent of children for computers and considers the application of the Internet as an interesting and captivating way of teaching.

According to the OECD (2019), even within the framework of international education, the curricula put emphasis on 21st century skills, such as creativity, digital literacy, critical thinking and social skills. One of the tasks of educational institutions is to prepare children for technologies that do not yet exist and we cannot foresee them. It is often the environment of computer games that teaches children to learn and adapt – in computer games it is necessary to apply the learnt knowledge and skills, otherwise it is impossible to advance in the game. The attractive environment and the reward in the form of a successful game stimulate children to acquire the necessary knowledge. According to the OECD (2019), it is desirable to develop skills that help children to be flexible and able to quickly adapt to relatively big changes – this is sometimes difficult to create in the learning process, but it is natural for the digital world.

Another way to divide games is according to the learning area; for example, games aimed at learning a second language or games aimed at learning biology. However, this reduces the real potential of digital games, because almost all educational computer games develop intellectual abilities, the ability to process verbal information, the use of rules, understanding, psychomotor skills, knowledge, logic, the ability to work with a story and solve algorithmic problems. From a narrower point of view, we can apply O'Brien's et al. (2010) division of games according to their genre and contribution to educational purposes:

- Linear games
    - players apply linear logic and consecutive steps to succeed
    - brainteasers, jumping games
    - decision-making, motoric abilities

- Competitions
    - apart from linear logic, players also predict other players' behaviour to succeed
    - sport and battle games
    - work with attitudes, use of a selected approach

- Strategic games
    - to succeed, players apply strategic planning and complex-system management
    - strategic military and management simulators
    - situational analysis, solution seeking, problem solving

- Roleplay
    - to succeed, the player uses development and maintenance of a fictional character in a complex environment
    - vast online environments for multiple players
    - dealing with dilemmas, case analysis, evaluation.

Educational games and socially disadvantaged children

The school results of children from families with a lower socioeconomic status have lagged behind their peers' for a long time (Prokop et al., 2020). This is a complex issue, in which many factors intervene, and therefore in this sub-chapter we will only look at the possibilities of using educational games, and not at the topic as such. Bartoňová and Vítková (2010) consider the alternation of individual, group and collective work as well as the application of various situational, activating and staging teaching methods suitable when working with children from socially disadvantaged backgrounds.

In addition to using games to increase students' general motivation and engagement in the learning process, Fuszard (2011) states that the games can reduce the gap between students who learn faster in the standard process and those who learn more slowly. One of the reasons for worse results in schools and worse overall adaptation to the formal educational process is also the socially disadvantaged environment in which the child grows up. Although it is not possible to completely eliminate social disadvantage, it is advisable to deal with strategies that enable the full development of the students' potential. At the same time, these are strategies that support inclusive education and the appropriate organisation of teaching and conditions for all students.

From a personnel point of view, the acceptance of any diversity in the collective is necessary primarily on the part of the teaching staff. It is the effect of teachers and their educational methods and work with students that shapes atmosphere in classrooms and, ultimately, school results. Moreover, it is an area with which it is possible to work conceptually (Starý et al., 2012), in the form of self-education or preparation of future teachers for teaching. Of course, working with a diverse team brings an added burden for the teacher, in which the teacher's assistant, the school's counselling services and the like are a considerable advantage. Many times it can be difficult for teachers to get to know students and identify their needs. Different games, for example role-playing, make it possible to get to know the student through a different lens and thus facilitate their educational process.

In practice, peer acceptance is just as important. It is natural that the child wants to be accepted in the peer group. Traditional education supports competition between students, for example in the form of grades, but also in the form of various competitions where students are ranked from the best to the worst. This method only deepens the perceived differences between students. On the contrary, formative assessment and educational games can help the creation of relationships in the team – especially if they are focused on cooperation or skills that students normally do not have the opportunity to demonstrate at school. Many games develop empathy or social skills that also help with classroom relationships.

It is also necessary to take into account the material point of view of pupils from a socially disadvantaged environment. A pupil from a disadvantaged environment sometimes does not bring, forgets or brings damaged school equipment, such as textbooks or notebooks, or does not have access to special equipment (computer at home, sports equipment, etc.). If the teacher deals with the absence of equipment more often than other aspects of education, the student feels attacked and is uninterested in participating in school activities. On the contrary, the student will certainly appreciate if at least sometimes she works without these aids – from activities such as guided discussion to more complex educational games.

The content aspect of teaching is tied to curricular documents that oblige teachers to standardised teaching. In some cases, direct activity in practice is more beneficial for students than theoretical knowledge. For example, the country's political system can be perceived as theoretical and incomprehensible, but it is a topic where it is possible to prepare a simulation of the election process, including the preparation of election materials for individual political parties.

Education is perceived as one of the tools for reducing social inequality in society (Pavlíčková & Matulayová, 2021). However, children from socially disadvantaged backgrounds are often not led to perceive education as an important value for their lives. Education reflects the ideas of the majority about the desirable development of an individual and strives for the assimilation of minority groups (Vágnerová, 2008). Tasks at school or classical teaching generally have little to do with the daily experiences of a child from a socially disadvantaged environment, and thus she gets into a different social reality at home and at school. One of the advantages of using game elements is the motivation of students to get involved in a task that they would otherwise not find attractive (e.g. Čokyna, 2019 gives several examples from practice). A simplified example of a motivational structure is starlets, points, or trophies. They provide students with immediate satisfaction from success and a clear overview when compared with their classmates. More desirable is the direct involvement of the players, which requires active participation – Domagk et al. (2010) distinguish three types of participation – cognitive engagement (e.g. mental processing), affective engagement (e.g. emotion regulation) and behavioural engagement (e.g. embodied actions). In order for the child to be able to participate in the game, it is necessary for the game to be adaptable to every environment and every player. This is room, for example, for evaluating the students' living conditions and reflecting on their specific situation, knowledge and social reality.

Benefits of using games in education

Nowadays, schools are expected to lead students to acquire not only theoretical knowledge, but also real competences applicable in life. Of course, the student's actions are also influenced by her theoretical knowledge. On the other hand, the experience she has gained also helps her significantly – for example, through "mock activities" using a game where it is possible to verify the adequacy of one's behaviour, the choice of cooperation or competition with an opponent.

Several listed real and computer games help participants work on the development of personal, social and moral competences. Pastorová (2011) includes, for example, self-knowledge, self-concept, self-regulation, mental hygiene or creativity among personality skills – these are developed, for example, by games based on experience or computer simulations of social interactions. Social competences include getting to know people, interpersonal relationships and communication, cooperation and competition – these are developed, for example, by playing roles in a regular or online environment. Among moral competences we include, for example, prosociality, everyday ethics, values or decision-making abilities in a situation with social and ethical potential – these are developed, for example, by working with real stories (e.g. Drál' et al., 2019) or adventure games.

A great advantage of educational games is that they appeal to different learning styles. It is the flexible nature of games that allows them to accommodate different educational goals and environments. At the same time, when properly set up, they reduce the competitive nature of the school and, on the contrary, support cooperation, the search for a compromise or a joint solution. It is also a means of incorporating partner learning, as different students excel in different games and it is thus possible to change roles.

There are games that help to acquire specific skills or knowledge in a certain area. In the book, we will deal with a concrete and practical use of a LARP focused on mathematics. This method of teaching is highly suitable because it connects three basic principles suitable for education according to Pastorová (2011) – the method must be practical (the student acts on the basis of her own experience of the facts), personified (develops the student's personal experience and vision of the world) and accompanying (non-directive, based on the student's own reflection).

Games and education: Mathematics

In the teaching of mathematics, the shift from abstract calculations to mathematics in real everyday life situations is increasingly visible. The goal is to prepare students for mathematical challenges they will encounter outside of school. During the process of this teaching, thanks to the context, mathematics is more motivating and loses the perceived coldness and austerity (Scanlon, 2005).

However, it is important that these are not pseudo-real problems where students do not engage their real-world knowledge and common sense to arrive at the correct answer (Boaler, 1994). One way to achieve this is through the use of interactive media that can simulate real-life situations. However, these games are sometimes only superficially prepared and do not reach the sufficient potential of these media – for example, there is no link to real life experiences or links to other subjects or related topics.

Another possible way is the EduLARP method, where it is possible to focus on mathematical principles and processes or on the application of mathematics in everyday life. A great advantage is the possibility to connect EduLARP to other taught subjects – students can thus perceive the teaching not only as individual subjects, but as associated knowledge. EduLARP also by its very nature develops the so-called soft skills.

At the same time, the game is a safe place for all participants, where they can try out different roles or tasks in a model situation. Every reaction, and thus also every mistake, does not have immediate impact on their life – it is advisable to motivate the participants to try different behaviours and to realise the beneficial potential of the game. It is the new situations that make it possible to realise facts that the participants might not have thought of even during a long-term theoretical study.

References:

Bartoňová, M., & Vítková, M. (Eds.). (2010). *Inkluzivní vzdělávání v podmínkách současné české školy.* Muni Press.

Bednařík, A., Hrubala, J., Labáth, V., Miková, K., & Ondrušek, D. (1998). *Tréning hrou: inštrukcie pre rolové hry, simulácie a prípadové štúdie pre trénerov.* PDCS.

Boaler, J. (1994). When Do Girls Prefer Football to Fashion? An Analysis of Female Underachievement in Relation to 'Realistic' Mathematic Contexts. *British Educational Research Journal, 20*(5), 551-564.

Boyle, S. (2011, October). *An Introduction to Games based learning.* UCD Teaching and Learning. https://www.ucd.ie/t4cms/UCDTLT0044.pdf.pdf

Čokyna, J. (2019). *A okraje máš kde?*. N press.

Domagk, S., Schwartz, R. N., & Plass, J. L. (2010). Interactivity in multimedia learning: An integrated model. *Computers in Human Behavior, 26*(5), 1024–1033. https://doi.org/10.1016/j.chb.2010.03.003

Dráľ, P., Lášticová, B., Findor, A., Popper, M., Petrjánošová, M., & Andraščiková, S. (2019). *Príbehmi proti predsudkom: využitie autentických výpovedí mladých ľudí vo vzdelávaní*. Ústav výskumu sociálnej komunikácie SAV v spolupráci s Fakultou sociálnych a ekonomických vied Univerzity Komenského v Bratislave.

Fuszard, B. (2001). Gaming. In A. J. Lowenstein, M. J. Bradshaw & B. Fuszard (Eds.), *Fuszard's innovative teaching strategies in nursing* (3rd ed.). Aspen Publishers.

Scanlon, M., Buckingham, D., & Burn, A. (2005). Motivating maths? Digital games and mathematical learning. *Technology, Pedagogy and Education 14*(1), 127-139. https://doi.org.10.1080/14759390500200187

OECD (2019). *Future of Education and Skills 2030 concept note*. OECD. https://www.oecd.org/education/2030-project/teaching-and-learning/learning/skills/Skills_for_2030_concept_note.pdf

O'Brien, D., Lawless, K. A., & Schrader, P. G. (2010). A Taxonomy of Educational Games. In Y. K. Baek (Ed.), *Gaming for Classroom-Based Learning: Digital Role Playing as a Motivator of Study* (p. 1-23). Information Science Reference.

Pastorová, M., (Ed.). (2011). *Doporučené očekávané výstupy, Metodická podpora pro výuku průřezových témat v základních školách.* Výzkumný ústav pedagogický v Praze.

Pavlíčková, J., & Matulayová, T. (2021). Implementace opatření na podporu žáků se sociálním znevýhodněním ve Zlínském kraji. *Sociální pedagogika/Social Education, 9*(2), 41–57. https://doi.org/10.7441/soced.2021.09.02.03

Prokop, D., Korbel, V., Dvořák, T., Marková, L., & Gardošíková, D. (2020). *Mají děti v Česku stejné šance ve vzdělávání? Hlavní zjištění studie Nerovnosti ve vzdělávání jako zdroj neefektivity*. Nadace České spořitelny.

Průcha, J., Walterová, E., & Mareš, J. (2009). *Pedagogický slovník: Nové, rozšířené a aktualizované vydání.* Portál.

Starý, K., Dvořák, D., Greger, D., & Duschinská, K. (2012). *Profesní rozvoj učitelů. Podpora učitelů pro zlepšování výsledků žáků.* Karolinum.

Vágnerová, M. (2008). *Psychopatologie pro pomáhající profese.* (4th Ed.). Portál.

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Mathematics and games

Zuzana Václavíková

Mathematics as a subject

Mathematics is a fundamental subject at all levels of education around the world, including the university level, in particular in the areas of natural sciences, technical disciplines and, against the backdrop of rapid growth of digital technologies, also other areas where a great deal of data must be processed. All degrees of data stress the importance of mathematics. Logical thinking is a step in the development of young children, who are fascinated by it. However, in the course of the educational process, mathematics loses its popularity and becomes difficult and is eventually rejected. Young students begin to perform badly, and with teachers exacerbating the situation, the circle closes and mathematics becomes a bogey. Unlike other subjects, mathematics does not teach facts but introduces ways of thinking, albeit seemingly with mathematical concepts in the background.

An emphasised aspect now coming to the fore in general is critical thinking. A system of education is expected to teach students to think critically. Consequently, teachers include activities that engage critical thinking to achieve the goals of the respective subjects; however, not in mathematics, where critical thinking is involved implicitly. Mathematics, known as the queen of sciences, teaches us to think about problems in a complex, in-depth manner, to analyse and synthesise, whereas these thought processes are extremely important for decision making in all areas of our lives. Hence if we want to have an educated society, we need to go back to mathematics in such a form that will actually meet its goal in terms of learning to think in the right way and, based on knowledge of the problem, to learn to make the right decision.

So, what is the issue and how can the attitude towards mathematics change? These are some of the most frequently asked questions not only in Czech education. In answering them, new models of teaching mathematics have been devises (Hejný, Kuřina, 2001) as well as teaching concepts, methods and educational tools. The common feature of the new ideas is to join mathematics and its application, or to connect it with other subjects.

Mathematics as a STEM education discipline

STEM education, at its core, simply means educating students in four specific disciplines, namely Science, Technology, Engineering, and Mathematics (hence the acronym). Instead of training students in the respective domains, STEM blends all four of them in an interdisciplinary applied approach, so as to better enable them to pursue a career and to consider real-world applications (Thibaut, Ceuppens, De Loof et al., 2018). It is one of the ways to teach mathematics in context and connect it with other subjects. The problem that this approach encounters is that even professional teachers have not been led to interdisciplinarity and thus teaching mathematics in connection with other discipline is quite challenging for them. Experience shows that the mathematical apparatus is often taught in non-mathematical subjects by teachers of other subjects and from other than mathematical viewpoints and that the teachers frequently use different notation, terminology and non-mathematical methods. On account of these differences in approach, students do not associate the given area with the application when learning the same topic. In addition, misconceptions occur chiefly. Similarly, in an effort to connect mathematics with another subject (unless they have been educated in it), mathematics teachers give examples of situations that in fact never occur in the given field, which results in misconceptions (Václavíková, 2022). It is therefore important to implement innovations in teaching mathematics not only in the education of students but also of active teachers.

Specifics of mathematics and its connection to real life

As already mentioned, the importance of mathematics lies primarily in the fact that it develops students' thinking. Nakonečný (Nakonečný, 2011) describes thinking as "a process that creates information from a given information or transforms the original information in order to use it in solving problems". Similarly, Plháková (Plháková, 2004) characterises thinking "as a process of information processing and use".

When thinking, we perform thought operations with various mental representations, which include perceptions, ideas, concepts, abstract characters and elementary ideas, which lead to the discovery and use of structural, functional, i.e. causal and purposeful relationships between objects and their properties (Plháková, 2004).

Usually, we apply the following types of thought operations

- comparison – a general thought operation that results in finding out whether two objects or phenomena are identical, similar or different;

- analysis – the decomposition of an object or phenomenon into individual parts by means of thinking;

- synthesis – the connection of individual elements of objects or phenomena into a meaningful whole;

- induction – inference from properties or regularities that apply to individual elements, regularities that apply to some class or group of cases;

- deduction – inference of new results from properties or laws that are already known;

- abstraction – concentration of thinking on capturing essential and revealing irrelevant features and properties of objects, phenomena and events;

- concretisation – concentration on concrete, illustrative, perceptible properties and features;

- generalisation – the creation of an idea or evaluation, applicable to a whole class of phenomena or events. It is a matter of subjecting individual phenomena to a general principle;

- specification – forming of ideas or evaluations concerning a phenomenon that differ from all related or similar phenomena, resembles concretisation.

The process of thinking begins when a problem situation arises, that is, when something specific needs to be solved.

Mathematical thinking is in line the definition of thinking in general. Additionally, it has its certain specifics related to the subject and methods of mathematical knowledge. Mathematical thinking also corresponds with the features of logical thinking because mathematics has its internal laws, principles and logical systems whereby it is governed, while it is also creative thinking. That is because despite being taught something already known, the students discover something new (Luhan 1990).

Mathematical thinking is used to solve logical problems. Actually, everything in our own lives – what we do and how we think – can be conceived and expressed mathematically. Mathematical thinking expands our consciousness and improves our logical abilities and thus expands the potential of our brain (Herald 2006).

Stacey (Stacey 2006) argues that "being able to use mathematical thinking in solving problems is one of the most fundamental goals of teaching mathematics, but it is also one of its most elusive goals. It is an ultimate goal of teaching that students will be able to conduct mathematical investigations by themselves, and that they will be able to identify where the mathematics they have learned is applicable in real world situations."

Therefore, it is very important to teach mathematics in close connection with real situations and in connection with other subjects.

Gamification in mathematics

If we want to solve both of the problems discussed above at the same time, i.e. to link the teaching of mathematics with practice and simultaneously teach it in a form that will be friendly and motivating for students, gamification of mathematics lessons is one of the best ways of achieving the goal. Gamification is a form of acquiring knowledge and skills in various areas of social life, based on the use of gaming elements in a non-game situation. The educational process enables a wide use of this technique as gamification can be included in various areas and directions of education.

The obvious benefit of a game is the fact that different subjects and activities can be combined in games which can be played at school, home, or indeed anywhere.

If we look at games that aim to educate in general, it is important for us to follow the activities that lead to

- learning something new (understanding the essence of a new phenomenon)
- memorising certain processes, algorithms, solutions,
- improving the ability to use knowledge to solve a specific problem.

In the first case, it is very important when designing a game or game activities to make sure that the phenomena take place in the same way as in real life. In fact, of course, we have to “idealise” scientific problems, phenomena or processes, so that they can be processed mathematically, physically, or otherwise. It is often a practical and widely used idealisation of reality that significantly simplifies description of the behaviour of the body, which is an advantage in solving many problems. The most important thing in working with an idealised model is to make sure that the things you’re stripping away are things that are not necessary for your analysis. The features that are necessary will be determined by the hypothesis that you are considering and the student/player has to know it.

In the second case, if we plan to include such activities in the game which aim for remembering something or for a consolidation of concepts, we need to realise that the brain retains predominantly information that

- we are considerably interested in
- evokes intensive emotions (positive or negative)
- is frequently repeated (Berliner, Calfee, 2004).

The last case, namely the ability to make use of knowledge in solving real-life situations, is specific to mathematics and is basically always based on adequate mathematisation of a real problem and a subsequent ability to interpret the result correctly. That said, mathematisation of a given problem may often be difficult even for experienced professionals. Unfortunately, drill work and practising of formulae is stressed in math classes and insufficient attention is paid to word problems. However, it is word problems that are to teach the student to translate the sentence into the language of mathematics. Then the student makes a calculation of the problem and must by capable of interpreting the result appropriately (for instance, not all solutions to a mathematical problem are also solutions to a word problem). Another frequently occurring error in books is that if word problems are included, they are directly linked to the particular area of mathematics. For example, after a series of typical exercises dealing with linear equations, the problem to be mathematised also leads to a linear equation, and the student often expects this to happen. In real life, however, we are not told that a word problem tests “a particular mathematical method or area”.

Eventually, even in this case the game enables us to tackle real-life situations spontaneously without any link to a specific thematic unit and with the necessity to mathematise a problem according to one's own knowledge.

Math games

Findings from neurosciences and psychology of education (Bresciani, 2016, or Collins, 2016) are used to increase the efficiency of teaching by making use of games in all subjects, in particular at primary and secondary schools. Certainly, the use of games in some subjects is easy, but gradually gamification is also being used in math classes in the system of education in the Czech Republic. Apart from games that teachers create by themselves, a number of web-based platforms offer games suitable for teaching mathematics, often available free of charge. The majority of these are digital games, which goes hand in hand with the development of digital technologies and the character of the target group – students of the "digital generation" – however, some of these games are not digital. Experts in the teaching of mathematics vary significantly in their opinion on computer games. Nevertheless, without any knowledge of a specific game, games should not be considered perfect or quite inappropriate. From the quality viewpoint, the decisive factor is the content of the game rather than whether it is digital or not. Just as non-digital games, also computer games have their pros and cons. Undoubtedly, the benefit is that the student can play the game whenever she has time. Co-players are often from another part of the world, and the students thus develop their linguistic abilities at the same time. The drawback is, however, the absence of social contact and the universal nature of the game. In the case of non-digital games, the teacher can adjust the game depending on the needs and knowledge of the class and with respect to the specific educational goals. Also such non-digital games are beneficial that develop students' physical ability, including fine motoric skills. The current time when students are overwhelmed with technologies shows that students no longer have the possibility to "put their hands on things" and that these skills are missing. In particular in math classes, where mentally demanding activities prevail, such activities are refreshing. Moreover, if short, these activities enable students to relax and to fully attend to mathematical calculations.

The second question as far as the type of the game is concerned is whether it is intended for a single player, for multiple players or for teams, or whether the players or teams compete or cooperate. If a game is intended for a single player, it is not as time demanding as games for multiplayers. The teacher can observe the individual development of each student using her own results. By contrast, multiplayer games support team cooperation, a competence that is currently also necessary and in high demand.

Nevertheless, team games raise the question of dividing students into teams, which may be far from simple. In order for team members to function and enjoy the game, the collaborating group must be a real team. From the educational viewpoint, the teacher must create balanced teams. Were a team to consist of students best at the given subject, whereas another team to comprise the weakest students, it is a foregone conclusion who the winner would be and the game would not work out. Therefore it is advisable to change various types of games, and to change teams in the case of team games.

The crucial aspects are the professional implementation of the game and the suitability to the target group. Many an educational games on offer currently fail to openly state the target group. These games are often created too universally and in the end are unsuitable for any target group despite the fact that the whole concept of the game (the idea, features, difficulty, etc.) are strongly related to the target group. When considering making use of games already created, it is necessary to regard their didactic description as well. As a rule, it becomes clear whether the game is elaborated from the educational perspective or whether the educational concepts has been only artificially inserted in a game which was originally not meant for educational purposes. Apart from an elaborate didactic description, a well-devised game also provides methodology for teachers which clearly states the steps preceding the game and the way an analysis following the game should be carried out. An analysis with the participants guided by the teacher must follow the game for the game to have a proper educational effect, regardless of the game having been played in or outside the classroom. In the analysis, the teacher emphasises the educational moments and may expand on some topics occurring in the game, or explain parts the may have been misinterpreted by the students. The teacher should also point out the real and fictional points – what does not work in the same way in the real world, and together they can discuss why it is implausible. Students can also share their experiences in an informal discussion, while the teacher will acquire feedback on the game, which can be beneficial in the coming years in working with other classes (Václavíková, 2013, 2017, 2019).

Adventure-oriented pedagogy, which uses experiences accompanied by positive feelings as a means of teaching, has been coming to the fore of late. Often going hand in hand with global education, it provides a good deal of space for the application of mathematics in real-life situations. The methodological handbook for global education offers elaborated themes for games (Čajka, Biolek, Ježeková a kol., 2012). Several games described in the methodology have implemented mathematics, in spite of not explicitly stating it as the main educational goal (e.g. Hra na rybáře – the game of the fisherman). The big advantage of adventure-oriented pedagogy is the fact that it can make an effective use of informal education. The activities are interrelated to the student's real world, so the student does a lot of thinking and activities in her free time. During the actual classes the game is analysed, which has no impact on the class already taking place under time constraints.

Among games falling into the category of adventure-oriented pedagogy that have been gaining experts' attention are also RP games (Role Playing Games).

EduLARPs and mathematics

In general, RP games can take many forms, including digital form. LARP games (Live Action Role Playing Game) are then played live, in costumes, in a location that corresponds to the story. The emphasis is primarily on the role-playing itself. Similar types of games close to LARPs are various escape games. These games place greater emphasis on solving a detective plot, solving a mystery, the outcome of which is liberation, or "escape" from a room. The expansion of these types of games, mainly for the purpose of entertainment or team building, contributed to the fact that RP games have also been becoming known in the field of education, including teaching mathematics.

If the main goal of a LARP game is teaching, we are talking about EduLARPs. The advantage of RP games is, of course, in addition to popularity and a huge emotional experience for students, above all the wide possibility of interdisciplinarity. Specifically, mathematics can be linked to a whole range of other areas – for example, the area of STEM education. Practically every mathematical area can be implemented, and always by application. Most often, mathematics appears in the form of:

- algebraic formulas of various types, e.g. necessary for the definition of indices,
- combinatorial problems,
- orientation in a system of coordinates,
- different types of codes and ciphers,
- work with functions and graphs,
- data analysis,

- logical reasoning, essentials of algorithmic thinking,
- among others.

The disadvantage of EduLARP games is their demanding preparation and the fact that the games are unsuitable to be played repeatedly. Once the player has played the game once, she already knows some of the clues and the flow of the story, and playing it again is no longer fun for her. Enthusiasm for the game and motivation for the given subject evoked by the game quickly decline after returning to the school environment. Another problem is that the games are offered by external entities as part of school lessons, so only little use is made of informal education and students' afternoon leisure time. For these reasons, we at the Faculty of Science of the University of Ostrava have decided to devise a year-round game, based on the idea of a story and role-playing.

A year-round EduLARP

The main idea of the year-round game is to link it to the year curriculum of the target group, and to organise the game's activities so that only a small part covers the educational time spent at school and most of the activities are carried out by the students themselves outside school in the afternoon. Although we wanted to preserve role-playing, it was necessary to supplement the game with a digital environment that would guide the player to individual activities in the story and would also evaluate the correct performance of individual game steps. The LMS system Moodle was chosen as the environment, which is used in schools and is well known to students and teachers alike.

The game "Úhelný kámen" (Coaly Stone) is part of the Interreg SK-CZ cross-border cooperation project, entitled Adaptation of a research-oriented concept of science and technical education for distance and online teaching / research in the open, NFP304010AZC7. The central element of the game is carbon, and the game is educationally oriented to the connection of chemistry, physics, biology and mathematics, which permeates all the mentioned areas. The game is intended for 8th and 9th-grade elementary-school classes. It consists of a total of ten escape rooms, connected by one story. One room corresponds to approximately one month of the school year. Each of the rooms is set either in a specific place - for example, the professor's office, laboratory, or in the city of Ostrava environment.

The story of the game is set in the future, the planet is in the midst of an energy crisis. In addition to the human population, artificial intelligence is also highly developed. The main character is a chemistry professor who made a "great discovery". Before he could share his discovery with his colleagues, he went missing. The player is in the role of a gifted student who follows in the footsteps of the professor. During the story, the player needs to get some items that he can buy in a virtual junk shop, operated by artificial intelligence, the currency is different types of diamonds (link to carbon). The diamonds can be obtained in the virtual shop in exchange for information in the artificial intelligence database – specifically by solving partial problems, which are also written in the language of the story (see Figure 1).

Figure 1: Printscreen from the game: digital junk shop (offer of tasks to obtain diamonds).

A virtual library is found in each room and it offers the player the possibility to expand their knowledge should she not remember or know something, or the player can get to know some additional information. The player can enter the library any time during the game and then move back to the same place in the story. The library is divided by topics and contains interactive books (see Figure 2).

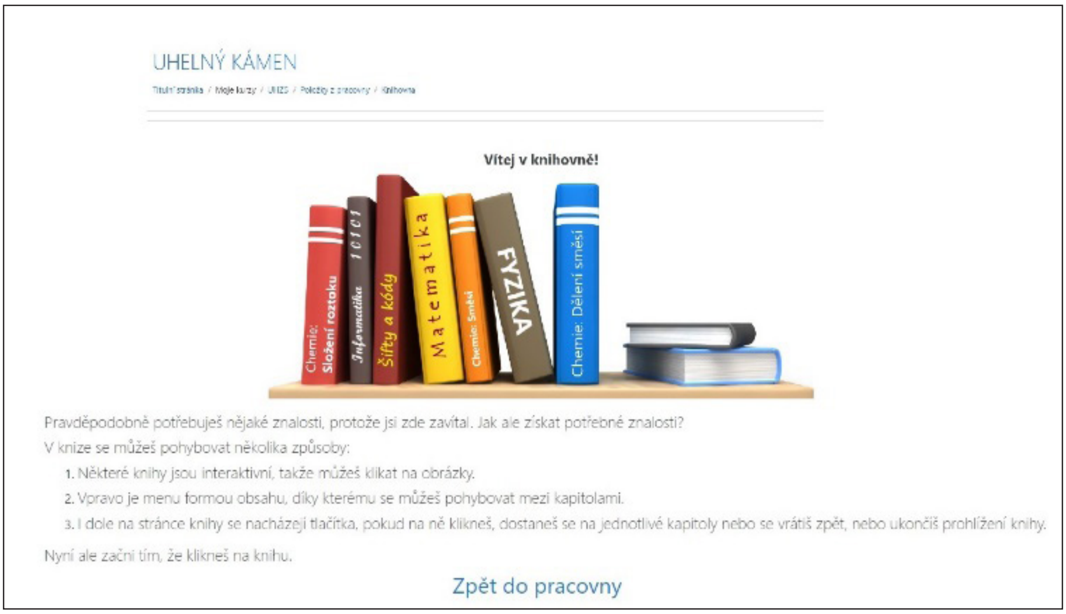

Figure 2: Printscreen from the game: library.

On the other hand, the player's ranking is penalised with small black coals, which are assigned to her should she need to use a hint. In the given room, the individual game elements are illuminated after hovering the cursor over the given item. The player goes through the individual game elements, for example the first room – the professor's study: the game offers a total of 10 items, four of which are actual game clues and six non-game items that only specify the personality of the professor (which should help the player in making decisions in other rooms). In Figure 3, we see a printscreen of the environment of the first room with an illuminated game element – the periodic table of elements that is a hint to open the door to the next room.

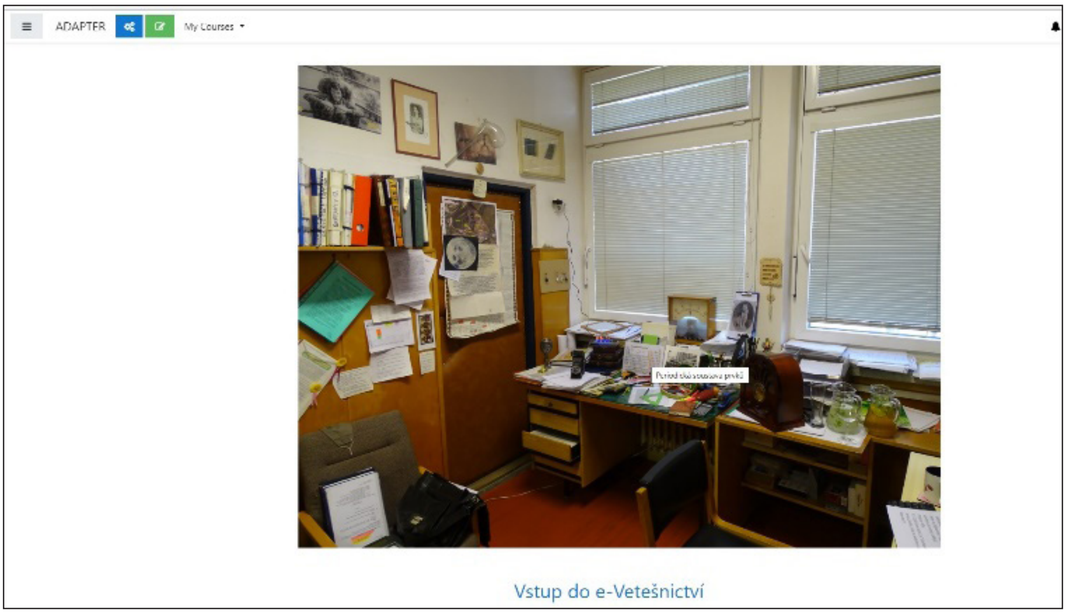

Figure 3: Printscreen from the game: professor's office – the first room

At the same time, each room is dedicated to one theme, which pervades the story in that room. Each room contains one IBSE task, the completion of which is a condition for advancing in the game. The IBSE task deals with the central plot in the given room. The plot is not immediately apparent at first glance, the player has to reach the task through several clues. The IBSE task in the form of an experiment is always designed for the student to be able to carry it out at home, using commonly available materials. The player is guided through the medium of the task in the digital environment, where she also enters her results on finishing the experiment. In each room, there are approximately 15 tasks in the antique shop of the database, the correct solution of which earns the player the diamonds mentioned above. The tasks connect physics, chemistry, mathematics and biology, they are not divided by areas, but are linked to the thematic focus of the given room. For example, the first room is devoted to mixtures and properties of substances, the second room is a laboratory used for measurements and experiments, using instruments, applying quantities, etc.

From a mathematical point of view, each room uses a different type of code, so the player encounters a certain type of encryption in each room. In the library, one part is also dedicated to ciphers, where the student can again expand her knowledge. For example, in the first room, considering the mixture theme, a secret ink was chosen (also linked to the IBSE task in the first room). In the laboratory, the ASCII code is selected in connection with the topic of powers, and the notations of numbers in the systems are explained in the book of ciphers.

In the mathematical part, the following areas are applied: integer powers, famous mathematicians, equations, inequalities, statistics, functions and graphs, approximation. Moreover, the use of geometry in plane and space also appears in the game.

The Moodle LMS system monitors the player's time spent on individual game items (library, example section, etc.), but the player is not limited by time. The system also monitors the status of collected diamonds and black carbons, the frequency of returning to individual parts, the success-rate in solving the individual parts. This information is then intended for the teacher who uses the game.

The game is currently in the preparation phase, the first room has undergone testing, which was primarily intended to verify the functionality of the system. We also monitored the extent to which students navigate the LMS Moodle environment, how they move, and how user-friendly the system is for them. Additional rooms are now being set up in the system. In parallel, training is also being prepared for teachers to use the game for their teaching. In the academic year 2022/23, the game should undergo pilot testing at partner schools and then be fully available to all interested parties.

It is also planned to upgrade the game for the 1st and 2nd years of high school, by adding some thematic units. For mathematics, it will be the topic of logarithms, an introduction to fuzzy mathematics and an increase in the level of examples and problems. The plan is also to translate the game fully into English in the future.

Conclusion

Playing games has been a part of human culture since time immemorial and has an irreplaceable role not only in the educational process, but also in the entire life. Considering the increase in information not only in general, but also in the school curriculum, it is clear that informal education will need to be used more intensively in the education of pupils in the future. Global education will also be emphasised more strongly, and it will be necessary to teach mathematics with focus on its application. It is also vital to transform the university curriculum of future mathematics teachers as well as close cooperation with active teachers, who were not trained for interdisciplinarity as part of their education. One of the ways that proves to be suitable is adventure-oriented pedagogy, which will hopefully become a common part of the educational process in the Czech Republic as well.

References:

Berliner, D.C., Calfee, R.C. (2004). *Handbook of Educational Psychology*. Mahwah, New Jersey: Lawrence Erlbaum Associates.

Bresciani, M. J. (2016). *The neuroscience of learning and development: Enhancing creativity, compassion, critical thinking, and peace in higher education*. Stylus Publishing.

Collins, S. (2016). *Neuroscience for Learning and Development: How to Apply Neuroscience and Psychology for Improved Learning and Training*. London UK: Kogan Page..

Čajka, A., Biolek, J., Ježeková, P. a kol. (2012). *Komu patrí Zem. Metodická příručka globálního vzdelávania pre učiteľov*. Centrum environmentálnej a etickej výchovy Živica, ULTRA PRINT, s.r.o.

Ferdiánová, V., Václavíková, Z. (2014) Hry v hodinách matematiky, Ostravská univerzita, Ostrava.

Hejný, M. and Kuřina, F. (2001). *Dítě, škola a matematika: konstruktivistické přístupy k vyučování.* Ed. 1. Prague: Portál.

Kim, S., Song, S., Lockee, B., Burton, J. (2018). *Gamification in Learning and Education*, Enjoy Learning Like Gaming. Cham: Springer.

Luhan, E. (1990). *Didaktika matematiky: Pro posluchače 3.a 4.roč.PF*. České Budějovice: Jihočeská univerzita.

Nakonečný, M. (2011). *Psychologie: přehled základních oborů*. Praha: Triton.

Plháková, A. (2004). *Učebnice obecné psychologie*. Praha: Academia.

Stacey, K. (2006). What is mathematical thinking and why is it important? Proceedings of the APEC-Tsukuba International Conference 2007: Innovative Teaching Mathematics through Lesson Study, pp. 4-13.

Thibaut L., Ceuppens S., De Loof H., et al. (2018). *Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education*. European Journal of STEM Education. 3(1) https://doi.org/10.20897/ejsteme/85525

Václavíková, Z. (2013). Science education – Formal versus informal education. In: New Challenges in Education (pp. 260-277). Ružomberok: Verbum.

Václavíková Z. (2017). Gamification and game-based learning – How to implement them into education. In: Proceedings of the 16th Conference of Applied Mathematics (pp. 1592–1597). Bratislava, Spektrum STU.

Václavíková, Z. (2019). Game: Experience as an Educational Tool. In (Ed.), Game Design and Intelligent Interaction. IntechOpen. https://doi.org/10.5772/intechopen.88853

Václavíková, Z. (2022). The Most Common Mathematical Mistakes in the Teaching of Scientific Subjects at Secondary Schools, to apper.

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Mathematical games to promote students' affect and motivation

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The second paragraph was written by Francesca Morselli and Elisabetta Robotti

New educational approaches for students' learning needs

Educational contexts follow the changes related to the dynamics of society: new ideas change perspectives and ways of life. So, new situations are created, which require different educational needs than in the past. In a "liquid society" (Bauman, 2000) like ours, to respond to emerging needs, the educational strategies and teaching methodologies are constantly development.

I don't just want to talk about ideological changes or the advent of new technologies. Students belong to new generations who have partly inherited from the past dreams and hopes. They find themselves immersed in new, complex, variable and complicated contexts that require new ways to take on reality. In order to develop useful skills, it is necessary to try to teach with new approaches.

Let's start from the consideration that every student is different and he (or she) needs to be enhanced for their diversity. It's necessary to build an educational path that takes into account his/her real needs. Diversity requires an environment that not only accepts differences, but reflects them as elements of enrichment in all educational situations (Tosi, 2019).

Then, even at school it is necessary to rethink the educational spaces and the didactic moments in order to be more effective the lessons. To promote new approaches, which give meaningful experiences for the students, some concepts are central. The learning process can start from "investigating" a specific topic or problem to "create" an explanation or solution to our questions. You can't learn on your own, so it's crucial to learn to "present" and "share" your ideas. "Interaction" with others allows you to listen to other ideas and possible solutions to the problem, so that you can "develop" what you have learned from others (Borri 2018). These concepts are very important to rethink teaching methodologies and new spaces for education. The beauty of work for teachers is: to understand the new needs of students and research the teaching methods closer to the new generations. The challenge is great, but it allows us to get closer to our students to listen to them and dialogue with them. Active listening (Sclavi, 2003) is certainly an important starting point; in addition, an open attitude allows the teacher to review his/her ways of teaching in the classroom.

Indeed, learning increasingly requires some moments in which to share experiences and considerations. Castoldi (2020) says that learning is determined by the context and is facilitated by collaboration. Then a comfortable context allows interaction among students. If they feel unjudged, they can try to express their opinion for a true discussion. A shared dialogue allows to co-construction.

Another aspect which is very important for learning process is metacognition, composed by "thought, self-control, purpose and expectation" (Castoldi, 2020, p.33). Students develop these concepts through concrete experiences of stimulation and shared reflection. Teachers must consider these elements while organizing the lessons and the educational path. Castoldi (2020) affirms that learning is acquired through construction, that is, from one's own models of mind and the processes of search and reworking.

If we consider all that, we see that it is necessary to rethink times and spaces of education with new approaches: this does not only mean stimulating students to study, but I would like to encourage you to create contexts that meet the new educational needs of students.

A very stimulating and innovative methodology is related to the game. If in the past play was an important part of the learning process for young children, now the ideas have changed and interest has grown for higher age groups: to use a playful perspective can be particularly significant and engaging.

Some studies (Maragliano 2020, Antoniacci e Schiavone 2021) confirm that the game is a fundamental element to set up a new, engaging and effective educational context. The teachers who grasp the situation and take up the challenge, now all that remains is to try, experiment and get involved.

New approaches in mathematics education

Research highlights positive effects of the use of games: they can increase students' motivation and engagement and encourage collaborative working. However, there could also be some considerable negative effects, for instance the fact that they are often too complex for the classroom context, resulting in educational focus being lost (BECTA, 2001).

This is the challenge for new categories of games, that are to reach a balance between promoting motivation and engagement and maintaining the focus on the educational objective.

Although research in mathematics education has a long tradition, only few studies focused on the use of games. The most represented trend of research concerns ICT-based tools (see Childs, Mor, Winters, Cerulli & Bjork, 2006 for a literature review), with a focus on the way they may support mathematical learning (Noss & Hoyles, 1996, Bottino, 2001, Bottino and Chiappini, 2002).

As Bottino (2001) points out, ICT-based games were initially considered as a limited resource, because they did not substantially change the way their users interact with a given object of knowledge, and do not provide the learner with new ways to give meanings to related concepts. In other words, they were conceived as an "environment where knowledge is transmitted in order to be acquired by the user" (Bottino, 2001., pp. 13-14). Such a focus was reversed when the interest on constructivist theories increased, leading to a shift of attention from the artefact to the user, to the internal aspects of the learner (Bottino, 2001, pp. 14). This paved the way to a new conceptualization of learning through ICT tools as based on active exploration. In this perspective, the ICT tool gets the learner involved in problem solving activities relevant to the topic. Such involvement is supposed to motivate the learner in seeking new knowledge and acquire new abilities (ibid., pp. 14; Bottino and Chiappini, 2002, pp. 758).

In the last years, the role of playing games in math education is mainly addressed to the computer based role-playing games because they provide a fun and motivating environment for teaching and learning mathematics. In particular, in the last years, role- playing games, allow students to assume the role of a character in the game world and to determine the actions of their characters based on the characterization. This seems to provide a motivating environment for students to practice skills that they have already learned or to develop new math knowledge.

The idea is that Game-based learning can be used as a teaching tool in the classroom to facilitate learning mathematics. According to Mitchell and Smith (2004), the use of game-based learning can stimulate the enjoyment, motivation and engagement of users, aiding recall and information retrieval, and can also encourage the development of various social and cognitive skills

However, the idea of role-playing games for learning mathematics outside the technological context of applications does not seem to be a widespread research topic.

Exploiting games in mathematics education opens to new opportunities that are coherent with research results in mathematics education, concerning: multimodality, embodied cognition, semiotic, commognition, storytelling and affect.

In particular, these theoretical stances have pointed to the importance of experiences of a sensorial, perceptive, tactile and kinesthetic nature for the formation of mathematical concepts and also the social dimensions of mathematical meaning construction (Arzarello, 2006; Gallese & Lakoff, 2005; Radford, 2003, 2006).

Embodiment is a movement in cognitive science that recognises the central role of the body in the mind activity and in the mind shaping. Embodiment involves different disciplines, such as the cognitive science and the neuroscience, which are interested in how the body is involved in thinking and learning. In particular, it emphasises the central role of the sensory and motor system and its importance for successful interaction with the environment. Concepts and the mathematical concepts as well, are thus analysed not on the basis of ''formal abstract models, totally unrelated to the life of the body, and of the brain regions governing the body's functioning in the world'' (Gallese and Lakoff 2005, p. 455) but considering the multimodality at the basis of our cognitive performances as well. Indeed, Gallese and Lakoff tell us in their Studies in neuroscience, that the sensory-motor system of the brain is multimodal rather than modular (Gallese and Lakoff 2005): ''an action like grasping… (1) is neurally enacted using neural substrates used for both action and perception, and (2) the modalities of action and perception are integrated at the level of the sensory-motor system itself and not via higher association areas.'' (Gallese and Lakoff 2005, p. 459).

Thus, since the sensory-motor system of the human brain is multimodal, the human activity , which includes thinking activity, is also multimodal. Therefore, analysing all the modalities we can understand cognitive processes (Arzarello and Edwards, 2005; Arzarello, 2008). During the mathematical activities with media, for instance, students produce a variety of signs such as words, gestures, and actions on the tools, interactions, and written or oral signs of whatever nature. They use these signs to communicate with others but also to develop thinking and to develop, through discursive approach, (mathematical) knowledge.

The experience of learning together or learning to be with others in mathematics, as written by Radford (2006), can be described by a frame that takes all the multimodal production of the students, into account. In this approach, learning mathematics is a matter of being in mathematics (Radford 2006), living in a classroom as a community, working together, and sharing activities and results.

According to Nemirovsky (2003), understanding and thinking are perceptuo-motor activities, modulated by shifts of attention, awareness, and emotional states. Moreover, "these activities are bodily distributed across different areas of perception and motor action based in part, on how we have learned and used the subject itself. This conjecture implies that the understanding of a mathematical concept rather than having a definitional essence, spans diverse perceptuo-motor activities which become more or less significant depending on the circumstances".

Thus, as Nemirowsky claims, the actions one engages in mathematical work, such as writing down an equation, are as perceptuo-motor acts as the ones of kicking a ball or eating a sandwich; For instance, "the equation-writing act and other perceptuo-motor activities relevant to the context at hand are not merely accompanying the thought, but are the thought itself as well as the experience of what the thought is about" (Nemirowsky, PME 27 Vol 1 p 109).

Also Radford (2006) highlights that the understanding of relationships between actions bodily carried out through artefacts (objects, technological tools, etc.) and linguistic and symbolic activity is essential in order to understand human cognition and mathematical thinking. In fact, representations of mathematical objects are essential for developing mathematical thinking, as we have no access to mathematical objects except through their representations.

Moreover, according to Lakoff & Nunez (2000), mathematical ideas are rooted in the experience of daily physical life and we are able to grasp them through conceptual metaphors in mathematics: a cognitive mechanism that allows us to reason about one kind of thing as if it were another and It allows us to use the inferential structure of one conceptual domain in another one.

Another emerging theme in mathematics is the narrative approach to teaching and learning. Organizing facts in a narrative form encompasses finding/attributing temporal and causal connections, thus turning a sequence of events in a coherent whole in which each part contributes to the global meaning (Bruner 2003). This leads the narrator, and those who read or listen a narrative, to become aware of more or less implicit relations. Hence, narrative can constitute an excellent starting point to foster reflection and meaning-making. We may note that the potential of narrative is fully exploited in the edu-larp experience, since students play the role of characters in a story.

Zazkis & Liljedahl (2009) show how the use of storytelling can raise students' interest in mathematics, reduce their anxiety toward the discipline and engage them into the activity. Interest, engagement and the matter of reducing anxiety introduce the last keyword of our overview, that is affect in mathematics education.

The crucial role of affective factors in mathematics teaching and learning was initially recognized in studies on problem solving (Schoenfeld, 1992) and has gained growing attention in the last decades (Hannula et al., 2019).

Following Hannula (2012), the domain of affect may de described around three dimensions. The first dimension identifies three broad categories of affect: *motivation*, *emotions*, and *beliefs*. The second dimension concerns the *trait* versus *state* nature of affective variables. Middleton, Jansen, and Goldin (2016) explain this feature of affective variables as '*long term*' and '*in the moment*' respectively. The last dimension concerns the theorizing level, that may be physiological (embodied), psychological (individual), and social.

In the following we focus on the constructs of *motivation* and *attitude* towards mathematics as relevant constructs in mathematics education.

Motivations are "*reasons individuals have for behaving in a given manner in a given situation*" (Middleton and Spanias, 1999, p. 66). According to Hannula (2011), motivation "*reflects personal preferences and explains choices. [...] Motivation varies from very local preferences (This would be a perfect moment for a cappuccino) to a variety of different levels of goals (I want to solve this task, I want my peers to think that I am clever) and very global needs such as needs for nutrition and social belonging*" (p. 42). A key distinction concerns intrinsic motivation (e.g. when students engage in the task because they enjoy learning) versus extrinsic motivation (e.g. when students engage in tasks to obtain rewards or avoid punishment). It is also possible to distinguish between "state" and "trait" aspects of motivation (Hannula, 2006). The *state* aspect of motivation refers to needs, values, desires and motivational orientations, while the *trait* aspect refers to active goals during mathematical activity. Needs are influenced by students' beliefs about self and mathematics, as well as by the school context and the socio-mathematical norms. For instance, a student may feel a need for competency and, consequently, the goal of solving tasks efficiently; or a student could have a "social" need, and the consequent goal could be to work collaboratively (Hannula, 2006). Goals can be described as the interaction of three dimensions (Middleton, Jansen and Goldin, 2016): goal proximity (the closer the goal is perceived, the more effort is put into activity), goal specificity (learning factoring is a proximal goal, while becoming an engineer is a long-term goal) and goal focus.

A key point it the role of motivation in mathematical activity and possible ways to promote motivation towards mathematics. Middleton and Spanias (1999) connect motivation to mathematical self-confidence (Bandura, 1987) and argue that motivations develop early, under the influence of teachers' actions and attitudes. Rellensmann and Schukajlow (2017) deal with the motivational construct of interest, conceptualized as a subject-object relationship that is established when a person demonstrates positive affect towards the object and is intrinsically motivated to engage with the object of interest. The authors reflect on ways to trigger students' interest in mathematics. They argue that there is at first a situational interest in a particular object (for instance, solving a problem) that lately may extend to other objects (other mathematical problems), finally resulting in a stable individual interest in mathematics. A crucial issue is to trigger the situational interest, and this is linked to the teacher's choice of meaningful mathematical tasks. Their experimental study shows that modelling problems and "dressed up" word problems, although promising for their connection with real life, are not necessarily considered more interesting by students, in comparison with problems without a connection to reality. The authors suggest that real-world problems in order to raise students' interest, should address contexts that are really interesting for the students (the mere connection with reality is not a guarantee for interest). Moreover, the teachers should raise the problem's value collectively in the class, communicating the problem's relevance and promoting small group solving process. This suggest that two issues are crucial when setting up a mathematics Edularp: the task design and the organization of group work.

The second construct we rely on is the construct of attitude, developed by Di Martino and Zan (2011) in terms a three-dimensional model, that encompasses: emotions related to mathematics, view of mathematics, perceived competence in mathematics. Such a theoretical characterization takes into account students' perspectives about their own experiences with mathematics. The authors specifically address the issue of negative attitude towards mathematics: attitude towards mathematics is to be considered negative when at least one of the three dimensions is negative.

We argue that it is crucial to find innovative teaching methods that improve attitude toward mathematics and/or prevents the development of negative attitude towards the discipline.

Following the definition, it is important to improve the emotional disposition to the discipline, and/or the perceived competence, still promoting the proper view of the discipline itself.

We argue that involving students in meaningful mathematical activity (with a good problem solving process, accompanied by understanding and final success) could improve perceived competence ("I was able to solve this problem") and, consequently, attitude. This suggest that, in a mathematics Edularp, the choice of tasks is highly relevant: tasks should be connected to the story, and at the same time relevant from a mathematical perspective.

Di Martino and Mellone (2005) document a teaching experiment, performed in grade 12, aimed at promoting a change in attitude (in a multidimensional sense) towards mathematics through “suitable teaching practices that may favour, at the same time, the achievement of important cognitive objectives” (p. 237). Together with the teacher, the researchers planned and carried out a teaching and learning sequence on trigonometry, based on games to be played in groups, subsequent systematization of trigonometric properties, utilization of such properties to solve a contextualized task, final recapitulation and creation of a class book. The authors justify the choice of trigonometry, usually perceived as a hard topic, with the aim of improving perceived competence and of promoting a richer view of the discipline, by showing meaningful applications of trigonometric instruments. Data showed a decrease of negative disposition towards the discipline (especially, fear of mathematics decreased) and, more in general an improvement in terms of attitude. Moreover, the students proposed to create a website to illustrate their experience to peers, thus showing a high level of appreciation and involvement into the experience.

Conclusion

In this contribution we presented different theoretical perspectives to promote students' affect and motivation in math activities through Mathematical games.

We argue that it is crucial to find innovative teaching methods that improve attitude toward mathematics and/or prevents the development of negative attitude towards the discipline.

To argue this claim we firstly observed that educational contexts follow the changes related to the dynamics of society thus, to respond to emerging needs, the educational strategies and teaching methodologies are constantly development. Moreover, it seems necessary to build educational paths that consider the different needs of each student since each of the student is different.

Diversity requires learning environments that accept differences and, at the same time, conceive them as elements of enrichment in the educational situations concerned.

This suggests teachers to rethink the educational spaces and the educational activities as well as the time devoted to teaching and learning to improve meaningful experiences for the students,

In this perspective, a stimulating and effective educational context is related to the game.

As far as it concerns the **mathematical education** approaches, some researches highlighted positive effects of the use of games because they increase students' motivation and engagement and encourage collaborative working in a virtual context. Nevertheless, only few studies focused on the use of games specifically in math education and the most represented trend concerns ICT-based tools where the learner is involved in problem solving activities.

Concerning the role-playing games in math education, it is mainly addressed to the computer based role-playing games. However, the idea of role-playing games for learning mathematics outside the technological context of applications does not seem to be a widespread research topic.

For this reason, EduLarp seems to be an interesting context for math education. Moreover, exploiting games in mathematics education opens to new opportunities that are coherent with research results in mathematics education, concerning: multimodality, embodied cognition, semiotic, commognition, storytelling and affect. These theoretical stances have pointed to the importance of experiences emphasising the central role of the sensory and motor system and its importance for successful interaction with the environment and the others and for developing of mathematical thinking

Thus, the experience of learning together or "learning to be with others in mathematics", as written by Radford (2006), can be described by a frame that takes all the multimodal production of the students, into account. In this approach, learning mathematics is an experience which concerns living in a classroom as a community, working together, and sharing activities and results.

We may note that all these characteristics can be considered as fundamental to design Edularp as an effective mathematical learning environment.

Another emerging theme in mathematics education, which can be related to the Edularp context, is the narrative approach to teaching and learning. Following the definition described before, the narrative can constitute an excellent starting point to foster reflection and meaning-making.

We may note that the potential of narrative is fully exploited in the edu-larp experience, since students play the role of characters in a story. Moreover, the use of storytelling raises students' interest in mathematics, reduce their anxiety toward the discipline and engage them into the activity. Interest, engagement and the matter of reducing anxiety introduce the crucial role of affective factors in mathematics teaching and learning. Among key words in affective factors, we identify Motivation.

Motivations are "*reasons individuals have for behaving in a given manner in a given situation*" (Middleton and Spanias, 1999, p. 66), which *reflect personal preferences and choices*. In Edularp we refer mainly on intrinsic motivation, which concerns students engagement in the task because they enjoy learning, and we argue that this can lead students in a stable individual interest in mathematics.

Some researches in math education suggest that real-world problems raise students' interest, but they should address contexts that are really interesting for the students. Moreover, the teachers should raise the problem's value collectively in the class, communicating the problem's relevance and promoting small group solving process. This suggest that two issues are crucial when setting up a mathematics Edularp: the task design and the organization of group work.

We argue that it is important to improve the emotional disposition to the discipline, and/or the perceived competence, still promoting the proper view of the discipline itself.

Thus, we argue that involving students in meaningful mathematical activity (with a good problem solving process, accompanied by understanding and final success) could improve perceived competence ("I was able to solve this problem") and, consequently, attitude. This suggest that, in a mathematics Edularp, the choice of tasks is highly relevant: taks should be connected to the story, and at the same time relevant from a mathematical perspective.

References:

Antoniacci, F., Schiavone, G. (2021) *Poetiche del gioco. Innesti ludici nei contesti educativi e scolastici.* Milano, Franco Angeli.

Arzarello, F., Edwards, L. (2005). In Chick, H. L. & Vincent, J. L. (Eds.). *Proceedings of the 29th Conference of the InternationalGroup for the Psychology of Mathematics Education*, Vol. 1, 123-154.

Arzarello, F. (2006). Semiosis as a multimodal process, *Relime, 9, Número Especial*, 267-299.

Arzarello, F., Robutti, O., (2010). Multimodality in multi-representational environments, *ZDM Mathematics Education*, 42, 715–731.

Bauman, Z. (2000) *Liquid modernity.* John Wiley & Sons, New York.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review*, 84(2), 191.

Becta (2001). Computer Games in Education.
http://www.becta.org.uk/page_documents/research/cge/report.pdf

Bottino, M. (2001) Advanced Learning Environments: Changed Views and Future Perspectives. *Computers and Education. Towards an Interconnected Society*,11-27.

Bottino, M. and Chiappini, G. (2002). Technological Advances and Learning Environments. In L. English (ed.), *Handbook of International Research in Mathematics Education*, 757-786, Lawrence Erlbaum Associates.

Bruner, J. (2003). *Making Stories*. Harvard University Press, Cambridge, MA.

Di Martino, P., & Zan, R. (2011). Attitude towards mathematics: a bridge between beliefs and emotions, *ZDM – The International Journal on Mathematics Education,43 (4)*, 471-482.

Di Martino, P. & Mellone, M. (2005). Trying to change attitude towards maths: a one year experimentation. In M. Bosch (Ed.), *Proceedings of the Fourth Congress of the European Society for Research in Mathematics Education*, Universitat Ramon Llull.

Castoldi, M. (2015). *Didattica generale* (nuova edizione riveduta e ampliata). Milano, Mondadori Università.

Castoldi M. (2020). *Gli ambienti di apprendimento. Ripensare il modello organizzativo della scuola*. Bologna, Carocci.

Childs, M., Mor, Y., Winters, N., Cerulli, M., Björk, S., et al. (2006). *Learning Patterns for the design and deployment of Mathematical Games: Literature review.* Kaleidoscope Report, hal-00190298.

Future Classroom Lab (a cura di) (2018). *Guidelines for rethinking and adapting learning environments at school*. Bruxelles, European Schoolnet.

Gallese, V., & Lakoff, G. (2005). The brain's concepts: the role of the sensory-motor system in conceptual knowledge. *Cognitive Neuropsychology*, 22(3–4), 455–479.

Hannula, M. S. (2006). Motivation in mathematics: Goals reflected in emotions. *Educational Studies in Mathematics*, 63, 165-178.

Hannula, M.S. (2011). The structure and dynamics of affect in mathematical thinking and learning. In M. Pytlak, E. Swoboda, & T. Rowland (Eds.), *Proceedings of the CERME7*. Reszow, Poland. 9-13 February 2011, 34-60. University of Reszow, Poland: CERME.

Hannula, M. S. (2012). Exploring new dimensions of mathematics related affect: embodied and social theories. *Research in Mathematics Education 14(2)*, 137-161.

Hannula, M.S., Leder, G.C., Morselli, F., Vollstedt, M., Zhang, Q. (Eds.) (2019). *Affect and Mathematics Education. Fresh Perspectives on Motivation, Engagement, and Identity*. Springer Publishers.

Klawe, M. and Phillips, E. (1995) A classroom study: electronic games engage children as researchers In Proceedings of CSCL '95: The first international conference on Computer support for collaborative learning, Lawrence, 209-213. http://portal.acm.org/citation.cfm?id=222177

Lakoff, G. & Nùñez, R. (2000). *Where Mathematics Comes From: How the Embodied Mind Brings Mathematics into Being.* New York: Basic Books.

Maragliano A. (2020) (a cura di). *Edularp. Game design per giochi di ruolo educativi*. Milano, Franco Angeli.

Messina, L., De Rossi, M. (2015). *Tecnologie, formazione e didattica*. Carocci, Roma.

Middleton, J., Jansen, A., & Goldin, G. (2016). Motivation. In M. Hannula (Ed.), Attitudes, Beliefs, *Motivation and Identity in Mathematics Education: An Overview of the Field and Future Directions*. *ICME-13 Topical Study* (pp. 17-23). New York: Springer.

Middleton, J. A., & Spanias, P. A. (1999). Motivation for achievement in mathematics: findings, generalizations, and criticisms of the research. *Journal for Research in Mathematics Education, 30 (1)*, 65-88.

Mitchell, A. & Smith, C.S. (2004). *The use of computer and video games for learning: A Review of Literature*. Learning and Skills Development Agency, London, UK.

Nemirovsky, R. (2003). Three conjectures concerning the relationship between body activity and understanding mathematics. In N.A. Pateman, B.J. Dougherty, J.T. Zilliox (Eds.), *Proceedings of the 27th Conference of the International Group for the Psychology of Mathematics Education, Vol. 1*, 103-135.

Noss, R. and Hoyles, C. (1996). *Windows on Mathematical Meanings: Learning Cultures and Computers.* Mathematics Education Library, Springer

Radford, L. (2003). Gestures, speech, and the sprouting of signs: A semiotic-cultural approach to students' types of generalization. Mathematical Thinking and Learning, 5(1), 37–70.

Radford, L. (2006). The anthropology of meaning. *Educational Studies in Mathematics, 61*, 39–65.

Radford (2008), Connecting theories in mathematics education: challenges and possibilities. *ZDM - The International Journal on Mathematics Education*, 40, 317–327.

Radford, L. (2014). Towards an embodied, cultural, and material conception of mathematics cognition. *ZDM, Mathematics Education*, 46(3), 349–361.

Rellensmann, J., & Schukajlow, S. (2017). Does students' interest in a mathematical problem depend on the problem's connection to reality? An analysis of students' interest and pre-service teachers' judgments of students' interest in problems with and without a connection to reality.
ZDM – Mathematics Education, 49(3), 367-378.

Schoenfeld, A. (1992). Learning to think mathematically: problem solving, metacognition and sense making in mathematics. in Grows, D. (ed.), *Handbook of research in mathematics learning and teaching*, New York, NY, Macmillan,334-370.

Schön, D. A. (1983). *The reflective practitioner.* Temple Smith, London

Sclavi, M. (2003). *Arte di ascoltare e mondi possibili. Come si esce dalle cornici di cui siamo parte.* Milano, Mondadori.

Sfard, A. (2008). *Thinking as Communicating: Human Development, the Growth of Discourses, and Mathematizing*. Cambridge University Press.

Sukstrienwong, A. (2018) Animo Math: the Role-Playing Game in Mathematical Learning for Children, *TEM Journal*, 7 (1), 147-154,

Tosi, L. (a cura di) (2019). *Fare didattica in spazi flessibili. Progettare, allestire e utilizzare ambienti di apprendimento*. Firenze, Giunti Scuola

Zazkis, R. & Liljedahl, P. (2009). *Teaching Mathematics As Storytelling.* Sense Publishers.

Zhao, X. (2002) Adaptive Support For Student Learning in Educational Games. http://www.cs.ubc.ca/grads/resources/thesis/May03/Xiaohong_Zhao.pdf

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Design and Story of the Starflyer EduLARP

Josef Kundrát, Hana Peigerová

The EduLARP Starflyer is a game aimed at acquiring and validating knowledge in the field of mathematics and at working with moral dilemmas. As part of the story, we move to the distant future, specifically to the 24th century, and the participants become the crew of the Starflyer spaceship of the United Alliance of Planets of the Solar System.

In the 23rd century, a procedure was discovered to preserve and use dark matter for energy purposes, thanks to which it is possible to travel through space using hyperleaps and thus colonise a number of habitable planets in all corners of the Galaxy. This substance can be obtained using giant particle accelerators and store in its form an immense amount of energy. However, the production and storage of dark matter is so expensive and difficult that it is only possible on Earth, where the infrastructure exists. Dark matter storage is possible thanks to new discoveries in quantum physics. Earth will disallow the export to other planetary systems of any machines or components that would make it possible to build giant accelerators and produce dark matter. It therefore has a monopoly on the sale of dark matter.

This hugely beneficial technological move provided Earth with an unlimited supply of resources through trade. The planet has become a paradise. Other planetary systems follow the rules of Earth, which maintains peace in the Galaxy. In return, they receive an allotment of dark matter and access to interplanetary trade. Planets that have not joined this order have to manage without dark matter and other advantages resulting from the technological dominance of the main planet of the Galaxy. Earth protects its technological secrets strictly.

Recently, however, scientists have come up with a theory, supported by "gossip" circulating around the Milky Way, that there is a completely new element in the galactic bulge, with the help of which it is possible to obtain dark matter without the use of particle accelerators. Such a discovery would completely change the shape of interstellar flights and the position in the Galaxy. Earth therefore sends several ships to search for the element and look for hints of what it might look like and where it is. The Starflyer is one of these ships that flies to explore several planets and stations where there has been information that this element could be explored further.

In this chapter, we will describe the setting, scenario, and game design of the Starflyer EduLARP, with an overview and analysis of selected story decisions and mechanics. From the countless options offered to game authors in the area of setting the game, i.e. framing the story in a fictional environment, in the case of the EduLARP Starflyer, we used the science fiction genre and setting it in the environment of space travel, visiting different worlds and staying in a spaceship. We decided on this placement for several reasons. We wanted to create the game in such a way that it was not demanding on space. Games that require more space (e.g. due to the division of players into several groups that are not allowed to come into contact with each other, movement activities indoors or outdoors, etc.) tend to be more organisationally demanding. In order to maintain the highest possible accessibility for future implementers, we processed the game in such a way that it could be used in a single school classroom. During testing, we played the game in various spaces, e.g. in a large hall or a basement restaurant area. If the minimum parameters of the room are observed (sufficient size for 30 participants, hygiene requirements, sufficient ventilation), then it is possible to implement the game in a wide range of spaces.

So setting the game in a spaceship provides us with a useful construct by which we frame the game situation. It provides an explanation as to why the player characters cannot leave (there is space outside), the so-called magic circle that forms the inner spaces of the given room is clearly defined. Information is provided to players through an on-board computer that presents interactive presentations. This element is commonly known from films and series of a similar setting, where the crew of a spaceship communicates through the central screen or the cockpit of the vessel.

Figure 1: Interactive presentation interface showing the interior of the spaceship

The communication screen allows us to bring a lot of diverse information and multimedia content (text, video, sound) into the game. In this way, we create an unlimited information space that is located outside the vessel itself, pupils are confronted with changing situations, while the physical space of the ship remains unchanged. Thanks to this element, it is possible to introduce new content into the game, if the future developers of the game decide to do so (for example, to create a continuation of the story).

Figure 2: Interactive presentation showing three ways to react to a game situation

Setting the game in a sci-fi setting makes it easier to explain the game mechanics and justifies the use of abbreviations (e.g. dark matter) as we can refer to the sci-fi nature of the whole game. If we were to create, for example, an EduLARP from the environment of a realistic historical period in the past, we would have to stick more closely to reality. The sci-fi setting provides more freedom in creating narratives explaining game mechanics and their context. We can demonstrate this using the example of dark matter mechanics.

Dark matter represents the central narrative of the entire EduLARP. In the game world, this is an essential source of energy and the technology to obtain, process and distribute it is found exclusively on the planet Earth. The other planets, of which there are dozens in the universe, receive this source of energy only through trade with Earth. Unsubstantiated information that this energy source has been produced outside the Earth is the main motivation to send a search mission into space, which is represented by the flight of the Starflyer. Space travel through leaps from one solar system to another is again explained through the use of dark matter. The game does not go into a detailed physical explanation of how such a principle might work (the nature of actual dark matter represents a very little-explored area of scientific research). However, for the purposes of the game, it forms a useful narrative shorthand that acts as a motivation for the characters to complete the story (is there really another source of dark matter outside of Earth? And if so, how do we deal with it?). At the same time, dark matter figures as an indicator of the success of the characters – the Starflyer ship is powered by dark matter, which decreases after each leap through space. It may happen that in the case of unsuccessful solutions to the mathematical problems with which the ship is controlled, the ship will run out of the dark matter and the game will be ended. Dark matter can be used in several places in the game to solve ethical dilemmas (donate a valuable resource to help others or keep it and increase the chances of successfully completing a mission). With this element, we can provide players with a positive motivation, when they receive dark matter as a reward within the story, or a negative motivation, when wrong calculations lead to damage to the ship and more consumption of dark matter for repairs. Physically, in the form of a prop, dark matter can be represented by tokens, dashes on a board, or some other form of a visible counter.

Game ushers can work with dark matter in several ways, i.e. strictly following the principles of adding and removing dark matter set by the game authors (e.g. when obtaining raw materials from space, the crew gains a unit of dark matter, when leaping to another solar system, they lose a unit of dark matter). The second option is to add and remove dark matter based on emergent situations that players create themselves during the game. During one of the pilot implementations of the game, it happened that the crew lost almost all the dark matter due to several miscalculations at individual stations. In strict adherence to the mechanics of dark matter, it was appropriate to end the game with the failure of the participants. However, the developers of the game evaluated that the players show an above-standard motivation to continue, and therefore hidden reserves of dark matter appeared in the game, which the crew could use further.

The roles of ushers within the magic circle represent an important question of game design. If the ushers were to occupy roles that are hierarchically superior to the crew (e.g. offering the possibility to make the usher the captain of the ship), this would have a significant impact on the social dynamics of the game. Participants in the crew roles could display a whole spectrum of reactions to this situation, from refusing and distancing themselves from authority, to obeying orders. It also wouldn't make sense in such a context why ethical story dilemmas are decided democratically by the crew and not all resolved by command from above. One of the didactic purposes of the game, i.e. to develop communication skills, discuss and solve ethical issues, could not be completely fulfilled. At the same time, we needed the roles of ushers, which would allow us to be in constant interaction with all crew members, control their progress, help and direct game situations when necessary. Therefore, the solution was to create another narrative element, which is the ship's central computer. The Starflyer is a vessel that players control through interactions with a central computer. The computer is not physically represented in the game. The presenters are androids, i.e. humanoid robots that are controlled by this computer. The ship's artificial intelligence cannot decide on human dilemmas, all story situations must be resolved by communicating the outcome to the computer.

Ushers in the roles of androids intervene in the game by administering math problems to the players in the form of assignments, playing or reading information from the central computer (communication screen), distributing hints and solutions to problems when necessary, or manipulating dark matter tokens.

The players in their roles represent the human crew of the ship. Once again, we were faced with the decision of whether to differentiate the player roles and establish their hierarchy, but this would have created a similar problem as with the roles of ushers – that is, an unpredictable social dynamics of the game, which could have a major impact on the educational goals of the project. That is why we created the player roles as equal members of the crew, who alternate their competences and professions during the game. The space leaps that the crew spend in hibernation are the explanatory narrative. After each hyperleap, the crew loses short-term memory and problem-solving skills to control the ship. Therefore, everyone is kept in constant training by the on-board computer in all positions of the ship (navigation station, repairmen, engineers, etc.). This is an obvious explanatory shortcut. In the case of questions from players, we comment on illogicalities with reference to the science fiction setting. If we follow the logic of such amnesia, it would be appropriate to ask how the crew can remember the events they experienced when memory loss affects their professional skills (solving mathematical problems). A partial explanation will be provided by the timing of the activities. The crew first solve problems related to the ship (math problems) and after solving them, enough time has passed for the effect of short-term amnesia to wear off and everyone remembers the events before the hyperspace leap.

The mechanism for players to make decisions about story and ethical dilemmas is based on the cooperation of players in small groups, in which they take turns at individual stations of the ship. In the course of the game, the participants are invited to create their own decision-making system for two or more alternatives in the group. With this step, all participants are included in the decision-making process. They are free to choose whether to obey authority in the group, vote or let chance decide. Creativity in setting up a decision-making mechanism within a small group is part of the educational plan. The group can then change their decision mechanism one more time during the game (they are prompted to do so by the computer) if it is unsatisfactory. The final decision for the crew is then made by the sum of the votes of each group. If, for example, it is being decided whether to help the inhabitants of a planet, the computer presents individual alternatives, usually two or three (e.g. help, not help, try to gain an advantage at the expense of the planet, etc.). The crew then decide within their groups, and finally the votes for each alternative are tallied. For this reason, five groups of players are always formed at the beginning of the game to acquire an odd number.

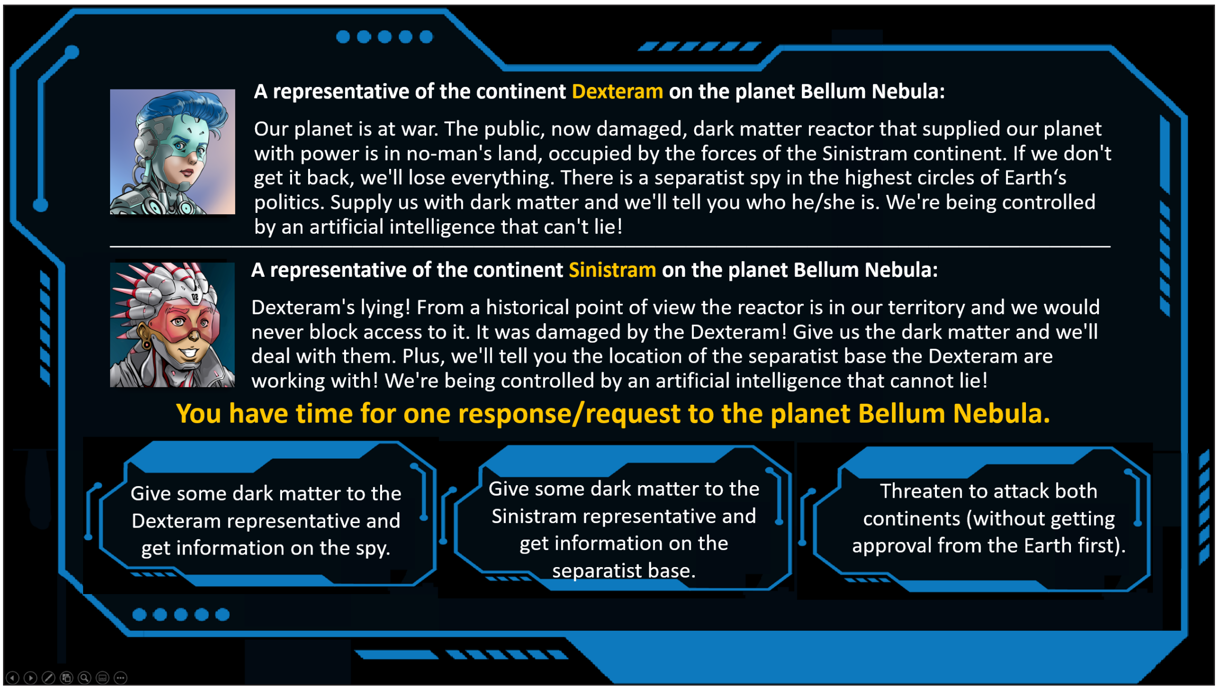

Figure 3: The interactive presentation shows the dilemma that the participants have to solve. Players choose one of three options

Dividing players into groups is another game mechanic that helps structure the game and affects the social dynamics between the participants. We wanted the participants to work together in smaller groups to solve the mathematical content. These groups then appear in the game as a unified part of the crew, they are distinguished from each other by the colour of their costumes. In each separate part of the game, one group solves a specific mathematical problem at one of the five stations in the game. Stations are presented as spaceship workplaces within the game's narrative. Each station has a different function. Groups always change stations after hyperspace leaps to be trained in a variety of ship control tasks. In this way, we ensure that the players get to all the prepared types of mathematical tasks, which are unique for each station. The division of players into groups takes place as part of the introductory workshop. This is a sensitive part of working with the team, which subsequently has an impact on the dynamics of the game. If we let the participants create the groups themselves, it would certainly happen that male and female friends would gather in one group. This could affect, for example, the participants' concentration on mathematical or story content. We have found that much better engagement in activities is shown by groups composed of participants who otherwise meet less often within the collective. There is a better mixing of school class members, which can have a positive effect, for example, on the climate in the collective. The optimal mechanism for dividing groups is the use of costumes. During the introductory workshop, the participants sit on chairs in a circle and naturally sit next to each other according to their liking. When distributing the costumes to the participants sitting next to each other, we alternate the colours. The result is that team members of one colour present a mixture of groups that originally sat next to each other in the circle.

Figure 4: Pupils sitting in a circle during the introductory workshop after being divided into groups.

The mathematical content of the game is modular, which means that individual mathematical problems or examples can be replaced by others. Their number or difficulty can be adjusted. The game's narrative presents mathematical examples like how to control the Starflyer ship. The nature of the mathematical content compiled by the author team is combined to match the purpose of each station. At the navigators' station, participants solve a task with a Cartesian coordinate system.

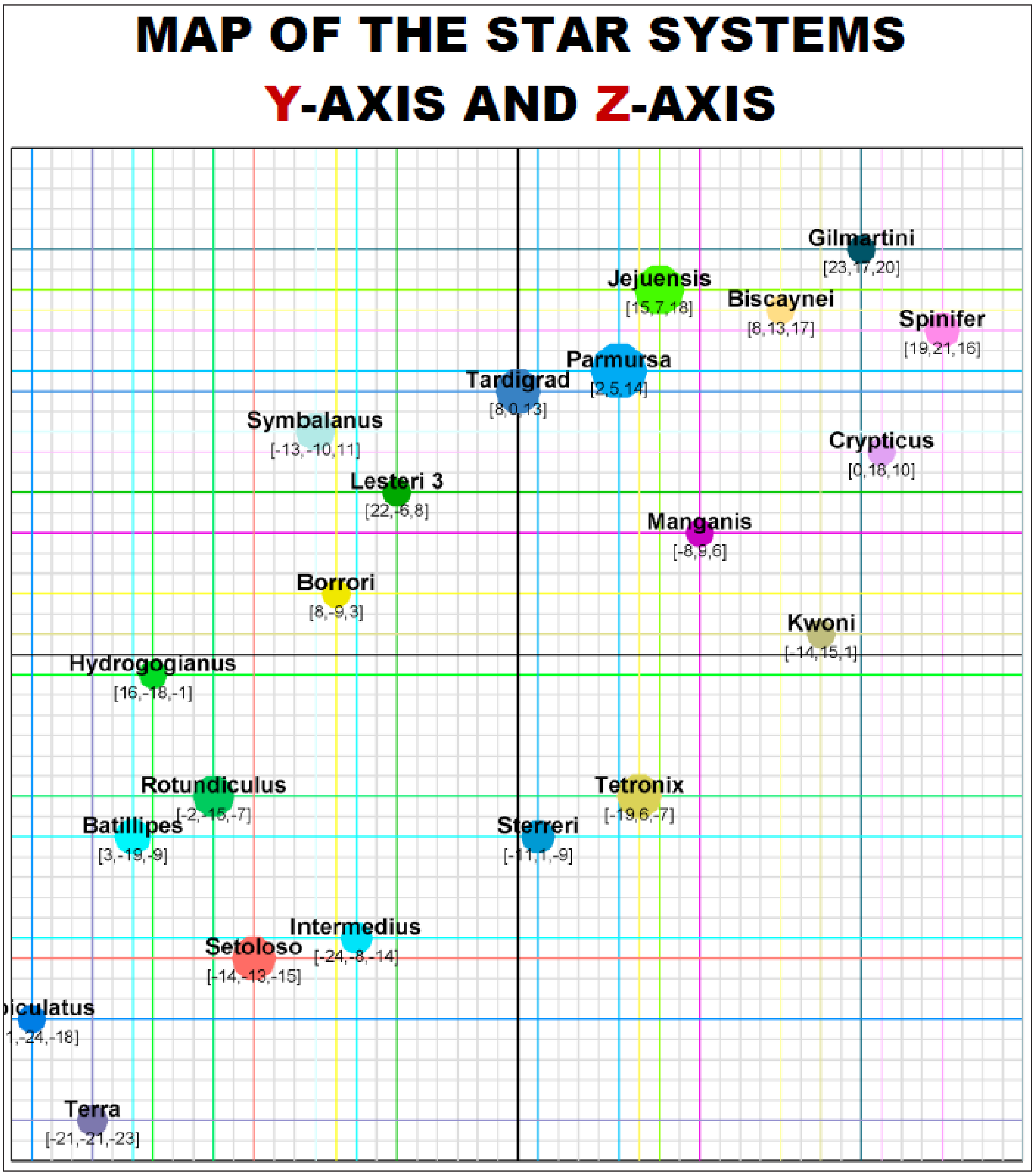

Figure 5: Map of the star system

The position of the shooters or laser operators solves the task associated with speed and distance calculations. When making adjustments, changes or additions to the mathematical content, it is advisable to adapt the assignment of the task to the given stations so that the magic circle of the game is not disturbed by questions from participants about the continuum of tasks at the given stations. The two stations – the workplaces of the ship – are connected within the story. That means that the success in one site conditions the success of another site. Specifically, they are explorers whose task is to map the space outside the Starflyer and find out if there is a dangerous meteorite or a source of raw material near the ship. The task of the shooters' station is to aim the object correctly and choose whether it should be captured and processed (to obtain dark matter) or destroyed. Both stations can solve their mathematical task simultaneously, but the correct information from the scout station is necessary for the success of the shooters.

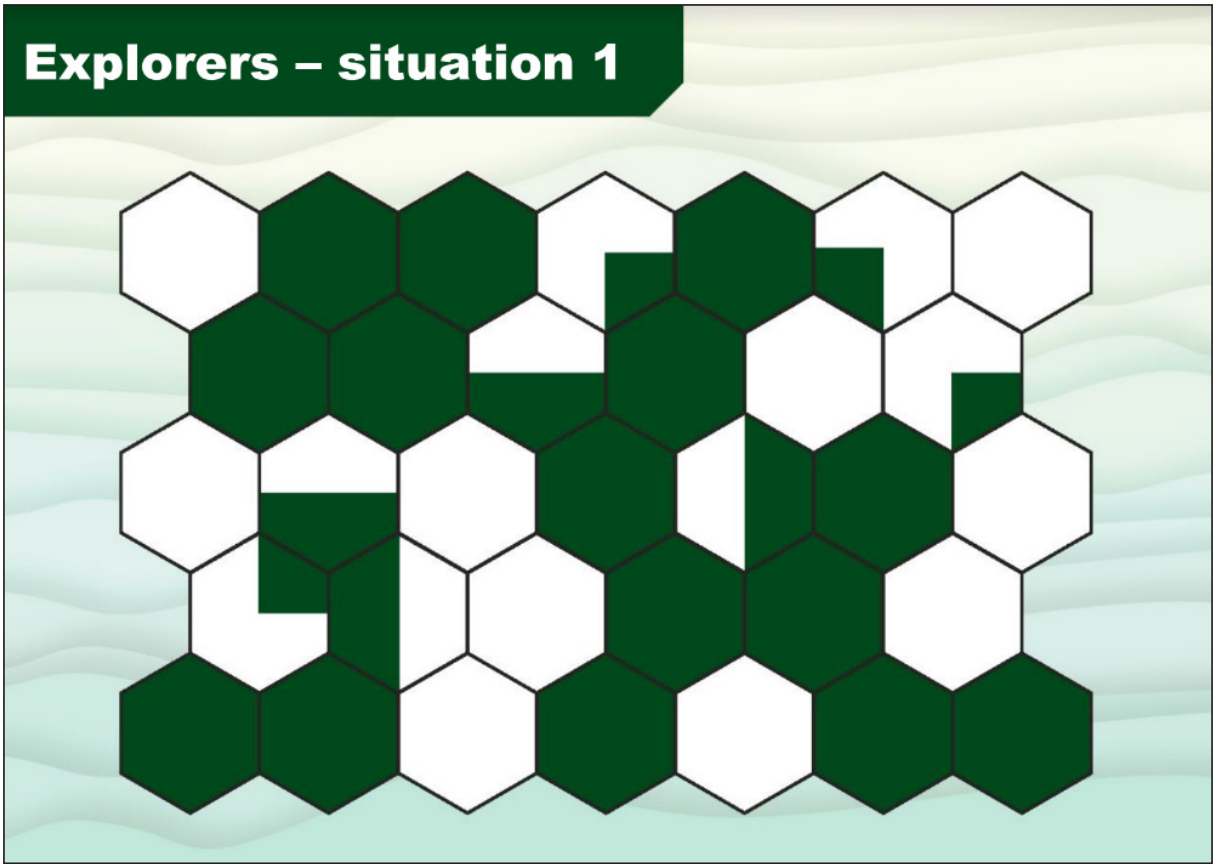

Figure 6: An example of a explorers´ station mapping the area around a spacecraft. In this problem, players need to express by a fraction the ratio of different coloured areas in the image

Connecting other stations would increase the complexity of the game mechanics, and at the same time, the course of the game would be more complicated and more demanding for the usher to evaluate. The connection of the navigators' and shooters' stations communicates to the participants the fact that in the Starflyer EduLARP other players also depend on the successful solution of tasks, each smaller group is part of a larger whole. Gradually, these two locations will be visited by all groups.

The modularity of the mathematical content also makes it possible to adjust the difficulty of the solved tasks or to adapt them to a specific team. A completely free category regarding mathematical content are problems connected with the optimisation of the use of dark matter. This is the sixth, optionally deployable station of the Starflyer. If the presenters choose not to include this location, the rest of the game will not be affected. The workstation should be located separately, outside of the existing five workplaces of the ship, and serves to supplement tasks for those groups that work quickly and finish their calculations before others. It is possible to add any number of tasks to this station, which should correspond directly to the mathematical content that the given group of participants is being taught.

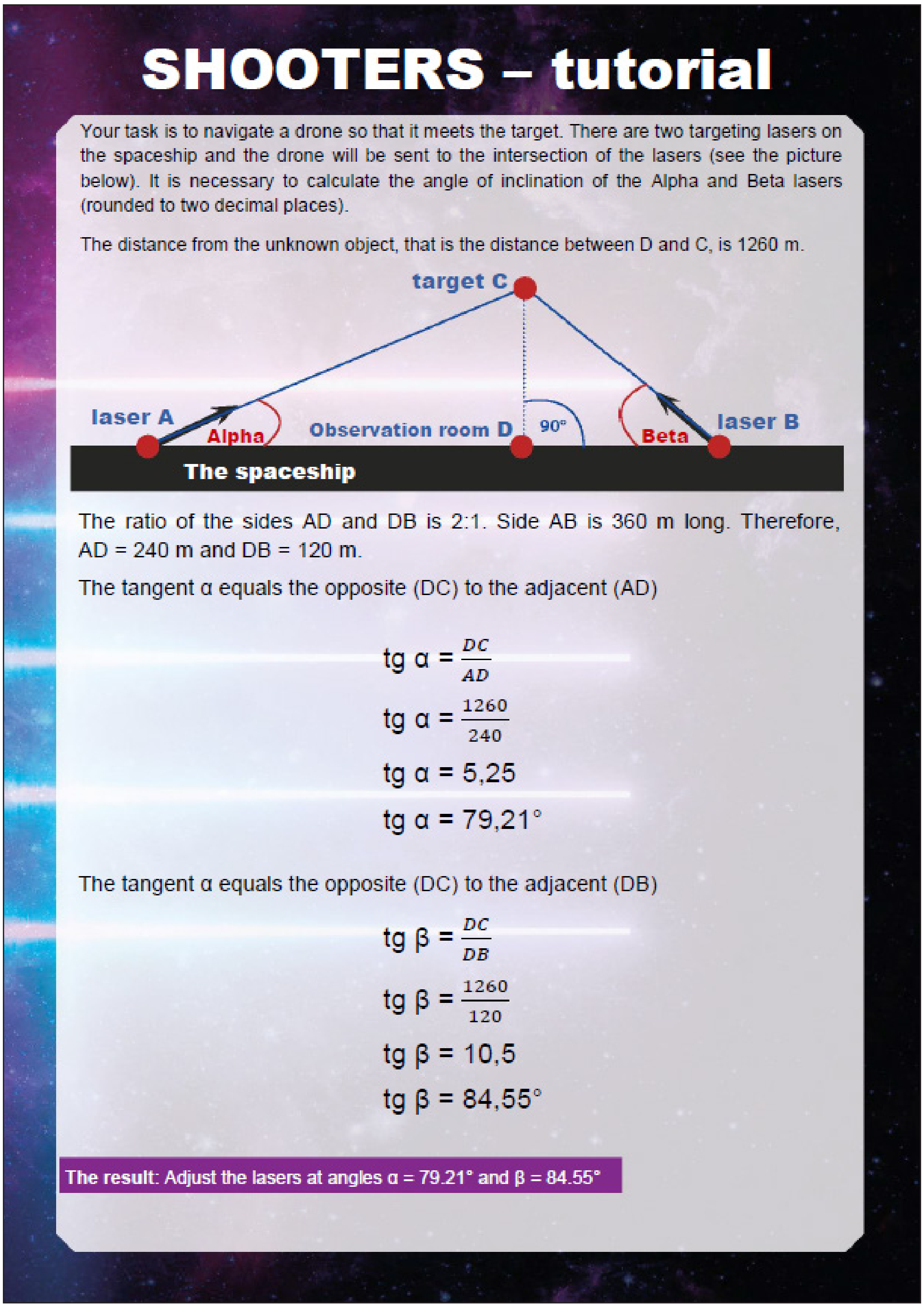

Figure 7: If players encounter a problem, they can be given a tutorial to help solve a mathematical task

An important element of the game design and its structuring are game rounds and the regularity in the actions that the crew of the Starflyer gradually performs. By game round we mean the artificial division of the EduLARP into time stages, the content of which is gradually repeated with minor variations. However, the term game round is not used explicitly. Each stage – round begins with a hyperspace leap. The on-board computer shows the crew a visualisation of the space leap and the Starflyer appears in one of the solar systems. The work of the crew at the stations follows immediately afterwards. It is necessary to repair minor damage to the ship (repairers' station), optimise the ship's dark matter reactor (engineers' station), explore the ship's surroundings (explorers), target threats or resources (shooters – operators) and find out where the ship will move in space next (navigators). The failure to solve any of the math problems has different consequences in the game. Some locations are essential for continuing the mission (e.g. navigators), other locations slow down the game, e.g. the ship cannot be steered without mechanics. The majority of failures can be solved constructively by the ushers, e.g. by calling for repeated solving of a mathematical problem or a temporary exchange of members of different teams (e.g. students strong in solving a specific mathematical problem).

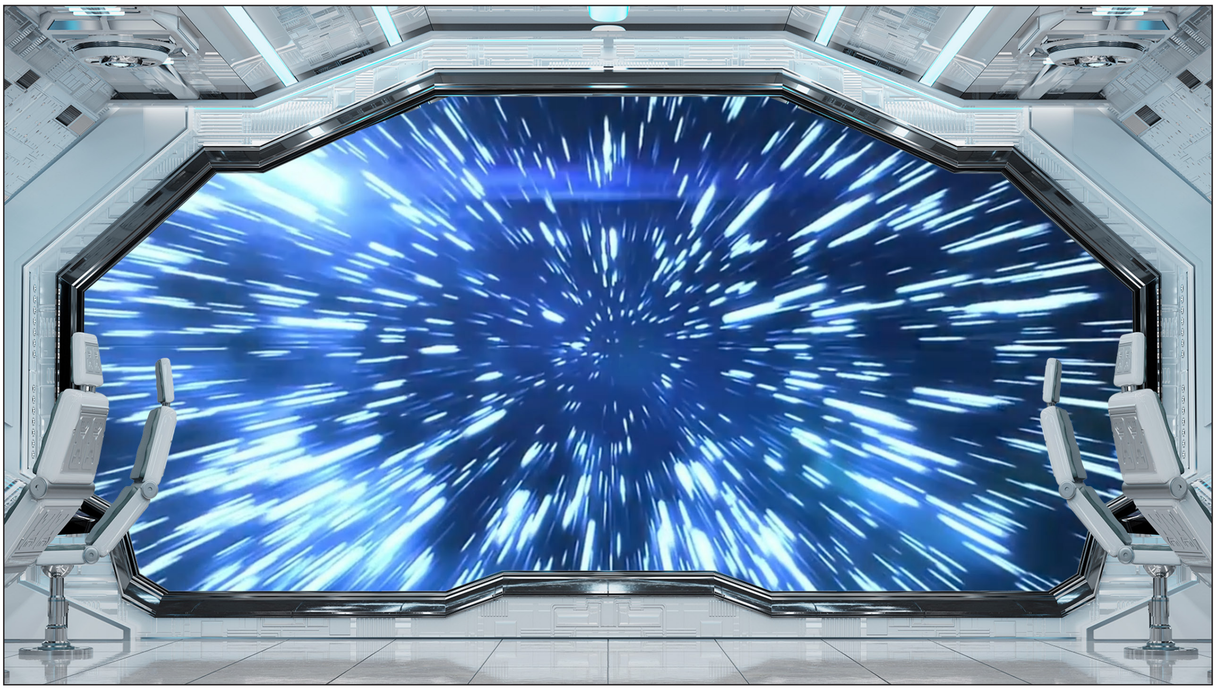

Figure 8: Screenshot from the hyperjump animation

The next phase is communicating with the planet in the particular solar system and solving the dilemma or problem in the story. At this point, participants decide in teams on the best solution to help accomplish the mission. After making a decision, another hyper leap follows.

An important issue in game design was deciding at what point to communicate the story implications of their choices to participants. We tested these messages in the form of an epilogue, where after the end of the game, the participants learned the fates and stories of the characters they decided on during the stops on different planets. In the end, it turned out to be a better solution to communicate the result of the ship's crew's decision immediately after making such a decision. This is not a so-called diegetic element, which would help adopt the role or immerse in the fictional world, because the game participant is, in a way, taken out of the role by such a meta-message. However, in practice, it turned out that participants experienced the fates of fictional characters and their stories much more when they could perceive the impact of their decisions immediately after making a choice.

The students who participated in the pilot runs most often appreciated the setting of the game in a story, which added interest to the activity and aroused their curiosity and motivation to continue. Specifically, the space environment was also mentioned, which interested them, and they would like to add content to this topic as well (not just mathematical and ethical content). Experiencing the story was supported by tight-fitting costumes, room lighting and thematic music. Some students mentioned that they were uncomfortable with too loud sounds, so it is up to the lecturer's "on-board computer" to balance the volume of sounds and music.

The participants perceived the possibility of interfering in the game and seeing the consequences of their decisions as a positive element. Some students admitted that mathematics was not their favourite subject, but in the framework of the game constructed in this way, they did not mind, in fact they forgot that they were practising it. Specific tasks that corresponded to the given station (e.g. counting angles when setting up the laser for shooters) were positively evaluated. They would appreciate the inclusion of tasks that are more logical (e.g. some word problems or puzzles) than numerical. However, there was mention of an imbalance in the difficulty of the tasks, when one team had completed its task and was waiting for the completion of the other groups, but this was dealt with by means of the sixth station during the testing and development of the game. It was also difficult to find out which stations would be easy and which would be difficult for the students. This is also why we included the sixth station after the first pilot runs, where the crew can calculate extra examples to relieve the on-board computer and thus save dark matter. The total time of inactivity of the participants during the game was thus significantly reduced.

Although the students were surprised at the beginning by being divided into groups that they could not create themselves, at the end they positively assessed that they had got in contact with classmates that they had not known so well until then. This mechanism is especially beneficial for first year students. The participants also highlighted the necessity of cooperation in a positive sense, although in some groups it happened that the tasks were solved by, for example, two active and mathematically proficient students and the other participants observed. The topic for further development of the game could be the creation of procedures for the ushers, how to make such students more active.

Most students appreciated that the role playing was rather superficial, the roles were not deep. Some participants would not have felt comfortable in more active role playing. However, students who in their free time look for entertainment such as role-playing games or LARPs would, on the other hand, have welcomed a deeper element of role-playing. The resulting level of the depth of role-playing thus represents a compromise that does not pose too much of a challenge or step out of the comfort zone for participants and allows them to focus on mathematical and other educational content.

Getting clues that required dark matter seemed difficult. Players could receive a hint or help from an android for a unit of dark matter, but if they were to fail to solve the task, they also would also lose one dark matter. In principle, therefore, it was not worthwhile for them to ask for advice, because they would lose the same amount of dark matter anyway.

The gameplay felt predictable to some players (counting at stations, then visiting a planet), but the story of the game still kept them engaged.

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Josef Kundrát focuses on pedagogical psychology, the development of psychodiagnostic methods and the creation of interactive educational programmes for primary and secondary school students. A senior researcher in the Edumath project, he participated in the creation of the story, game mechanics and design of the Starflyer EduLARP. His area of interest is the application of games in education, in particular the connection of the development of soft-skills and subject-matter knowledge.

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Starflyer Programme evaluation

José Manuel Diego-Mantecón & Zaira Ortiz-Laso

This chapter presents the evaluation of the Starflyer programme designed within the EduMath (Mathematics EduLarp) project. This programme has been implemented in high schools across the Czech Republic, Italy, and Spain, reaching thirty-one teachers and about 800 students. For the evaluation purpose, qualitative and quantitative data was gathered through questionnaires and interviews. The following summarises the main results concerning the suitability of the Starflyer programme for promoting mathematics problem-solving and collaborative learning. Other benefits of the programme, as for example its motivational aspect for learning and the use of real contexts where ethical decisions were relevant, are also discussed. This chapter concludes with the main challenges when implementing the programme in the mathematics classroom.

Starflyer Programme

Figure 1: Cover of the Starflyer programme

The 'Starflyer Programme' is an Educational Live Action Role Playing (EduLarp) designed for promoting the teaching and learning of mathematics in high school. It is an educational experience in which both teachers and students take a role as part of a narrative. This educational experience deeply immerses participants in detailed roles that facilitate active experimentation. In particular, the Starflyer Programme is set in a futuristic spaceship in the 24th century (see figure 1) where students are the crew of the Starflyer ship. The crew is composed of different professionals— engineers, shooters, explorers, navigators, and repairers —that must lead the Starflyer ship with their decisions. The objective is to preserve Earth's technological control, as well as its stability which implies investigating whether there are elements, distinct from the ones possessed by the Earth, capable of exploiting dark matter in the galaxy. During this adventure the crew will encounter mathematical problems similar to the ones that professionals tackle in real life. As a consequence, the resolution of these problems implies taking ethical dilemmas that require reaching a consensus without knowing the consequences of the decisions taken. The participants of the game will thus have to put into practice mathematical and collaborative problem solving competences for figuring out contextualized problems where mathematics flourish. More information about the Starflyer Programme can be found in Chapter 6.

Objectives of the Evaluation

The general objective of the evaluation was to test the potentialities of the Starflyer programme for promoting the teaching and learning of mathematics. In particular, we aimed to profoundly analyse:

- the suitability of the narrative and dynamic of the Starflyer programme;
- the appropriateness of the Starflyer programme for incorporating mathematical problems with different content and for different ages;
- the flexibility of the Starflyer programme for promoting problem-solving competences and collaborative learning;
- the potentiality of the Starflyer programme for becoming a motivational tool for promoting learning; and,
- the challenges when implementing the Starflyer programme in the classroom.

Schools, teachers, and students participating

3 Countries

793 High school students

31 High school teachers

To refine and to evaluate the consistency of the Starflyer Programme, it was implemented in 15 schools across the Czech Republic, Spain and Italy during the academic year 2021/22. In total, almost 800 students got involved in the programme, guided by thirty-one teachers. The following subsections contain specific information about the schools, teachers and students participating in the programme per country.

The Czech Republic

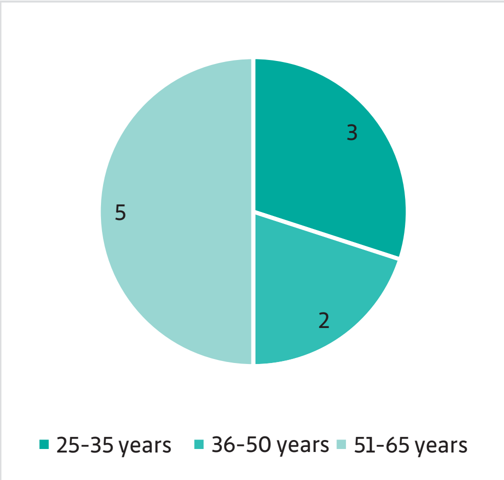


Figure 2: Czech teachers' age

In the Czech Republic, the programme was implemented by ten teachers from four high schools in two municipalities of the region of Moravian-Silesian: Ostrava and Frýdek-Místek. The teachers were women with ages ranging from 25 to 62 years old; three from 25 to 35, two from 36-50, and five over 50 years old (Figure 2). All teachers instruct mathematics, with eight of them teaching also a second subject: either physics, chemistry, ICT or English. Four Czech teachers had experience in the implementation of game-based learning methodologies in regular lessons. All teachers involved a total of 225 students in the experiment with ages ranging from 15 to 19. The students belonged to different secondary education levels and were representative of different academic achievements.

Figure 3: Czech students implementing the programme

Italy

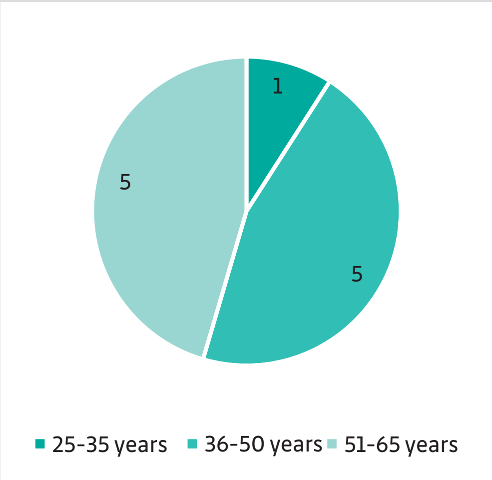


Figure 4: Italian teachers' age

Eleven Italian teachers from six high schools participated in the Starflyer Programme. The schools were from six municipalities of the region of Liguria: Genova, Chiavari, Savona, San Remo, Genova, and Spezia. These six contexts vary somehow in relation to population, economic well-being, and job opportunities. The teachers were 8 women and 3 men, and their age varied from 32 to 60 years old: one aged 32, five were between 36-50, and the other five over 50 years old (Figure 4). All of them were mathematics teachers in their schools, and none had previous experience in gamification nor other innovative methodologies. In total, 360 Italian high school students participated with ages ranging from 14 to 19 years old. The students were enrolled in different specialisations of the Italian educational system and their academic achievement varied from low to medium and high achievers.

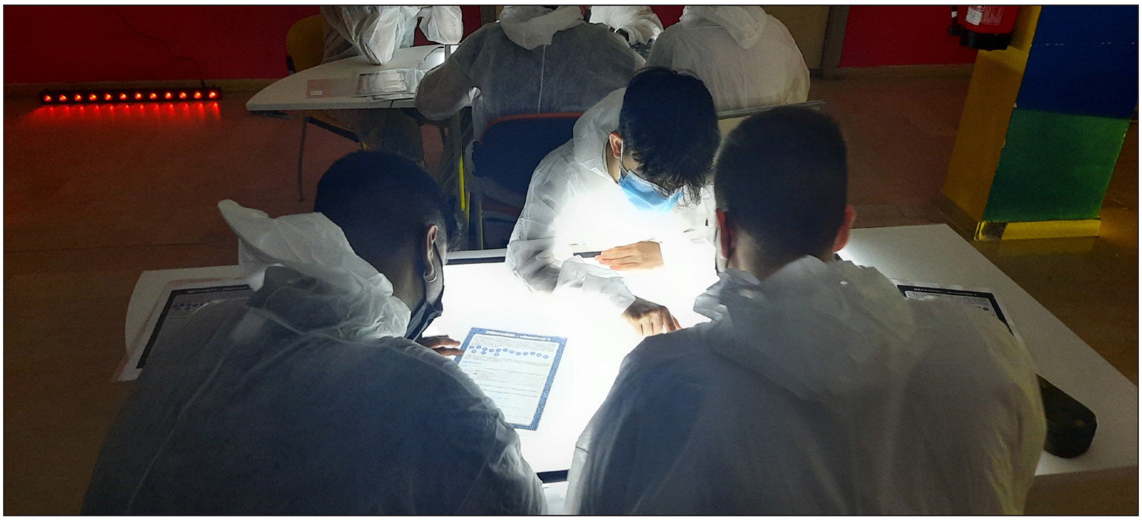


Figure 5: Italian students implementing the programme

Spain

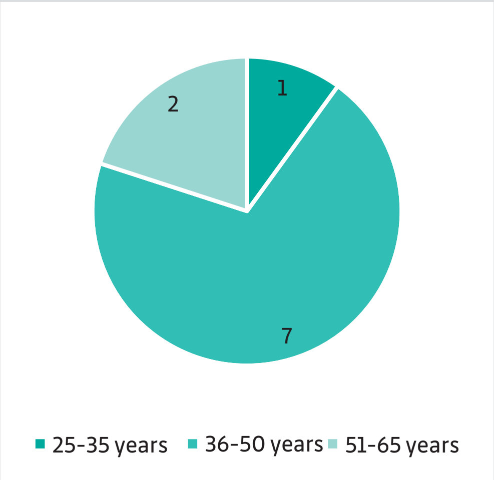


Figure 6: Spanish teachers' age

In Spain, ten teachers took part in the Starflyer implementation. They are from five schools located in five municipalities of the region of Cantabria in the North of the country: Santander, Torrelavega, Barreda, Solares and Reinosa. Three are state-subsidised schools and two are state schools, involving students with different profiles in terms of social and economic status. The teachers (6 males and 4 females) are 30 to 54 years-old, with the majority between 36 and 50 (Figure 6). Most teachers are specialized in mathematics; four of them also teach subjects from the Science disciplines (e.g., biology or physics) and from Technology (e.g., ICT). Three teachers involved in the trials were specialised in English as their schools run a bilingual programme. As a consequence, in Spain the Starflyer implementation was carried out in both English and Spanish, with the English teachers providing bilingual support.

In Spain, 208 students participated in the Starflyer programme. Students' ages ranged 15-17 years old, although a trial was also run with students at the first year of the Spanish secondary education (13-14 years old). Students were, in general, representative of a medium and high academic achievement; although, in order to achieve a broader inclusive scope, two trials were undertaken with students at risk of school failure and early school leaving.

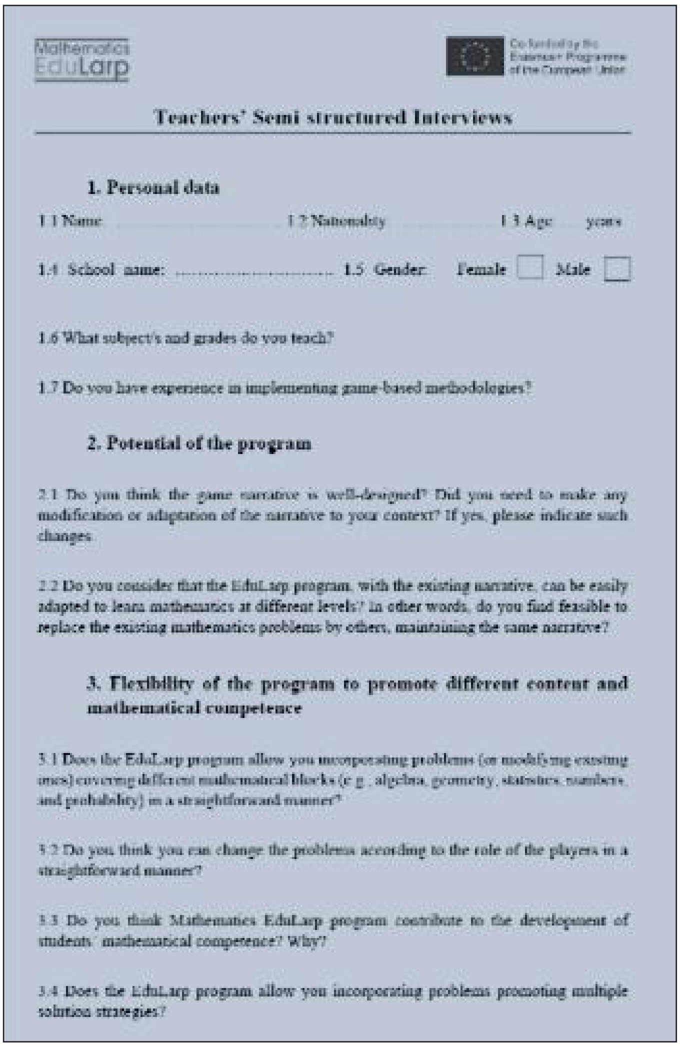
Figure 7: Spanish students implementing the programme

Data analysis approach

To test the consistency and potentiality of the Starflyer programme, a mixed-method approach was adopted. The analysis was preliminary qualitative to evaluate in-depth the potentialities and handicaps of the programme, but also a quantitative approach was employed to numerically categorise the results. The qualitative approach was helpful to get precise information about the opinions of the teachers about the Starflyer programme, its flexibility for promoting problem-solving and collaborative learning, and its suitability for being implemented in the classroom.

Two main instruments were designed for data collection: semi-structured interviews and questionnaires. To ensure the cross-cultural validity of the instruments, i.e., to verify that the questions measure what they were intended to measure equally well in diverse cultural contexts (Beck et al., 2003; Peña, 2007), conceptual and linguistic equivalence was considered (Andrews & Diego-Mantecón, 2015; Diego-Mantecón & Córdoba-Gómez, 2019). A special effort to eliminate questions producing a response bias or terms difficult to translate into other languages was made. After an iterative process of refinement, the instruments were produced in the consortium languages: Italian, Czech and Spanish.

Semi-structured interviews



Mathematics EduLarp

Teachers' Semi structured Interviews

1. Personal data

1.1 Name .... 1.2 Nationality .... 1.3 Age ...... years

1.4 School name: .... 1.5 Gender: Female ☐ Male ☐

1.6 What subject/s and grades do you teach?

1.7 Do you have experience in implementing game-based methodologies?

2. Potential of the program

2.1 Do you think the game narrative is well-designed? Did you need to make any modification or adaptation of the narrative to your context? If yes, please indicate such changes.

2.2 Do you consider that the EduLarp program, with the existing narrative, can be easily adapted to learn mathematics at different levels? In other words, do you find feasible to replace the existing mathematics problems by others, maintaining the same narrative?

3. Flexibility of the program to promote different content and mathematical competence

3.1 Does the EduLarp program allow you incorporating problems (or modifying existing ones) covering different mathematical blocks (e.g., algebra, geometry, statistics, numbers and probability) in a straightforward manner?

3.2 Do you think you can change the problems according to the role of the players in a straightforward manner?

3.3 Do you think Mathematics EduLarp program contribute to the development of students' mathematical competence? Why?

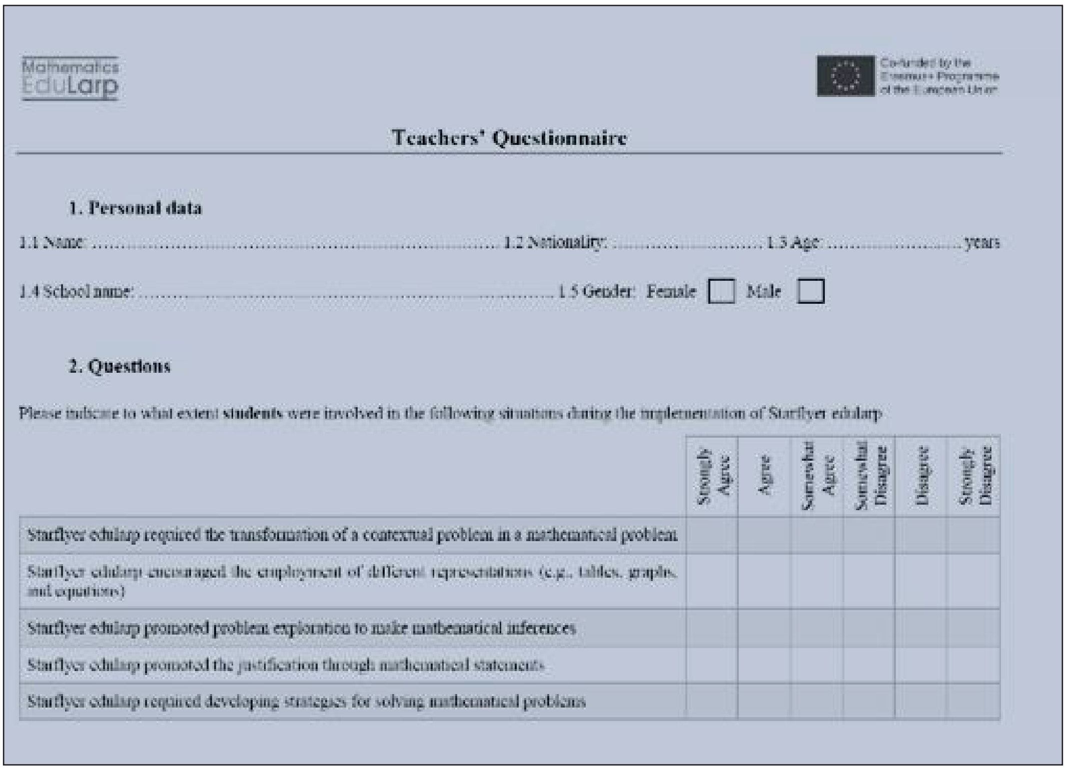
3.4 Does the EduLarp program allow you incorporating problems promoting multiple solution strategies?

Figure 8: Teachers' interview guide

The teachers' semi-structured interviews were conducted after the implementation of the Starflyer programme, aiming to collect in-depth information about the suitability of the narrative and dynamic of the Starflyer programme, its appropriateness for incorporating diverse mathematical problems, for promoting problem-solving, collaborative learning, and motivation. The teacher interview guide (see Figure 8) included fifteen core questions. In particular, two questions aimed at gaining information about the first objective, four related to the second and third ones, and nine associated with the last two objectives. Additionally, seven questions were posed at the beginning of the interview for collecting personal data such as age, sex, school characteristics and teaching experience.

Questionnaire

The teachers' questionnaire was administered after the implementation of the Starflyer programme. The questionnaire, partially shown in Figure 9, was designed considering part of the information generated from the interviews. The data collected aimed to categorise results, across gender and socio-cultural contexts. The most elaborated part of the questionnaire and the one that took longer to be designed corresponded with: the nine items intended to explore the suitability of the Starflyer programme for developing students' mathematical problem-solving competence, and the twenty items aimed at evaluating teachers' perceptions about the suitability of the programme for promoting collaborative learning. Collaborative problem-solving involved not only items related to mathematical problems, but also to ethical issues.


Mathematics EduLarp

Co-funded by the Erasmus+ Programme of the European Union

Teachers' Questionnaire

1. Personal data

1.1 Name: .... 1.2 Nationality: .... 1.3 Age: .... years

1.4 School name: .... 1.5 Gender: Female ☐ Male ☐

2. Questions

Please indicate to what extent **students** were involved in the following situations during the implementation of Starflyer edularp

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
Starflyer edularp required the transformation of a contextual problem in a mathematical problem						
Starflyer edularp encouraged the employment of different representations (e.g., tables, graphs, and equations)						
Starflyer edularp promoted problem exploration to make mathematical inferences						
Starflyer edularp promoted the justification through mathematical statements						
Starflyer edularp required developing strategies for solving mathematical problems						

Figure 9: Teachers' questionnaire

Main results of the evaluation

This section reports the main findings concerning our evaluation of the Starflyer programme in the Czech Republic, Italy and Spain. The findings are organised as follows: Narrative and dynamic of the Starflyer programme; Suitability of the Starflyer programme for incorporating mathematical problems with different content and for different ages; Flexibility of the Starflyer programme for promoting problem-solving competences and collaborative learning; The Starflyer programme as motivational tool for promoting learning; and The challenges when implementing the Starflyer programme.

Narrative and dynamic of the Starflyer programme

The teachers from three international contexts (Czech Republic, Italy and Spain) concurred about the suitability of the narrative of the Starflyer programme for posing mathematical problems at secondary school education. Czech, Italian and Spanish teachers considered that the narrative was meticulously constructed, well-designed and of interest to the students. Still, seven out of eleven Italian teachers would have liked the programme to provide more engaging feedback. They particularly highlighted the need of incorporating more information about the effects that the ethical choices may have on the evolution of the game and the decisions to be taken by the players. In a similar line, teachers from the Czech Republic and Spain pointed out the necessity of giving greater emphasis to the navigators' role. Two Spanish teachers proposed incorporating an extra slide with an informative map, after selecting whether the object is dangerous or valuable, for students feeling in a more realistic way that they are managing the ship. Three Czech teachers suggested the importance of establishing stronger connections among the members of the stations (navigators, repairers) for participants having a more convincing perception of how the successes and failures of solving mathematical problems impact on the progression of the game.

The contextualization of the problems set up in space with a crew in a ship was highly appreciated for all the teachers. The teachers valued positively the opportunity to offer students contextualized problems involving mathematical content that attempted to maintain the professional identity in the real world. In general, no objections were reported about the dynamic of the game. Just the Italian teachers suggested that the mathematics tasks could change after three cycles of the same task. Generally, all thought that rotating the students through all the five stations (with the corresponding battery of tasks) was a good strategy for all experiencing the different roles of the crew (engineers, shooters, explorers, navigators, and repairers) and their different mathematical tasks. All teachers argued that the Starflyer programme, with the existing narrative game dynamic, can be easily adapted to learn at different levels in secondary school education, in particular, for students of ages ranging from 12 to 16 years old. Teachers did not recommend the programme for students older than 17 as they believe that the topic may not be of interest after that age.

Suitability of the Starflyer for incorporating mathematical problems with different content and for different ages

Teachers from the three countries agreed that the narrative of the game supports the incorporation of new mathematical problems, and that these problems can be easily adapted to most of the curricular content required in each context as well as to the level and age of the students, without any need of modifying the core of the narrative. Czech and Italian teachers stressed that the mathematical problems of the Starflyer were in consonance with the role of the players, pointing also out that the level of the problems could be straightforwardly modified to reach younger students. In particular, a female Czech teacher aged 25 stated: “The math exercises fit well for the role players, but the examples might be modified for younger children”.

The majority of the Spanish teachers as well as many of the Italians suggested using the Starflyer programme for combining mathematics learning with other disciplines. Several teachers suggested that it would be valuable to implement larps where the narrative is framed in the past to learn history. Others proposed incorporating into the problems the use of content from the science and technology disciplines. They highlighted that the narrative of the game especially facilitates the Physics integration. These suggestions are aligned with the objectives of the new Spanish curricula that will be implemented in September 2022, and which fosters content integration through a STEM approach.

Flexibility of the Starflyer programme for promoting problem-solving competences and collaborative learning

As shown in Graph 1, Czech, Italian and Spanish teachers valued the potential of the Starflyer as a tool for developing students’ problem-solving competences as well as collaborative learning. Concerning problem-solving competences, the teachers from the three countries highlighted the benefits of incorporating in the game real problems that students have to transform into mathematical ones. The fact of solving the mathematical problem and transforming the mathematical solution into a contextual one related to the original problem was well valued for all the teachers. Czech teachers especially highlighted the importance of doing calculations and putting into practice the knowledge acquired during the regular lessons, while Italians and Spanish teachers appreciated the benefits of solving the problems by using different types of solution strategies (e.g., pictorial, algebraic and arithmetic strategies).

Graph 1: Teachers' perceptions per country for solving mathematical and collaborative problem-solving competences

Again, all teachers from the three cultural contexts reported about the potential of the Starflyer programme for promoting students' collaborative learning when playing the different roles of the game. All the teachers believed that the programme contributes to promoting decision-making and reaching consensus. Both aspects were well emphasised during the interviews: "The students got into the game and made decisions ethically, not randomly. They did not make fun of those situations" (Czech female teacher aged 25). Italian teachers found the game particularly valuable for promoting social interaction, for encouraging debate among team members to achieve a solution, as well as for sharing visions of the ethical and mathematical problems. Similarly, Spanish teachers pointed out the benefits of sharing different views and different solutions to the problems: "efforts were made to encourage students to explain their decisions after the group agreement, especially to prevent them from making random decisions in ethical problems and establishing certain consensus" (Spanish, female teacher aged 54 years old).

The Starflyer programme as motivational tool for promoting learning

The teachers from the three contexts also agreed on the benefits of the Starflyer programme as a motivational learning tool for the students. All the teachers perceived the game as an opportunity to present mathematics to the students in a completely different way as they are normally doing, projecting in this way a different and positive image of mathematics. The fact that mathematics was applied to real situations was also considered a rather positive point of this methodology, as it could help them to explain the usefulness of the mathematics discipline itself. All teachers appreciated that students lived a fun and immersive experience, making them part of the game, improving problem solving, ethical decision making, dialogue and teamwork. Two Spanish teachers valued also as a motivational factor for the students the fact of combining mathematics and ethical issues. They stated that this contributed to engage students in the larp and consequently in the learning process. The teachers who run the programme in a multilingual context also saw this fact as a way of enhancing students' motivation for learning.

Challenges when implementing the Starflyer programme

As observed in the above sections, the teachers described many positive advances of the Starflyer programme. However, challenges during the implementation phase of the programme were also detected for each of the three cultural contexts: Czech, Italian and Spanish.

The main difficulties faced by the Czech teachers were related to time consumption and preparation. Most teachers considered that the programme required an extended period to be carried out; this fact does not completely fit with the way in which the Czech educational journey is often structured. In fact, some of them recommend implementing the programme in days close to vacation periods, or after regular exams. Three teachers also expressed that the implementation of the programme required efforts to be prepared, being necessary to understand the game dynamic and to create an appropriate space for working collaboratively in each station. Despite the above challenges, most teachers expressed that they would implement the programme again.

The main pitfalls identified by Italians were related to the mathematical knowledge and preparation required for running the larp. The mathematical problems required applying previous knowledge related to different mathematical content. This was sometimes challenging for students because they had to apply concepts and procedures that they had not applied in the last months. This required preparation also from the teachers. Despite this fact, they advocated for the necessity of implementing larps more often. Consequently, all teachers expressed their intention to use edularp again, because they believed that it could be used as a supplement to traditional teaching. Some proposals were made by Italian teachers, such as, detailing deeply some aspects of the game such as the characters and the ethical consequences, and giving extra time for ethical choices.

As main disadvantages of the implementation, the Spanish teachers pointed out school curriculum and classroom spaces. Regarding the former, several teachers indicated the difficulty of undertaking the programme in regular lessons that last 50 minutes, and the necessity of using at least two lesson slots (1,7 hours) asking other colleagues' participation. In relation to the spaces, several teachers indicated that their classrooms were not suitable for implementing the programme. They had to turn the classrooms into a transitory workroom by moving chairs and tables. Despite the above difficulties, the ten teachers expressed their willingness to implement new larps or reuse this one with other students in the future. One of the teachers went beyond and suggested that the programme may only fit with teachers and students that usually work through active learning methodologies.

Conclusions

In general, rather positive feedback was obtained from the twenty-seven high school teachers after the implementation of the Starflyer programme in the Czech Republic, Italy, and Spain. Teachers defined the Starflyer as a flexible tool that can be adapted according to students' grades to promote mathematical and collaborative problem-solving competences. In addition, they found in the programme an opportunity for promoting, with minor modifications, not only mathematics learning, but also the integrated one— an educational approach promoted worldwide.

Teachers expressed that the game itself contributed to engaging students in the learning process. The larp was appealing for students because of the animations, the environment, and the details. Teachers highly appreciated the facts of promoting the transformation from a contextual problem into a mathematical one, as well as encouraging calculations. They also valued positively to achieve consensus for solving ethical and mathematical problems, and fostering teamwork. The Starflyer programme was implemented successfully because teachers made efforts to fit the game in the regular school timetable, and they invested time in preparing it.

References:

Andrews, P., & Diego-Mantecón, J. M. (2015). Instrument adaptation in cross-cultural studies of students' mathematics-related beliefs: Learning from healthcare research. *Compare: A Journal of Comparative and International Education*, *45*(4), 545-567. https://doi.org/10.1080/03057925.2014.884346

Beck, C. T., Bernal, H., & Froman, R. D. (2003). Methods to document semantic equivalence of translated scale. *Research in Nursing and Health, 26*(1), 64-73. https://doi.org/10.1002/nur.10066

Diego-Mantecón, J. M., & Córdoba-Gómez, F. J. (2019). Adaptación y validación del MRBQ (Mathematics-Related Beliefs Questionnaire) al contexto colombiano con estudiantes de secundaria. *Educación Matemática, 31*(1), 66-91. https://doi.org/10.24844/em3101.03

Peña, E. D. (2007). Lost in translation: Methodological Considerations in Cros-Cultural Research. *Child Development, 78*(4), 1255-1264. https://doi.org/10.1111/j.1467-8624.2007.01064.x

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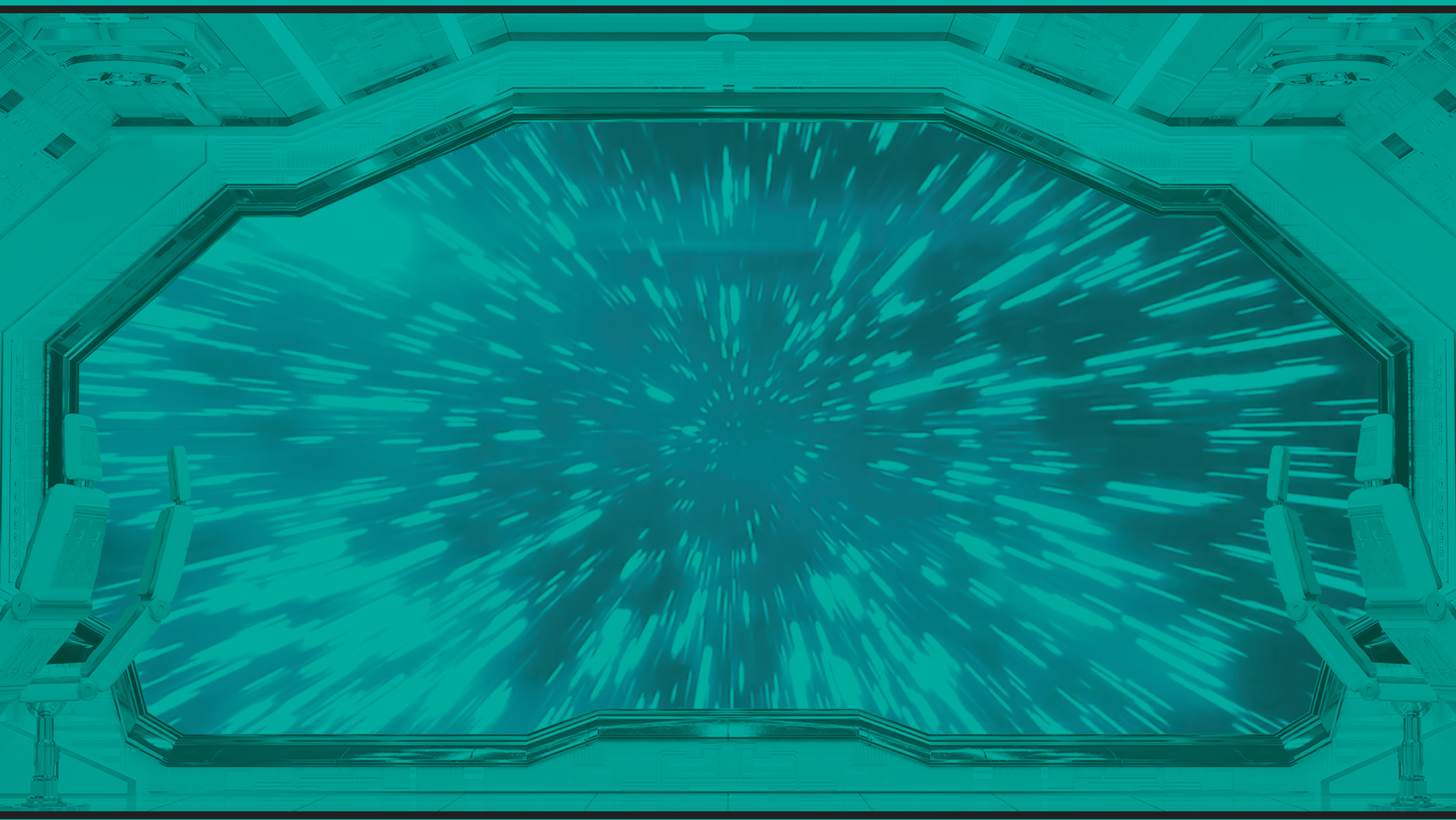

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