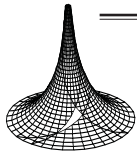

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Teaching
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The time spent on board games pays off: links between board game playing and competency motivation

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Abstract. The impact playing has on the development of thinking is an important topic of psychology of learning, brain research and mathematics didactics.

Our research is also connected to the aforementioned topic. We investigated the effects of playing board games on competence motivation and the development of mathematical competencies.

In this paper, we present the results of an experiment carried out in a secondary school class.

The experimental group spent one of three weekly mathematics lessons playing board games.

Apart from the several advantages of playing games in general, we can conclude that, based on the results of the national competence measurement, the mathematical competence of the students developed properly.

The readiness and the progress of the pupils were compared on the basis of input and output tests and an initial knowledge measurement and, at the same time, we compared their level of mathematical competence with the results of the national competence measurement.

Key words and phrases: board games, assessments, mathematical competence motivation and competence acquisition.

MSC Subject Classification: 97C70, 97D40.

Introduction

The impact playing has on the development of thinking is an important topic of psychology of learning, brain research and mathematics didactics.

To name just a few of the abundant literature on the subject, such as changes in the brain function of digital natives (Prensky, 2001a) (Prensky, 2001b); a website reviewing the literature on the relationship between playing and learning (Kirriemuir & McFarlane, 2004) or the relationship between mathematics and playing (Oldfield, 1991) (Török & Fried, 2020).

Even though gamification associated with digital devices and applications receives a lot of attention in researches, in this experiment we returned to the classic trend of study, to games played on a real, physical board.

During an experiment, we observed the impact playing board games has on competence motivation and mathematical competencies.

Siegbert Warwitz and Anita Rudolf (Rudolf & Warwitz, 1982) described some elements of playing from the aspect of the game methodology.

These elements − such as curiosity, desire to research, playfulness, need for movement, desire for performance, need for design, need for trials and adventure, need for socialization, desire to act, desire for recognition, spirit of competition, need for recreation − arise on the one hand from the instincts of the individual, and, on the other hand from the demands of the environment.

The playing elements can overlap and complement each other in many ways, but they can also compete or even conflict with one another in the reality of the game.

Research questions and hypotheses

Our hypotheses relate to some direct effects of board games. These effects were measured by input and output tests and questionnaires.

H1. The achievement in mastering the secondary school curriculum of the ,,board game group" will be at least as good as the control group. H2. The logical thinking of the ,,board game group" will develop more than that of the ,,non-board game group".

H3. Playing board games developes competence motivation.

We also have some research questions that we cannot answer due to the sample size, the duration of the experiment, or the experimental design we have chosen.

According to the experiences of the psychology of learning, activation of game elements can directly contribute to competence motivation (self-efficiency awareness, optimal challenge, intrinsic motivation, desire for discovery, curiosity, internal attribution, self-determination motivation, self-esteem and self-image,

achievement motivation), which paves the way for the development of competencies, including mathematical competencies (Herber & Vásárhelyi, 2006b). We also know from learning psychology that the resolution of tension, positive emotions, has a dual effect on learning (Herber & Vásárhelyi, 2006a). The positive emotions have a ,,broaden-and-build" effect. Positive emotions act as engines, mobilizing and accelerating the processes of attention, cognition and action. This action is accompanied by the loosening of discipline, what is up to the teacher to keep up. At the same time, the positive experience of playing can contribute to success later in the processing of gamified mathematical content.

Description of the experiment

The selection aspects of the games

We were looking for board games that require little factual knowledge, have a simple set of rules and can be played in the time frame of a lesson (35-40 minutes, at most), and at the same time, players have to perform complex logic operations.

We picked Avalon and Da Vinci Code for one group and Azul for the other group.

Description of the game Avalon played in the first semester (see, for example: https://www.ultraboardgames.com/avalon/game-rules.php)

Avalon is a fun game of fantasy characters.

Secret role cards (good and evil characters) are distributed among the players. The evil characters reveal themselves secretly to each other without showing themselves to the good ones. Merlin is the wizard who knows who the evil characters are but they do not know him. He is one of the good characters. The good ones (with the exception of Merlin) do not know whom to trust.

The task for the good ones is to figure out who they can trust and who is sabotaging the good ones. ,,The game consists of several rounds; each round has a team building phase and a Quest phase. In the team building phase the leader proposes a team to complete a Quest – all the players will either approve the proposed team and move to the quest phase, or reject the proposed team passing leadership to the next player and repeating the process until a team is approved. In the Quest phase those players selected to be on the team will determine if the Quest is successful." as it is written at https://www.ultraboardgames.com/avalon/game-rules.php.

The quest is successful if all the selected player vote secretly for success. (So the good character vote every time to success but there can exist situation where it is worth for an evil character to vote for success to mix up good ones.) There are five quests. The number of players taking part in a quest depends on the number of quests and the number of total players. The evils win, if there are three unsuccessful quests. Otherwise the good team wins except if at the end of the game the evil characters (after revealing themselves and discuss) guess correctly who Merlin is.

The good ones must be impeccably inferred; the evil ones must cleverly conspire and deceive others. Merlin is supposed to help his companions in a way that the evil ones do not recognize.

Players have to guess each other's imaginary personalities based on indirect information.

All communication takes place in the common space.

The rules are easy to understand, and the game can be made gradually more and more difficult by additional rules.

Description of the game Da Vinci Code played in the first semester (see, for example, http://kdoes.nl/uni/mas/index.php?id=thegame)

Another selected board game is the Da Vinci Code, which also has a very simple set of rules, and students could create the pieces of the game themselves. However, this game is built on logical thinking in a more explicit way. Actually, the strict logical thinking is more prominent than the heuristics. The aim of this game is to guess the secret code of the opponents. Players pick some number tiles and arrange the numbers in increasing order. The number they get is their secret number code, which they hide. Then, taking turns, players pick one from the pile of the remaining number tiles one by one and try to guess any tile of any other player. If the guess is correct, the tile has to be flipped over. (The guess itself can be any blind guess or can be based on previous information indirectly.) The last player, who still has concealed tiles, wins the game. These rules are again easy to follow. The game requires a logical inference and an understanding of the order of numbers.

Description of the game Azul played in the second semester (see, for example, https://www.ultraboardgames.com/azul/game-rules.php)

The board game selected for the second semester is the Azul. The aim of this tiling game is to make patterns on a board according to some rules. There are more complex versions of this game. The game connects to the curriculum through logic, combinatorics and geometric patterns.

The population

The experimental and control groups were formed by splitting a secondary school class specialized in languages of about 30 students. Such so-called language preparation classes take the 9th grade in one year and in the next year and then they take it again. In the first year, they learn almost only the language chosen and have a reduced number of lessons in other subjects, for example two lessons a week in mathematics.

The class was divided into two groups according to the language they learned.

The design of the experiment

Both groups were taught by the same teacher with the same methods and essentially the same content. Input measurements were performed in the second week of the school year. Before the experiment, approximately for a month the teacher taught mathematics to both groups the same way and at the same pace. The curriculum consisted of a summary of the previous year's material and the first chapters of the 9th grade's curriculum of algebra and number theory. In the first semester the experimental group spent one of their three weekly mathematics lessons with playing board games Da Vinci Code and Avalon. The board games were not available in the school at any other time.

The students played the games freely, without any interference and instructions from their teacher. The board game and the teams were selected by the teacher in some cases and there were occasions when children were allowed to choose their playmates or the game. In such cases they preferred to play with Avalon. The pupils were not given any observational aspects and no other direct didactic intervention took place. Sometimes, the rules were changed. On the other two lessons, the regular mathematical content prescribed in the curriculum was processed. Meanwhile, the other group processed the mathematical content given in the curriculum in 3 lessons a week. In the second semester, those in the experimental group took three mathematics lessons a week; those in the control group spent one lesson a week playing Azul and took mathematics in the other two lessons, as if they swapped roles. The students were aware that they take part in an experiment, however they were not told if they were in the experimental or the control group.

The experiment was designed as if the role of the experimental groups was changed, but the effect of playing games on logic skills was tested at the end of the first semester. The structure of teaching was similar in the second semester, but we chose a different board game and did not take output and input measurements.

This method led to pupils not knowing that the experiment was actually only done for the first semester. All they knew was that the teaching of logic was an important element of the experiment, which was in fact the case, since logic is not usually taught so deeply in 9th grade.

Teaching material

At the time of our experiment, education in Hungary was conducted in accordance with the National Core Curriculum adopted in 2012 and the related framework curricula. In the National Core Curriculum (*110/2012. (VI. 4.) Korm. rendelet a Nemzeti alaptanterv kiadásáról, bevezetéséröl és alkalmazásáról*, 2018) a number of development goals are formulated that are either aimed at or based on the development of logical thinking. Our experiment included a thematic block of mathematical logic. The block was designed (according to the Core Curriculum which was designed) for both groups over a 15-lesson time frame.

This block was exactly the same for both group. There were not any board game lessons during this block neither for the experimental nor for the control group. The block took place after the experimental group's board game lessons (and before the control group started playing with Azul). The aspects of the experiment related to the teaching of logic were discussed in detail in the study volume "Komplexer Mathematikunterricht: Die Ideen von Tamás Varga in aktueller Sicht". (Dukán, Szabó, & Vásárhelyi, 2020).

Results of the experiment

Initial knowledge level measurement (13. 09. 2018.)

We interviewed the teachers of the two groups from the previous year, focusing mainly on the mathematical skills pupils had acquired. With the help of these and based on experiences at ELTE TTK, we compiled a knowledge level measurement. The types of tasks of the assessment were simplification and finding the common denominators of fractions, application of divisibility rules, finding the smallest common multiple, the largest common divisor, solving linear equations, and word problems. According to the initial knowledge level measurement, we found that there was no significant difference between the knowledge of the two groups (to be precise, the control group even had a slightly better result).

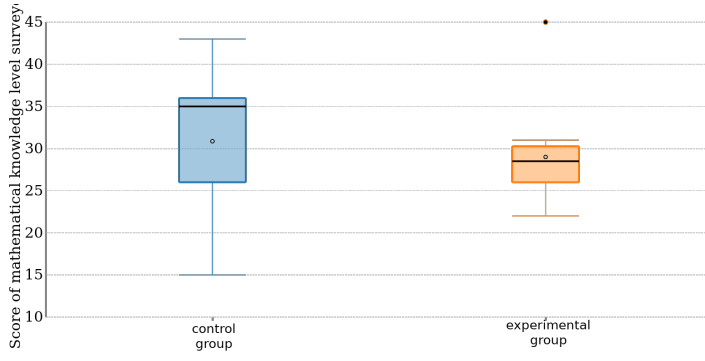

Figure 1. Comparing the initial mathematical knowledge of the two groups

Measurement of logic skills (11. 03. 2018.)

An input measurement to test logic skills was conducted on 3 October 2018. The absentees make up later, before the first lesson spent playing with the first board game. The test consisted of three tasks. Each task had several items. About half of them were embedded in a mathematical environment, the rest dealt with logical thinking in an everyday situation. When wording the tasks, we paid special attention to not to expect the knowledge of logical operations and the related terminology for the solution. The same test was given to pupils at the end of the experiment to compare the logical readiness before and after the experiment. The two-sample t-test shows that there was no significant difference between the two groups in terms of either the mathematical knowledge level surveyor or the input logic measurement.

The probability that the experimental group is better than the control group is $p = 0.5166$ in the case of the assessment test and is $p = 0.6962$ for the test in logic.

Because of the small sample, of course, we treat the statistical conclusions somewhat cautiously, but the results of the input test measuring knowledge level and logical readiness support our assumption that the mathematical and logical readiness of the two groups are essentially the same.

Similarly, we found that there was and did not arise a significant difference in the mathematics grades of the groups after the first semester, although the experimental group spent one-third of the time playing board games. This supports our hypothesis H1.

We continued the statistical comparison in terms of logical readiness. We compared the input and output measures and we concluded that the mean of the improvement of the experimental group is a bit higher but it is not significant. On the other hand there were two student in the control group whom performance decrease significantly and there was none in the experimental group. These supports partly our hypothesis H2.

The end-of-semester anonymous feedback form (15. 01. 2019.)

13 of the 15 pupils of the experimental group remaining in the group by the end of the semester completed the end-of-semester anonymous feedback form in an evaluable manner. Three of these students responded that their views on their fellow students did not change during playing board games, 10 wrote that their views have changed when they got to know their fellow students better. The experience of playing brought a positive change in general, but there were some mentioning fellow pupils being annoying while playing, or playing worse than what they expected. Thus the change in opinion about fellow students is not one-way. The vast majority of students confirmed our assumption: they also felt that their interpersonal relationships have improved, their social competencies had developed. 6 participants out of 13 considered the lessons spent with playing board games as the best mathematics lessons of their lives – 10 on a scale of 10, where 10 being the best and 1 being the worst mathematics lessons of their life; – and apart from one mark 7 and one mark 8, the rest of the answers were 9-s. This fact is also evident from other free-speech responses. This supports our hypothesis H3.

The same question was posed to all pupils after the second semester, when the control group played with Azul and the experimental group had 3 regular mathematics lessons. We organized the answers into Table 2.

Measurement of competency (29. 05. 2019.)

The Hungarian competence assessment is harmonized to the EU key competences and the PISA 2012. The official report about the assessment of the children in the given school provided by the Hungarian government on the basis of the nationwide measurement uses a complex model to evaluate the performance of children and schools. Besides the measured proficiency results, this is based on a questionnaire concerning the family background of the students (if answered) (*OKM 2019 FIT-jelentés, Útmutató a Telephelyi jelentés ábráinak értelmezéséhez*, 2020) Due to the specific language training, this model does not

fit the examined class and school completely, but the result is still very informative. Table 3. shows the performance in the language specialised 5-years classes (our class and the other language specialised 5-years class where were not any special curricula or experimental methods) in May of 2019. (*FIT-jelentés, Telephelyi jelentés, 10. évfolyam :: 4 évfolyamos gimnázium, VII. Kerületi Madách Imre Gimnázium*, 2020)

According to the data, we can conclude from the questionnaire that the students' mathematical competence developed appropriately despite the fact that instead of 3, they had only 2 regular mathematics lessons a week for one semester, and spent one lesson a week playing games. These results support the thesis that our experimental teaching method is applicable in the Hungarian mathematical teaching system.

Discussion, further questions

We have found that playing board games pay off – not only in kindergarten or elementary school, but in high school as well. The results obtained on our small sample support our hypotheses, however, we need to analyze item analysis before involving a larger population and improve our measurement tools based on the results of the analysis. The positive effects of playing real games on acquiring gamified forms of mathematics have to be investigated. (This was not possible in our case, since both groups taking part in our experiment were in fact playing.) It would be interesting to follow up the same groups, to include further board games that require thinking. It would be important to involve representative samples regarding each parameter of the experiment (time span, number of people, age).

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group of student	input logic measurement (out of 46 points)	output logic measurement (out of 46 points)	mathematical knowledge level assessment (out of 57 points)	previous year-end grade of mathemematics	grade of mathematics at the end of experimental semester
control	27	37	36	5	5
control	32	38	36	5	4
control	32	38	28	4	4
control	31	34	23	3	4
control	31	35	31	5	4
control	32	34	18	5	4
control	41	31	37	4	4
control	33	39	43	5	5
control	26	39	38	5	5
control	34	32	35	5	5
control	38	33	35	5	5
control	26	33	29	5	5
control	29	41	35	4	4
control	29	38	15	4	3
control	25	27	24	4	5
control	28	34		5	5
experimental	35	35	26	4	4
experimental	31	36		5	5
experimental	28	36	26	4	4
experimental	29	35	22	5	3
experimental	31	41		5	4
experimental	30	41		5	4
experimental	35	39	31	5	5
experimental	30	38	30	5	4
experimental	32	37	29	3	4
experimental	26	41	30	5	5
experimental	38		27	5	5
experimental	37	45	23	4	5
experimental	29	31	31	5	5
experimental	37	36	45	5	5
experimental	32	35	28	4	4

Table 1. Data of measurements

	Avalon group after the first semester not anonymous	Avalon group at the end of the year anonymous	Azul group at the end of the year anonymous
10	7*	10	2
9	4	1	3
8	1	1	5
7	1	0	2
6 or less	0	0	0

Table 2. Rate this year's board game math lessons on a 10-point scale (compared to the mathematics classes of recent years)!
10: the best mathematics lessons of your life, 1: the worst mathematics lessons of their life
*there is one answer "9-10"

	our class	other class (with same mathematics curricula)
better than expected	15	10
significally better than expected	0	1
same or worse than expected	13	20
significally worse than expected	4	11

Table 3. Student perfomance on national competence assessment