JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

EVALUATING THE IMPACTS OF NTC LEARNING SYSTEM ON THE MOTIVATION OF STUDENTS IN LEARNING PHYSICS CONCEPTS USING CARD–BASED LEARNING APPROACHES

Bojan Lazarevic,
Maja Stojanovic,
Jelena Pisarov,
Nemanja Bojanic

Abstract. *This study examined the impact on the motivation of students toward learning physics upon applying the Nikola Tesla Center (NTC) learning system. The research was conducted using a quasi–experiment with a pretest–posttest non–equivalent control group design. The participants considered were a large group of 1371 students, from various grades and mixed genres, selected from the same district in Serbia. The instrument of this research was the students' motivation toward science learning (SMTSL), which has been adapted to measure the motivation of students and their learning strategies for physics. Statistical analysis included calculations of Cronbach alpha, chi–square, Kolmogorov–Smirnov (KS) test, independent Samples t–test and ANCOVA, and Pearson correlation test. The study found that using the NTC learning system had a positive effect on students' motivation to learn physics. The experimental group had significantly higher scores on various subscales of motivation such as self–efficacy, active learning strategy, physics learning value, performance goal, and learning environmental stimulation compared to the control group. The research results determined that the NTC learning system is an effective method for promoting motivation of students toward learning physics and it can be recommended for implementation in schools.*
Keywords: *physics education, experimental design, NTC learning system, student motivation, game–based learning*

Bojan Lazarevic
American University of the Middle East, Kuwait
Maja Stojanovic, Jelena Pisarov, Nemanja Bojanic
University of Novi Sad, Republic of Serbia

Introduction

Since the early start of studying physics, students have faced many drawbacks in comprehending and understanding complex laws of physics. To facilitate their intake on scientific concepts, students need to (i) recall previously learned mathematical components such as equations, functions, and figures as well as (ii) apply algebraic and arithmetic operators (Ataíde & Greca, 2013; Korsunsky, 2010). During this learning period, students tend to rote memorize symbols and abstract physics concepts, which negatively influence their motivation and how they approach learning physics (Cavallo et al., 2004; Kizilgunes et al., 2010; Novak, 1988). Thus, the engagement of students in class and their motivation to learn are still one of the fundamental problems in our contemporary education methodologies (Archer et al., 2020; Clark et al., 2017; Göksün & Gürsoy, 2019).

A recently conducted study performed by the Program for International Student Assessment (PISA) (OECD, 2019) on Serbian students resulted in statistical data that attest to the urgent need to enhance learning by boosting the motivation of students. Data have shown that only 62% of students obtained an acceptable level in science, compared to an expected average that should be close to 78%. Such results support the importance of increasing students' motivation to learn science and, thus, their ability to easily apply the physics they have learned. Keeping students actively engaged greatly affects their ability to learn and ultimately leads to enhanced motivation which impacts their behavior both in and out of the classroom. In order to encourage active student participation within the classroom, researchers adopted a number of strategies some of which were based on games, commonly referred to as "educational games," classroom activities that proved to be effective at enhancing students' motivation (Muniwastia et al., 2018).

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Games are among the first types of educational techniques where both educators and students attest to their successful outcomes as they engage learning environment (Prensky, 2001; Rieber & Noah, 2008). Moreover, educational games are believed to create pedagogic pathways that enable students to better comprehend learned scientific concepts, while stimulating their motivation, and scientific curiosity (Baek et al., 2015; Franco–Mariscal et al., 2016; Partovi & Razavi, 2019) and creativity (Chung, 2013). Educational classroom games have been shown to have a positive impact on students' understanding of concepts as well as their soft skills such as communication abilities and the ability to constructively interact with other classmates (Blakely et al., 2009).

In fact, many research groups have been found dealing with the application of educational cards as game–based learning approaches. Indeed, in a study conducted by (Moğol & Özçifçi, 2003), the authors demonstrated that using card games makes the learning process of abstract topics and concepts more enjoyable and easier. In the same context, Md Rashid et al. (2021) evaluated the impact of using the Smart Conversion Card (SCC) on the perception of students toward understanding scientific concepts such as unit conversion, a concept commonly encountered when teaching physics. In the recently published research, the authors demonstrated the usefulness of matching card games in enhancing students' engagement and memorization of physical and chemical quantities (Lhardy et al., 2022). These studies highlight the importance of encouraging student interaction and engagement in order to promote learning and motivation in the classroom.

Moreover, these authors and others (Baines & Slutsky, 2009; Byusa et al., 2022; Chen et al., 2014; Duvarci, 2010; Haris, et al., 2018; Höft & Bernholt, 2019; Kirikkaya et al., 2010; Liu & Chen, 2013; Romine, 2004) stressed the fact that applying educational games is believed to promote the active participation of students in classrooms enhancing their motivation in learning and improve creative problem–solving skills (Chen et al., 2021), cognitive improvement and spatial abilities (Gallagher & Grimm, 2018). On the other hand, teachers also should be creative in designing the class, and the research of (Yildiz et al., 2021) showed that working with the games, teachers' skills and motivation increased too.

Research Problem

As motivation is a complex phenomenon, it should be evaluated by considering multiple factors that address student "depth of learning", comprehension, and analysis of scientific concepts (Tuan et al., 2005). These factors are better described as self–efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environmental stimulation. Those factors are important as they describe:

Self–efficacy is the students' belief in their own ability to succeed; Active learning strategies as students' active participation in the use of different strategies to construct new knowledge; Science learning value describes students' competence to solve problems; Performance goals as a student's goals are to compete with other students and attract the teacher's attention; Achievement goal describes that students feel satisfaction as they increase their competencies and achievements while learning science; Learning environmental stimulation describes how the environment affects learning, such as the curriculum, teacher's teaching, and student interaction (Bandura, 2010; Brophy, 1988; Dogani, 2023; Eccles & Wigfield, 2002; Pintrich et al., 1991).

Tuan et al. (2005) included these motivational factors because they believed that it emphasizes the importance of learning science and that it allows students to acquire competencies for solving problems, engage in research activities thus stimulating thinking, and find the relevance of science and everyday life. It is worth highlighting that a similar questionnaire has been already adopted and validated for Serbian students to measure their motivation in learning chemistry (Olic et al., 2016), and later it was adapted for use in in studies analyzing motivation in learning physics (Blajvaz et al., 2022; Radulovic et al., 2022; Radulovic et al., 2023). Nonetheless, their questionnaire was based on 5 out of 6 motivational factors, and the depth of the questions did not cover thoroughly the basic factors needed to evaluate motivation as the last factor, 'learning environmental stimulation', has been excluded. As the existing questionnaire didn't fully cover all 6 proposed factors, as suggested by the author (Tuan et al., 2005), there was a recognized need to examine this missing factor. In light of these recent findings, the content of the questions used in this study tackles a deeper exploration level for assessing students' motivation toward learning physics (SMTPL).

Research Focus

The Nikola Tesla Center (NTC) learning system provides one of the most promising game–based learning approaches, as its activities are specifically designed to stimulate and support cognitive abilities and to promote the brain and physical development of children during preschool and subsequent learning stages (Rajovic, 2012a). The

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

child will be motivated as activities are processed naturally to induce combined movement and thinking actions. Beyond physically related activities (i.e., eye movement and body coordination) provoked by applying the NTC learning system, mentally related ones will also be established while playing. During this process, research has shown that learning about abstract symbols in life is of a special priority, and it focuses on developing divergent and convergent thinking and improves creativity and functional knowledge (Rajovic, 2012a; Rajovic, 2012b; Rajovic, 2012c; Rajovic, 2016). The recognition of abstract symbols is one of the complex and important learning abilities (Girgin & Akgün, 2020), as it allows for the understanding and interpretation of written language, mathematical notation, and other symbolic systems (Rajovic et al., 2018).

While playing an education game, a child will alleviate stress and stay motivated, as opposed to constantly listening in an inactive state (Rajovic et al., 2018), and the child will experience many emotions, which then the brain creates the hormone of happiness. It has been reported that the regulation of emotions, the fact of feeling energetic and motivated, as well as the desire to think and generate thoughts, could all be related to the release of dopamine (Ratey, 2008). This dependency relationship is simply caused by the stimulation of the brain by an activity. Specifically, dopamine is recognized as one of the most crucial neurotransmitters as it affects the rationality of decision–making, induces a feeling of reward upon learning, and most importantly, catalyzes motivation (Schultz, 1998; Wise, 2004). Moreover, it has been recently reported that the role of dopamine extends to cover additional physical and psychological activities. Notably speaking, dopamine was shown to have direct effects on the activation of working memory (Lisman & Grace, 2005) and on the control of cognitive and executive functions (Cools, 2008; Cools & D'Esposito, 2011). More free play, as well as organizing planned activities, can alter children's brain chemistry and promote creativity, motivation, and engagement (Brown & Vaughan, 2009).

This learning process helps group the five-motivation related NTC elements listed in Table 1. These activities stimulate cognitive processes which, in turn, promote associative thinking such as mental classification, mental serialization, and association (Rajovic, 2012a).

Table 1

Cognitive Processes – Learning Elements of Associative Thinking

Learning element	Description	Associated example relevant to card–based games
Classification	Students will learn how to group cards into categories based on a single attribute.	Separating cards based on color and/or drown objects.
Serialization	Students will learn how to arrange cards into groups.	Sorting cards based on color, shape, and type.
Analogies	Students will learn to correlate symbols to concepts.	Correlating the letter "m" on cards with a quantity for a mass.
Association	Students will learn to connect symbols to previous ideas or learned knowledge.	Connecting the quantity mass with the drawing of a sumo wrestler.
Abstraction	Students will learn to recognize symbols from abstract concepts.	Recognizing that letter "s" is used for second and connected with the quantity time (t).

Note: Learning elements as deduced from NTC4memory cards from "MENSA NTS Learning System– Creative and functional thinking development and effective learning", by (Rajovic, 2012a)

As one of the solutions for the cognitive power of teaching materials related to the SI system of measurement units, the authors of the NTC learning system designed and manifested the NTC4memory game, particularly in learning scientific concepts, as per these main elements (Table 1). This game should have an impact on thought classifications and associations; the development of divergent and convergent thinking, as well as functional knowledge, and in addition to the theoretical aspect, the game should encourage the development of motor skills, and orientation in space, and teach children patience. This game should not only teach students about game effects and subject topics, but it should also improve their motivation in learning and creativity.

The learning elements of cognitive processes, such as classification, serialization, analogies, association, and abstraction, are important for the student's motivation because they describe how students memorize and understand new information (Mayer, 2014). For example, a student who has high self–efficacy may be more likely

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

to engage in classification and abstraction as he is more confident in identifying and understanding underlying principles (Wolters, 2003; Zimmerman, 2000). Similarly, a student who is motivated in physics learning due to his natural curiosity (Physics learning value) may be more likely to engage in analogies and association as he is seeking to connect new concepts to real–world phenomena. Active learning strategies, such as group work and problem–solving exercises, can also facilitate the use of cognitive processes like analogies and abstraction by encouraging students to connect new concepts to prior knowledge and think more deeply about their meaning (Freeman et al., 2014; Prince, 2013). The teaching techniques that focus on students' motivational interests and goals result in an enhancement of students' use of cognitive processes such as analogies and abstraction, which are crucial for constructing new knowledge and understanding (Palmer, 2005).

Research Aim and Research Questions

Despite the readily available literature on the positive impacts of card-based games on improving learning and motivation, scarce are the studies reporting quantitative results on the impact of such games on improving motivation in learning, specifically a cognitively designed approach to comprehend abstract physics symbols among students, stimulate their motivation, and foster their scientific curiosity and creativity. Additionally, the findings inspire educators to investigate creative pedagogical approaches, therefore advancing the field of physics education.

However, educational games have their limitations. They may not be suitable for all subjects or educational goals (Steinkuehler & Duncan, 2008) and they may promote surface–level learning, where students focus on winning the game rather than gaining a deep understanding of the subject matter (Zhang & Shang, 2015). Also, it is unclear whether the skills and information acquired in-game will be retained over time (Tobias & Fletcher, 2011). Finally, educators should be adequately prepared or trained to use these tools effectively (Hamari et al., 2014).

Based on this state–of–the–art, this study aimed to apply the NTC learning system to assess motivation in learning abstract concepts in physics. This aim was fueled by concerns raised due to the recognition discovery that physics has been one of the least favorite subjects among older elementary school students in Serbia (Rajovic et al., 2020). The motivation for using the NTC method relies on the demonstrated positive impacts on improving student ability and willingness to learn. In light of this, the research question arises: How does the implementation of the NTC learning system impact students' motivation to learn abstract concepts in physics?

Research Methodology

General Background

Unlike conventional game-based learning methodologies, which typically involve integrating educational content into traditional gaming structures without tailoring for specific subjects or learning objectives, this study provided a novel strategy exclusively designed for the acquisition of abstract scientific concepts. The emphasis was on card-based learning, an interactive method that fosters active student engagement. Conventional game-based learning often has a broader focus and incorporates features such as motivational elements, scenario-based learning, immediate feedback, and adaptability without a specific emphasis on abstract scientific concepts. In contrast, as a systematic and organized guide, the NTC learning system promotes a dynamic learning process aimed at enhancing cognitive talents and promoting the brain, fostering creativity and motivation, and enhancing critical thinking skills. The research explored how the NTC learning system generated a natural feeling of competition, encouraged students to seek out extra resources, and converted previously indifferent learners into committed physics lovers.

Research Design

To answer the research question, a pedagogical quasi–experiment with a pretest–posttest non–equivalent control group design was conducted. The experimental (E) and Control (C) groups were constructed from existing classes, and schools were chosen from the same region, to ensure homogeneity in students' living and studying environments. The experimental study was designed to measure students' motivation to learn in terms of abstract physics concepts such as physical quantities and units of measurement. The research was carried out from the beginning of May until the middle of June in 2023.

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

The research design was composed of six stages, summarized in Table 2, and lasted for 6 weeks. The first stage deals with evaluating the prior motivation of students toward learning physics. In stage one, the initial level of motivational factors of all students was assessed by distributing a verified and standardized test for testing motivation in physics to all students. The test assessment was based on a questionnaire originally developed to measure student motivation in all science fields (Tuan et al., 2005), and it has been tuned in a way to accentuate physics. From stage two to stage five, the research was designed such that the experimental group of students played the NTC4 memory card games once a week for 10 minutes at the end of their class. Simultaneously, as the control group did not participate in the card game, students of the C group followed conventional teaching methods. This involved summarizing abstract concepts using SI units, where students solved gaps with missing quantities or units on the whiteboard and participated in the quizzes for recap. After the last intervention, the SMTPL survey was administered once again (stage six), to evaluate and measure the impact of the game on the motivation of students toward learning physics.

Table 2
The Designed Research Stages Adopted in This Study

Group	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
	Week 1/15 min	Week 2/10 min	Week 3/10 min	Week 4/10 min	Week 5/10 min	Week 6/15 min
Experimental	Initial survey	NTC4memory	NTC4memory	NTC4memory	NTC4memory	Final survey
Control	Initial survey	Conventional	Conventional	Conventional	Conventional	Final survey

In this study, the NTC4memory cards were used to promote motivation toward learning abstract symbols and science concepts. The NTC4memory is an educational card game, designed and developed by the NTC learning system team, relying on pedagogical knowledge with cognitive–based learning the science, especially physics at an early stage, and chemistry later. The game resembles a classic memory game, but using the NTC method, the game is designed to activate higher mental levels. Each of the 7 physical quantities has a unit card and two associations to each card. In this way, associative thinking is activated, which is at the core of the NTC program, and (Rajovic et al., 2018) emphasize that the activation of associative regions is the way to develop the ability to think and, therefore, more effective learning. Following the curriculum, the research was designed following the Education Standards guidelines of the country.

Research Sample

The research involved 1371 students from sixth, seventh, and eighth–grade classes and both genders within the North Backa district in Serbia. Among the major schools in the same district and a total number of 1414 students, 43 of them were excluded from the research, and the total number of examined students was 1371 (97% of the initially planned sample approached). The participant flow throughout the experiment is illustrated in (Figure 1).

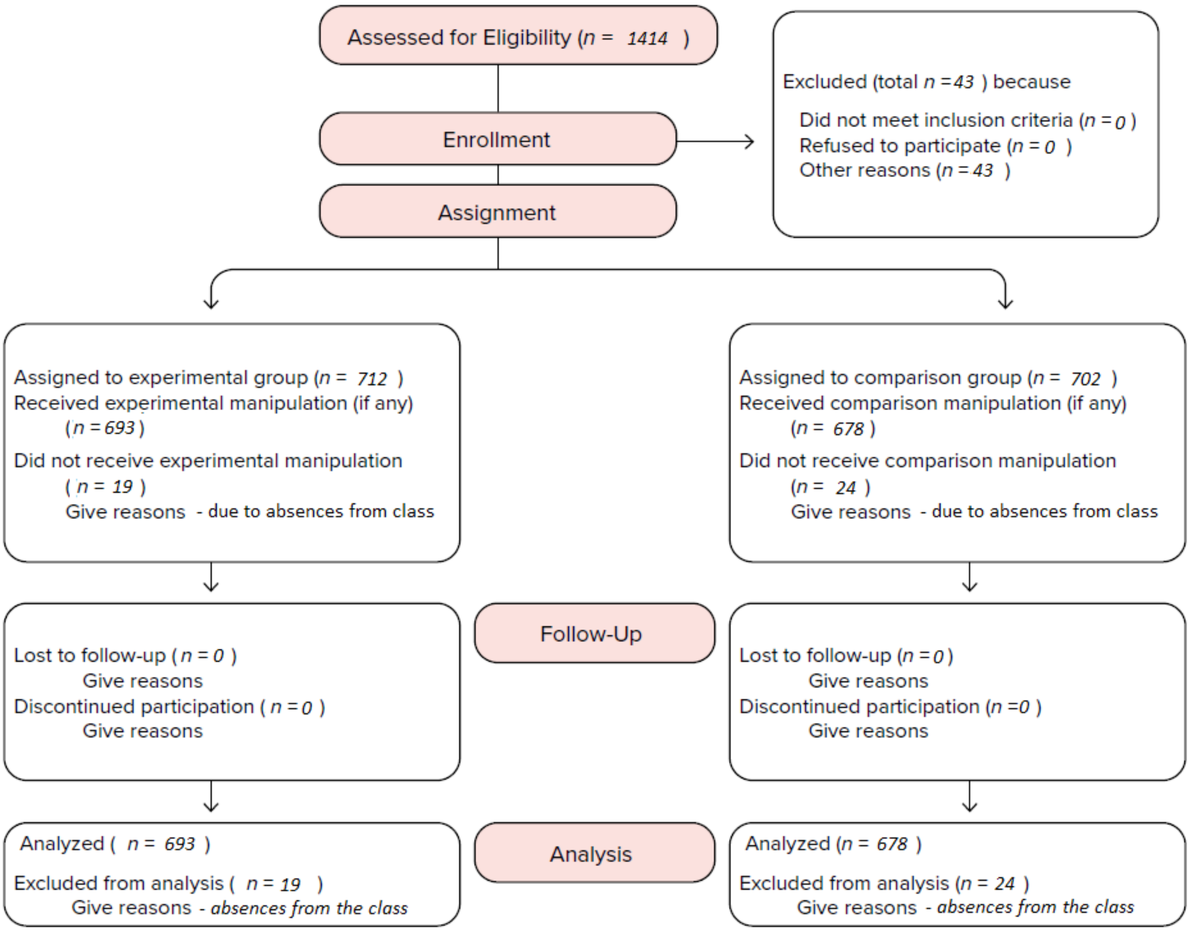
Among them, 693 students (50.5%) were assigned to experimental groups, where they used the NTC4memory card game, while 678 students (49.5%) comprised control groups that used the previously mentioned conventional teaching methods. The participants learned in three different languages (Serbian, Croatian, and Hungarian), but they were similar in terms of their educational background and the same district. The total gender ratio was 48.4% male (663 students), and 51.6% female (708 students). The large and diverse sample size of the study improves the external validity of the results. Sociodemographic characteristics, including language diversity and gender distribution, contribute to the generalizability of the study. The study was conducted in accordance with the Declaration of Helsinki, where all school boards approved the research. The students were informed prior to the research that it was anonymous and that their participation was voluntary, with the option to withdraw at any time.

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 1

The Flow of Participants Through the Experiment



Note: adaptation of the flowchart offered by the CONSORT Group (Schulz et al., 2010)

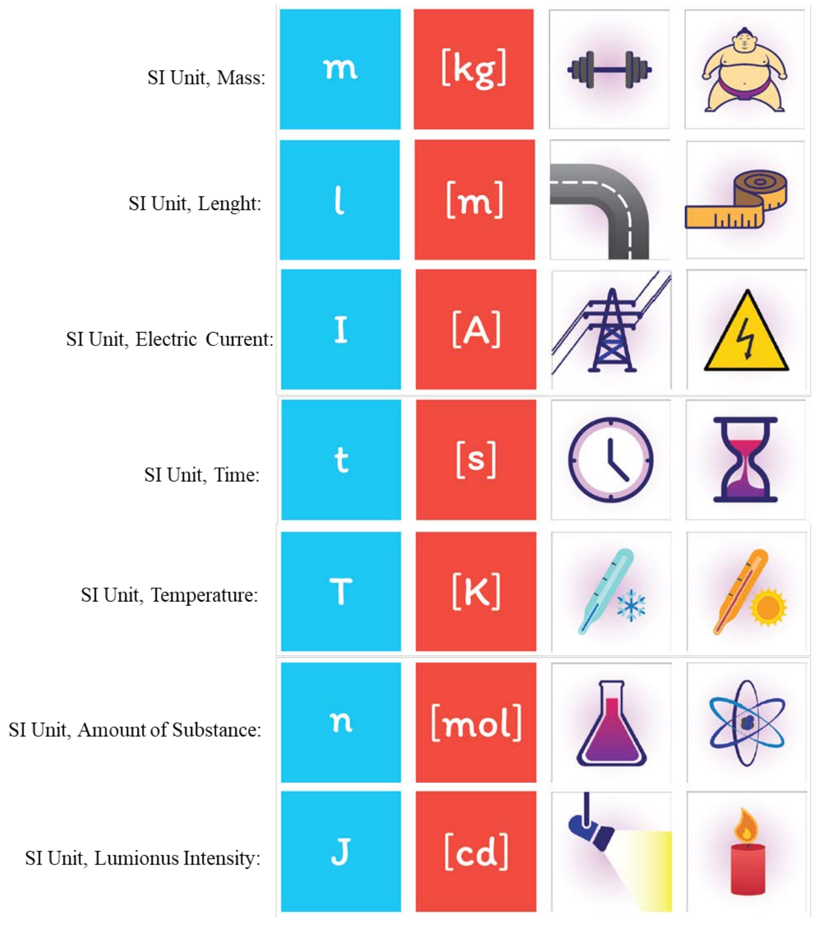
Research Instrument

For this research, the NTC4memory card–based game served as a central research instrument. The game itself is uniquely designed to align with the International System of Units (SI System). It uses universally recognized letters and signs, and it can be played without any language barrier (Figure 2). This not only enhances the inclusivity of the educational approach but also ensures that students, regardless of their primary language, can actively engage with the game's content and foster a collaborative and diverse educational environment. The NTC4memory game engages students with abstract physics concepts, such as physical quantities and units of measurement, making it an ideal tool for assessing motivation.

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 2
The NTC4memory Cards with Quantity Symbol, Unit, and Their Associative Idioms



The questionnaire created by Tuan et al. (2005), has been adopted to extract questions toward learning specifically physics as a subject (SMTPL) (Appendix A). To quantitatively evaluate motivation, it included all 6 motivational factors, and a confirmatory factor analysis (CFA) was conducted to determine the dimensionality of the questionnaire as it was adopted from the original one and translated into the Serbian language. The survey is composed of 35 items related to the already validated six motivational factors. The instrument was designed in the form of a 5-point Likert–type scale where students responded by following a scale of numbers with number 5 corresponding to "strongly agree" and number 1 to "strongly disagree." The reliability of the questionnaire used in the study is presented in Table 3.

Table 3
The Reliability of the Questionnaire

α	Self–efficacy	Active learning strategies	Physics learning value	Achievement goal	Performance goal	Learning environmental stimulation
Pre-test	.818	.874	.837	.804	.837	.766
Post-test	.795	.872	.844	.845	.849	.821

The reliability of the above questionnaire has a threshold value of .70, and all scales were satisfactory. These results indicate that the questionnaire has good psychometric values to validate these research measurements.

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

The Implementation of the Teaching Methods

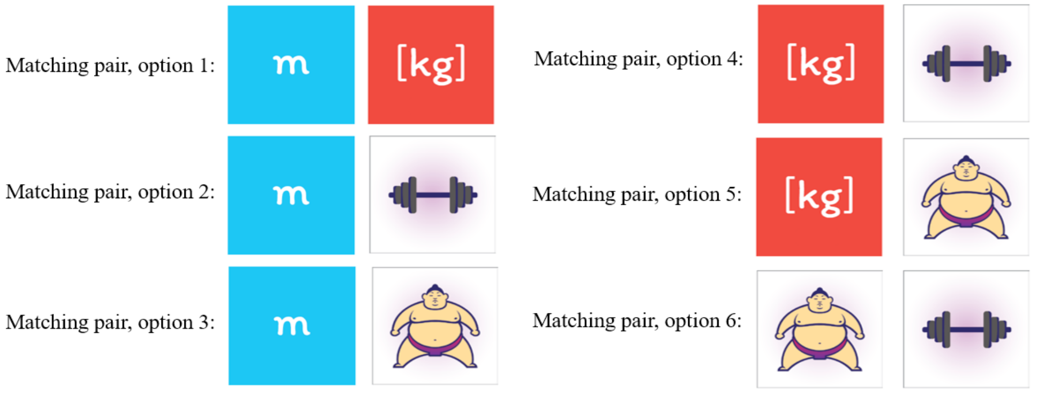
In order to ensure the fidelity of the research for both conditions (E and C groups), each teacher received detailed instructions on how to introduce, facilitate, and debrief the experiment effectively. Teachers were also instructed to follow students' absences and sessions they missed during the research program to accordingly adjust the sample size. Prior to the implementation, copies of the initial motivational test (SMTPL) were distributed to all students for which they had 30–35 minutes. Based on the number of students per class and school, the E and C groups had been chosen randomly so the number of students in both conditions would be similar.

For the E groups, each teacher received the necessary sets with cards of the NTC4memory card game regarding the number of students. In the beginning, teachers emphasized the importance of understanding the SI system in Physics and how the game can enhance their knowledge. Additionally, teachers briefly explained the game rules, similar to ordinary memory games, ensuring that all students understood how to play.

In brief, the game started by pairing two students where each one, in their turn, flipped two cards searching for a matching pair. In a classical memory game, two of the same pictures represent a matching pair. In the game NTC4memory, a matching pair is constituted by two pictures that represent an association for the specific physical SI unit. For example, possible combinations of the matching pairs for mass as one of the SI units could be shown in Figure 3. As there are six possible combinations for one SI unit, and since there are 7 SI units, the total of combinations for creating a matching pair is 42. Once a pair is collected, cards are extracted, and the game continues for the same player until they miss. The game is over when all of the cards are extracted and the player with the most collected cards is the winner.

Figure 3

Possible Matching Pairs for Mass, SI Unit



The aforementioned rule is a crucial difference between NTC4memory card games in contrast to classical memory games. The NTC4memory game involves an association for specific SI units and not two identical pictures. Thus, while playing the NTC4memory game, players stimulate associative regions of the brain in order to solve problems and collect matching pairs. Since associational areas of the brain are involved in higher–order cognitive functions like memory, language, and problem–solving, the hypothesis is that by stimulating them, the NTC4memory game influences its development and consecutively enhances aforementioned functions and skills.

During the above–mentioned experimental stages, teachers reviewed all physical quantities on the board (name, symbol, and unit) at the end of the class (10 min) for students in the C group. Similarly, they highlighted the importance of understanding the SI system in Physics and gave students the option to randomly fill in missing gaps, fully write quantities on the board or in their notebook and participate in quizzes for recapitulation.

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Data Analysis

The validity of the factor analysis was verified by the statistical significance of Bartlett's sphericity test (χ^2 = 19599.938, *p* < .001). Omitting one item from the questionnaire, as it has low satisfaction (item 21: "*I study physics to get a good grade.*"), the principal components analysis established the presence of 6 components similar to the proposed 6 factors. This low factor loading of question 21 has been also reported in (Cavas, 2011; Dermitzaki et al., 2013; Olic et al., 2016), recommending better translation for the question. As the analysis explains 56.32% of the variance, it has been used the Guttman–Kaiser Criterion, which is a predictor of the number of common factors and the direct Oblimin principle. By rotating matrix components, the questionnaire with 34 items, results obtained that the items are grouped as the theoretically expected components. The model of the confirmatory factor analysis (CFA) was accepted, where six factors with the same names as in the original version of the guide were separated.

For the analysis of the data, independent Samples t-tests, chi-square, descriptive statistics, and ANCOVA have been used. In order to determine whether the correlations between six motivational factors are statistically significant, a statistical test, Pearson correlations, has been conducted (Appendix B). To help determine whether a collection of items consistently measures the same characteristic (internal consistency), the questionnaire reliability was tested by Cronbach alpha (*α* = Cronbach Alpha coefficient) in Table 3, by using the statistical data processing program SPSS ver. 24.

Research Results

The results obtained from the initial and final tests reflect the influence of the NTC learning system on students' motivation to learn physics. The observed differences in students' motivation before and after the pedagogical experiment highlight the significant impact of the implemented NTC learning system.

Differences in Motivation at the Initial Measurement

Students' motivation for learning physics was examined with the SMTPL questionnaire before the implementation of the experimental program. Using the *t*–test for large independent samples, it has been examined whether the students of the experimental and control groups differ according to their average values on the motivation subtests, i.e., before implementing the NTC learning program. Levene's Test of equality of variances was also calculated within the *t*-test (Table 4).

Table 4
Students' Motivation for Learning Physics on Initial Testing

Subscales	Group	*N*	*M*	*SD*	Levene test		*t*	*df*	*p*	95% Confidence interval	
					F	*p*				Lower limit	Upper limit
Self–efficacy	E	693	3.14	0.93	0.093	.760	-0.544	1369	.587	-.125	.07081
	C	678	3.16	0.91			-0.544	1368.98	.587	-.125	.07079
Active learning strategy	E	693	3.35	0.96	0.001	.978	-2.283	1369	.023	-.220	-.017
	C	678	3.47	0.97			-2.283	1367.777	.023	-.220	-.017
Physics learning value	E	693	3.25	0.99	0.270	.603	-1.676	1369	.094	-.198	.016
	C	678	3.34	1.02			-1.676	1366.286	.094	-.198	.016
Achievement goal	E	693	2.51	1.18	0.113	.737	0.533	1369	.594	-.091	.159
	C	678	2.47	1.18			0.533	1368.635	.594	-.091	.159
Performance goal	E	693	3.50	1.06	0.080	.778	-1.597	1369	.110	-.204	.021
	C	678	3.59	1.06			-1.597	1368.021	.110	-.204	.021
Learning environmental stimulation	E	693	3.08	0.85	2.548	.111	-2.054	1369	.040	-.193	-.004
	C	678	3.18	0.93			-2.052	1352.577	.040	-.193	-.004

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

The test showed that there are no differences between the groups, for all observed parameters, except for the Active learning strategy, where the $p < .05$ suggested a difference in the observed parameters.

Differences in Motivation at the Final Measurement

After the initial measurement, it was checked whether the experimental and control groups differed in motivation after the applied the experiment (see Table 5). Differences were tested by the *t*-test for large independent samples.

Table 5

Students' Motivation for Learning Physics on the Final Test

Subscales	Group	*N*	*M*	*SD*	Levene test		*t*	*df*	*p*	95% Confidence interval	
					F	*p*				Lower limit	Upper limit
Self–efficacy	E	693	3.40	0.82	12.793	<.001	4.100	1369	<.001	.101	.288
	C	678	3.21	0.93			4.095	1343.560	<.001	.101	.288
Active learning strategy	E	693	3.58	0.81	16.605	<.001	2.178	1369	.030	.010	.197
	C	678	3.48	0.94			2.174	133.535	.030	.010	.197
Physics learning value	E	693	3.50	0.83	2.726	<.001	2.546	1369	.011	.029	.222
	C	678	3.37	0.99			2.542	1321.771	.011	.029	.222
Achievement goal	E	693	2.53	1.18	0.002	.961	.701	1369	.483	-.081	.170
	C	678	2.48	1.18			.701	1368.247	.483	-.081	.170
Performance goal	E	693	3.76	0.89	24.160	<.001	3.139	1369	.002	.062	.267
	C	678	3.59	1.04			3.133	1326.137	.002	.061	.267
Learning environmental stimulation	E	693	3.48	0.77	28.582	<.001	6.332	1369	<.001	.205	.389
	C	678	3.18	0.96			6.316	1293.791	<.001	.205	.389

After the implementation of the NTC learning system, the differences in motivation between the groups were noted on five of the subscales, while on the subscale Achievement goal, there was no statistical difference.

Differences in Motivation after Removing the Effects of the Initial Test

To confirm that the statistical significance between the experimental and control groups on the final test is a consequence of the implemented experiment and not a consequence of the differences between the groups in the basic (initial) motivation for learning physics, it also has been checked the difference with an analysis of covariance (ANCOVA) in Table 6.

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 6
Difference Between E and C Groups after removing the Effect of the Initial Test

Subscales	*Group*	*N*	Type III Sum of Squares	*df*	*MS*	*F*	*p*	η^2
Self–efficacy	E	693	814.462	1	814.462	3132.375	<.001	.696
	C	678	13.274	1	13.274	51.050	<.001	.036
Active learning strategy	E	693	818.117	1	818.117	4591.907	<.001	.770
	C	678	13.513	1	13.513	75.845	<.001	.053
Physics learning value	E	693	82.973	1	82.973	3519.003	<.001	.720
	C	678	13.090	1	13.090	56.107	<.001	.039
Achievement goal	E	693	1338.438	1	1338.438	3154.391	<.001	.698
	C	678	0.092	1	0.092	0.216	.642	<.001
Performance goal	E	693	943.384	1	943.384	3764.550	<.001	.733
	C	678	19.046	1	19.046	76.003	<.001	.053
Learning environmental stimulation	E	693	549.894	1	549.894	156.115	<.001	.533
	C	678	46.087	1	46.087	13.755	<.001	.087

Since the achievement goal had a statistical difference ($p > .05$), this subtest has been excluded, and only the subtests on which a difference was noted were observed.

Changes in the Motivation for Learning Physics

In addition to analyzing the differences between the groups, the aim was also to examine whether there was a change in the motivation to learn physics in two measurements in each group separately. Given that motivation was measured in two–time intervals, the Paired *t*–test was used to test the changes (Table 7).

Table 7
Changes in the Motivation for Learning Physics (Paired t–Tests)

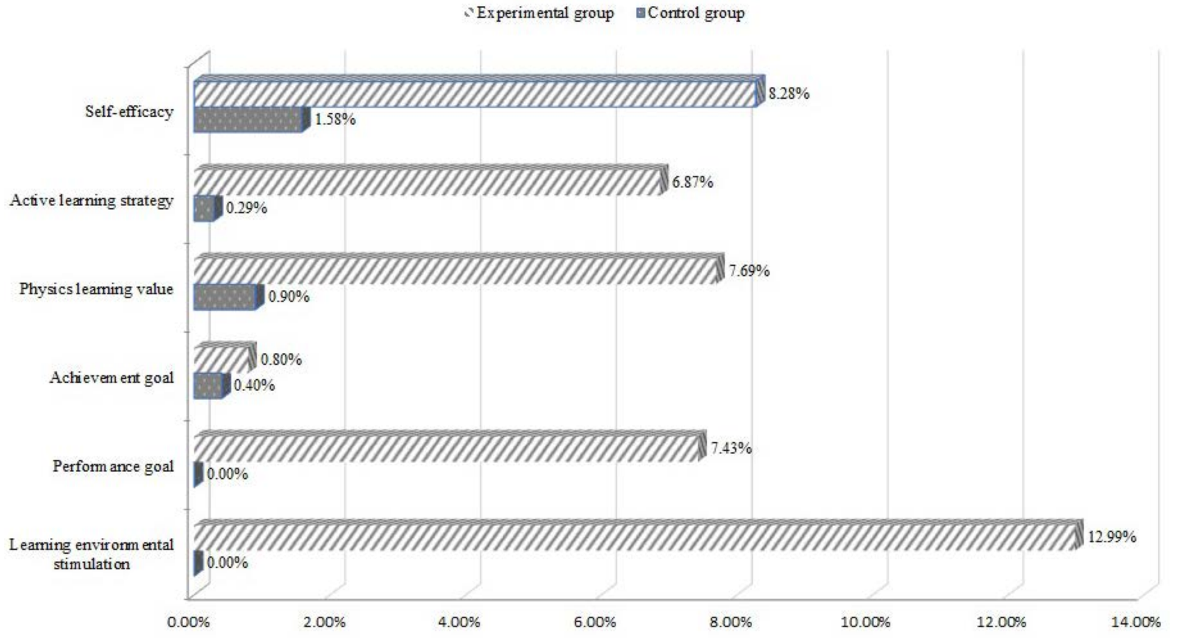
Subscales	Experimental group (N = 693)				Control group (N = 678)			
	M	*SD*	*t*	*p*	*M*	*SD*	*t*	*p*
Self–efficacy. I test	3.14	0.93	12.943	<.001	3.16	0.91	2.203	.028
Self–efficacy. II test	3.40	0.82			3.21	0.93		
Active learning strategy. I test	3.35	0.96	-12.285	<.001	3.47	0.97	-0.674	.501
Active learning strategy. II test	3.58	0.81			3.48	0.94		
Physics learning value. I test	3.25	0.99	-11.699	<.001	3.34	1.02	-1.768	.078
Physics learning value. II test	3.50	0.83			3.37	0.99		
Achievement goal. I test	2.51	1.18	-0.823	.411	2.47	1.18	-0.368	.713
Achievement goal. II test	2.53	1.18			2.48	1.18		
Performance goal. I test	3.50	1.06	-11.469	<.001	3.59	1.06	-0.122	.903
Performance goal. II test	3.76	0.89			3.59	1.04		
Learning environmental stimulation. I test	3.08	0.85	-15.082	<.001	3.18	0.93	-0.174	.862
Learning environmental stimulation. II test	3.48	0.77			3.18	0.96		

Percentage changes in motivational outcomes between the initial and final tests for the experimental and control groups are illustrated in Figure 4.

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 4
Percentage Changes in Motivation



The values of percentage changes in the chart graph represent the difference between the initial and final test scores, expressed as a percentage of the initial test score. Specifically, after comparing the results before and after the motivational test, the percentage changes are significantly changed for the experimental group.

Discussion

The results of this study show that using the NTC4memory educational game can significantly enhance student motivation toward learning, particularly during learning abstract symbols in physics. Additionally, including five learning elements in specifically developed educational card games, such as the NTC4memory game, improves students' motivation toward learning, thereby enabling a more natural cognitive approach to comprehending abstract physics symbols, motivating them to learn physics as a subject.

The results from the initial test suggest that there were no significant differences between the groups (experimental and control); otherwise, any differences in motivation can be described as experimental manipulation rather than pre-existing differences in motivation or other factors. The classic way of teaching, which usually includes a teacher–directed teaching method and employs the frontal method to summarize the key points covered during the class, may lead students to be motivated by a desire to compete with their peers and gain the attention of their teacher, based on the high scores on the Performance goal subscale on initial measurement. This attitude can lead to stress and pressure related to achieving high grades and standing out among their peers. This can also lead to students being afraid of making mistakes and not to have negative attention from the teacher. This highlights the negative impact of conventional teaching methods on students' motivation and self–esteem (Rajovic et al., 2018).

Before applying the pedagogical experiment, it was told to both student groups that these abstract symbols wouldn't directly contribute to their grades in physics subject, so this might be the reason for the low score on the achievement goal subscale. This de–prioritization of achievement related to goals aligns with goal theories, where motivation is related to earning high grades and receiving praise (Ames & Archer, 1988). As conventional teaching methods mainly focus on memorization and recall, they may not inherently foster intrinsic motivation for academic achievement, leading students to perceive these activities as imposed rather than personally meaningful.

The initial measurements showed differences in motivation between the groups on two subscales: active learning strategy and learning environment stimulation. The differences were statistically significant, and the control group had higher average scores on both, and this initially underscored the importance of delving into

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

the analysis of, a mostly omitted motivational factor, learning environmental stimulation. No other statistically significant differences were noted on other subscales.

The results of post–test motivation showed that the NTC4memory game had a positive impact on the motivation of students toward learning physics. This outcome effectively addresses the research question posed in the study. The results are further examined using statistical tests, including the Pearson correlation test, to determine the significance of the correlations between the six motivational factors, providing additional evidence of the impact of the NTC4memory card game on students' motivation toward learning physics [Supplementary material – Appendix B].

The results suggested that there are significant relationships between the motivational factors before and after the final test, where the experimental group was more motivated by self–efficacy, active learning strategy, physics learning value, performance goal, and learning environmental stimulation, except only one factor, achievement goal, which had small positive, but not significant result. The observed positive impact of the NTC4memory card game on the results aligns with the previous research on education games, where our results in self–efficacy resonate with results reported by (Huang et al., 2012), which indicate a substantial improvement in students' confidence and motivation toward learning physics. Enhancing memory recall through classification, serialization, analogies, association, and abstraction, played an essential role in achieving these positive outcomes. Likewise, (Liu & Chen, 2013) used their designed card game to promote game–based learning and succeeded in stimulating students' motivation. This is in line with outcomes related to learning environmental stimulation as they increase learning effectiveness and their interest in scientific knowledge among students. The study by Aisah (2016) on the effect of fun teaching methods, particularly using flashcards, aligns with the motivational factors of active learning strategy and learning environmental stimulation, as they led to a positive response and increased motivation among students. Significant results gained in motivational factor (learning environmental stimulation), support previous motivational studies and the importance of supporting learning environment created for students, indicating that a well–designed, stimulating environment enhances engagement and creates a more gratifying learning experience (Brophy, 1988; Csikszentmihalyi & Schneider, 2000).

The positive and interactive learning environment, obtained as the result of active learning strategies and physics learning values, contributes to fostering student motivation. This observation aligns with the findings of (Haris et al., 2018), who introduced a card game that facilitates understanding and memory recall of basic physics concepts. Their results promote discussion, encourage student interaction, and assess the playability, playfulness, and usefulness of the game, elements that are at the core of active learning strategies and physics learning values. In addition to the concept of active learning strategy, Dogani (2023) emphasized engagement, interest, and motivation, which contribute to better memorization and improved academic performance. Additionally, the implementation of a similar approach using activity cards in a chemistry class, as reported by Duvarc (2010), resulted in improved retention of concepts, increased student interactions, and enhanced cognitive and collaborative engagement. This suggests that the incorporation of memory–enhancing strategies, such as those found in card games, contributes positively to students' performance goals, providing further support for the effectiveness of the NTC4memory game in our study. It is worth noting that there is a lack of the use of measurable and valid instruments to specifically measure motivation using card–based games, as they mostly focus on general motivational outcomes.

The results undoubtedly show that the NTC4memory games can offer many benefits to learners, provoking many motivational factors toward learning physics. The major advantage of the game is its ability to help with memory recall by incorporating main learning elements such as classification, serialization, analogies, association, and abstraction (Rajovic, 2012a; Rajovic et al., 2018). By playing the game specifically designed for SI system knowledge acquisition, students quickly become familiarized with concepts and relationships between various symbols and quantities, which otherwise could take longer through teacher–directed teaching method in physics classes, in which teachers are active and students are passive. It is worth mentioning, according to the data presented in Table 7 and percentage changes in Figure 4, that the change in motivation within the same control group, between the two conducted measurements, is insignificant. This indicates that the teacher–directed, or classical, teaching method did not tackle the motivation of students. Nevertheless, an improvement in the level of self–efficiency has been noted when comparing the final to the first measurement and, this is an expected outcome as students become more aware of the task during the learning process. This positive result could be interpreted through the self–awareness of students of the task due to the learning period, while the opposite result was recorded in recent research (Blajvaz et al., 2022) noting that the reason may be conventional teaching methods or this difference in the result can also be hidden in the small number of evaluated students.

The differences between the experimental and control groups are a consequence of the experimental program

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

and not a consequence of the differences between the groups in the initial motivation for learning physics (Table 6). The chart graph was created as a result of percentage changes in motivation between initial and final tests. The chart bars in the graph show the percentage changes between the experimental and control groups before and after the implemented experiment, where the experimental group deviates statistically significantly from the control group in all scales except for the achievement goal subscale. The results are very important because they indicate that such a teaching environment has been created that favors children and is pleasant to them, which is an important factor for more successful learning, and developing cognitive skills, communication, and creativity. For the rest motivational factors, the control group didn't show significant percentage changes. Similarly, the experimental group did not show significant changes in the achievement goal motivational factor.

Finally, some limitations should be acknowledged in the study. As one question has been omitted from the analysis, it suggests that questions in this particular factor should be revised. Instead of randomly selecting students, the researchers used pre–formed classes for E and C groups, which introduces a potential source of bias. Also, the inclusion of students from all grades, as opposed to focusing only on sixth graders who are exposed to physics for the first time, may contribute to variability in prior exposure and familiarity with the subject matter.

It's important to note that when the teacher questioned students about their memory retention while playing the NTC4memory game, they observed the following pattern: When asked to recall SI units, their symbols, and their associations, students consistently began the recall process by relying on associations. For instance, if they were asked to remember the unit for temperature, students often responded with something like, "Temperature, thermometer... Oh, it's Kelvin, K!" This highlights the idea that the brain naturally tends to use associative thinking when remembering, and in this mode of operation, it requires less effort and is more effective, especially during gameplay.

Overall, the NTC learning system and its specifically designed NTC4memory educational game, have a significant effect on students' motivation toward learning physics.

Conclusions and Implications

The study aimed to examine the impact of the NTC4memory educational card game on the motivation of students toward learning physics, where the results showed a positive effect on their motivation, in favor of the experimental group. The games' interactive and enjoyable nature made the learning process more engaging and activated students, making them motivated for learning. The NTC4memory game also improves cognitive skills such as speed of thinking, attention, creativity, teamwork, and it can identify gifted students. Incorporating the NTC4memory game in the classroom delivers learning in a cognitively acceptable way that reduces passive boredom, resulting in higher motivation toward learning physics.

Nevertheless, the results indicated that the conventionally established teaching tactics did not have a direct influence on the motivation of students yet, it affects positively their self–efficiency. The results attest to the fact that the NTC teaching method does motivate students, which is crucial for learning and absorbing abstract physical symbols and quantities. As the achievement goal subscale in the analysis was omitted due to low factor loading, future research should revise and tighten the questions to obtain better results and include all derived physical quantities relevant to the specific grade level. This research underscores the need for future study endeavors, emphasizing the importance of refining the motivational questionnaire and evaluating the actual outcomes achieved by children through playing the game. This dedication to continuous development in educational strategies remains at the center of our objectives.

Acknowledgements

The authors gratefully acknowledge the financial support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451–03–47/2023–01/200125).

Ethical considerations – Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by Director of the Department of Physics, Faculty of Sciences, University of Novi Sad (protocol code 0601–117/23–2–2; date of approval 11 April 2023). The students were voluntarily participating in the research, and informed consent to participate in the research was obtained from each participant.

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Funding

This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia under Grant No. 451–03–47/2023–01/200125.

Declaration of Interest

The authors declare no competing interest.

References

Aisah, I. (2016). Effect of fun teaching methods using flash card on motivation and learning mathematics. *ITEJ (Information Technology Engineering Journals), 1*(1), 59–70. https://doi.org/10.24235/itej.v1i1.5

Ames, C. A., & Archer, J. (1988). Achievement goals in the classroom: Students' learning strategies and motivation processes. *Journal of Educational Psychology, 80*, 260–267. https://doi.org/10.1037/0022-0663.80.3.260

Archer, L., Moote, J., & MacLeod, E. (2020). Learning that physics is 'not for me': Pedagogic work and the cultivation of habitus among advanced level physics students. *Journal of the Learning Sciences, 29*, 347–384. https://doi.org/10.1080/10508406.2019.1707679

Ataíde, A. R., & Greca, A. R. (2013). Epistemic views of the relationship between physics and mathematics: its influence on the approach of undergraduate students to problem solving. *Science & Education, 22*(6), 1405–1421. https://doi.org/10.1007/S11191-012-9492-2

Baek, Y., Xu, Y., Han, S., & Cho, J. (2015). Exploring the effects of intrinsic motivation and prior knowledge on student achievements in game–based learning. *Smart Computer Review, 5*, 368–377. https://doi.org/10.6029/smartcr.2015.05.001

Baines, L. A., & Slutsky, R. (2009). Developing the sixth sense: Play. *Educational Horizons, 87*(2), 97–101.

Bandura, A. (2010). Self–efficacy. In I.B. Weiner and W.E. Craighead (Eds), *The Corsini Encyclopedia of Psychology* (pp. 1–3). Wiley. https://doi.org/10.1002/9780470479216.corpsy0836

Blajvaz, B. K., Bogdanovic, I. Z., Jovanovic, T. S., Stanisavljevic, J. D., & Pavkov–Hrvojevic, M. V. (2022). The jigsaw technique in lower secondary physics education: Students' achievement, metacognition, and motivation. *Journal of Baltic Science Education, 21*(4), 545–557. https://doi.org/10.33225/jbse/22.21.545

Blakely, G., Skirton, H., Cooper, S., Allum, P., & Nelmes, P. (2009). Educational gaming in the health sciences: systematic review. *Journal of Advanced Nursing*, *65*(2), 259–269. https://doi.org//10.1111/j.1365-2648.2008.04843.x

Brophy, J. (1988). Educating teachers about managing classrooms and student. *Teaching & Teacher Education, 4*(1), 1–18. https://doi.org/10.1016/0742-051X(88)90020-0

Brown, S., & Vaughan, C. (2009). *Play: How it shapes the brain, opens the imagination, and invigorates the soul*. Penguin.

Byusa, E., Kampire, E., & Mwesigye, A. R. (2022). Game–based learning approach on students' motivation and understanding of chemistry concepts: A systematic review of literature. *Heliyon, 8*(5), Article e09541. https://doi.org/10.1016/j.heliyon.2022.e09541

Cavallo, A. M., Potter, W. H., & Rozman, M. (2004). Gender differences in learning constructs, shifts in learning. *School science and mathematics, 104*(6), 288–300. https://doi.org/10.1111/j.1949-8594.2004.tb18000.x

Cavas, P. (2011). Factors affecting the motivation of Turkish primary students for science. *Science Education International, 22*(1), 31–42.

Chen, M.–P., Wong, Y.–T., & Wang, L.–C. (2014). Effects of type of exploratory strategy and prior knowledge on middle school students' learning of chemical formulas from a 3D role–playing game. *Educational Technology Research and Development, 62*, 163–185. https://doi.org/10.1007/s11423-013-9324-3

Chen, S., Tsai, J., Liu, S., & Chang, C. (2021). The effect of a scientific board game on improving creative problem solving skills. *Thinking Skills and Creativity, 41*(5), Article 100921. https://doi.org/10.1016/j.tsc.2021.100921

Chung, T.–S. (2013). Table–top role playing game and creativity. *Thinking Skills and Creativity, 8*, 56–71. https://doi.org/10.1016/j.tsc.2012.06.002

Clark, D. B., Tanner–Smith, E., Hostetler, A., Fradkin, A., & Polikov, V. (2017). Substantial integration of typical educational games into extended curricula. *Journal of the Learning Sciences*, *23* (2), 837–850. https://doi.org/10.1080%2F10508406.2017.1333431

Cools, R. (2008). Role of dopamine in the motivational and cognitive control of behavior. *The Neuroscientist, 14*(4), 381–395. https://doi.org/10.1177/1073858408317009

Cools, R., & D'Esposito, M. (2011). Inverted–U–shaped dopamine actions on human working memory and cognitive control. *Biological Psychiatry, 69*(12), e113–e125. https://doi.org/10.1016/j.biopsych.2011.03.028

Csikszentmihalyi, M., & Schneider, B. (2000). *Becoming adult: How teenagers prepare for the world of work.* Basic Books.

Dermitzaki, I., Stavroussi, P., Vavougios, D., & Kotsis, K. T. (2013). Adaptation of the students' motivation towards science learning (SMTSL) questionnaire in the Greek language. *European Journal of Psychology of Education, 28*(3), 747–66. https://doi.org/10.1007/s10212-012-0138-1

Dogani, B. (2023). Active learning and effective teaching strategies. *International Journal of Advanced Natural Sciences and Engineering Researches, 7*(4), 136–142. https://doi.org/10.59287/ijanser.2023.7.4.578

Duvarci, D. (2010). Activity–based chemistry teaching: A case of "elements and compounds". *Procedia – Social and Behavioral Sciences, 2*(2), 2506–2509. https://doi.org/10.1016/j.sbspro.2010.03.362

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109–132. https://doi.org/10.1146/annurev.psych.53.100901.135153

Franco–Mariscal, A. J., Oliva–Martínez, J., & España–Ramos, E. (2016). A game–based approach to learning the idea of chemical elements and their periodic classification. *Journal of Chemical Education, 7*, 1173–1190. https://doi.org/10.1021/acs.jchemed.5b00846

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America, 111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Gallagher, D., & Grimm, L. R. (2018). Making an impact: the effects of game making on creativity and spatial processing. *Thinking Skills and Creativity, 28*, 138–149. https://doi.org/10.1016/j.tsc.2018.05.001

Girgin, d., & Akgün, N. R. (2020). A case study: activity–based learning process prepared by ntc's (nikola tesla center) system of learning approach. *International Journal of Progressive Education, 16*(4), 229–247. https://doi.org/10.29329/ijpe.2020.268.15

Göksün, D. O., & Gürsoy, G. (2019). Comparing success and engagement in gamified learning experiences via Kahoot and Quizizz. *Computers & Education, 135*, 15–29. https://doi.org/10.1016/j.compedu.2019.02.015

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

Haris, N. I., Talip, A., Yusra, A. Z., Zahidah, M. N., Rakeish, K. P., Nasuha, M. N., & Vikneswaran, P. (2018). MechE: The design and evaluation of augmented reality card game for physics. *AIP Conf. Proc.* 9 November 2018; 2030 (1), 020021. https://doi.org/10.1063/1.5066662

Höft, L., & Bernholt, S. (2019). Longitudinal couplings between interest and conceptual understanding in secondary school chemistry: An activity–based perspective. *International Journal of Science Education, 41*(5), 607–627. https://doi.org/10.1080/09500693.2019.1571650

Huang, C. W., Liu, E. Z., Liu, L. C., & Lin, C. H. (2012). A development and evaluation of educational board game design course: An example of pre–service teacher. *2012 IEEE Fourth International Conference On Digital Game And Intelligent Toy Enhanced Learning*, 99-101. https://doi.org/10.1109/DIGITEL.2012.25

Kirikkaya, E. B., Işeri, Ş., & Vurkaya, G. (2010). A board game about space and solar system for primary school students. *The Turkish Online Journal of Educational Technology, 9*(2), 1–13. https://doi.org/10.17244/eku.982955

Kizilgunes, B., Tekkaya, C., & Sungur, S. (2010). Modeling the relations among students' epistemological beliefs, motivation, learning approach, and achievement. *The Journal of Educational Research, 102*(4), 243–256. https://doi.org/https://doi.org/10.3200/JOER.102.4.243-256

Korsunsky, B. (2010). Improper use of physics-related context in high school mathematics problems: Implications for learning and teaching. *School Science and Mathematics, 102*(3), 107–113. https://doi.org/10.1111/j.1949-8594.2002.tb17904.x

Lhardy, C., García–Ortega, H., Gracia–Mora, J., Marín–Becerra, A., Reina, A., & Reina, M. (2022). Unit Kemps: A matching card game to learn physical quantities, units, and symbols. *Journal of Chemical Education, 99*, 3170–3176. https://doi.org/10.1021/acs.jchemed.2c00482

Lisman, J. E., & Grace, A. (2005). The hippocampal–VTA Loop: Controlling the entry of information into long–term memory. *Neuron, 46*(5), 703–713. https://doi.org/10.1016/j.neuron.2005.05.002

Liu, E. Z., & Chen, P.–K. (2013). The effect of game-based learning on students' learning performance in science learning–A case of "conveyance go". *Procedia-Social and Behavioral Sciences, 103*, 1044-1051. https://doi.org/10.1016/j.sbspro.2013.10.430

Mayer, R. E. (2014). Richard E. Mayer. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 43–71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005

Md Rashid, S. N., Baha, A., & Abidin, D. (2021). Students' perception on learning unit conversion through a smart conversion card tool. In *Proceedings of the International Conference on Applied Science and Technology on Social Science (ICAST-SS 2020)* (pp. 448-451). Atlantis Press. https://doi.org/10.2991/assehr.k.210424.087

Moğol, S., Özçiftçi, S. (2003). Fizikte Bazı Denklemlerin Öğretimi İçin Kart Oyunu [Card game for teaching some equations in physics]. *Milli Eğitim Dergisi, 157*. https://dhgm.meb.gov.tr/yayimlar/dergiler/Milli_Egitim_Dergisi/157/mogol.htm

Muniwastia, I., Muniwastia, Y. F., Fitria, Y., & Ardipal, A. (2018). Improving elementary school motivation in learning science. In I. Ifdil, & Z. Ardi (Eds.), *Education, social sciences and technology application in digital era* (pp. 985 - 992). Fakultas Ilmu Pendidikan UNP. https://doi.org/10.29210/20181142

Novak, J. D. (1988). Learning science and the science of learning. *Studies in Science Education, 15*(1), 77–101. https://doi.org/10.1080/03057268808559949

OECD (2019), *PISA 2018 Results (Volume I): What Students Know and Can Do*, PISA, OECD Publishing, https://doi.org/10.1787/5f07c754-en

Olic, S., Ninković, S., & Adamov, J. (2016). Adaptation and empirical evaluation of the questionnaire on students' motivation towards science learning. *Psihologija, 49*(1), 51–66. https://doi.org/0.2298/PSI1601051O

Palmer, D. (2005). A motivational view of constructivist-informed teaching. *International Journal of Science Education, 25*(15), 1853–1881. https://doi.org/10.1080/09500690500339654

Partovi, T., & Razavi, M. R. (2019). The effect of game–based learning on academic achievement motivation of elementary school students. *Learning and Motivation, 68*, Article 101592. https://doi.org/10.1016/j.lmot.2019.101592

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1991). *A manual for the use of the motivated strategies for learning questionnaire (MSLQ)*. The University of Michigan. https://eric.ed.gov/?id=ED338122

Prensky, M. (2001). *Digital game–based learning.* McGraw–Hill.

Prince, M. (2013). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Radulovic, B., Dorocki, M., Ninkovic, S. O., Stojanović, M., & Adamov, J. (2023). The effects of blended learning approach on student motivation for learning physics. *Journal of Baltic Science Education*, *22*(1), 73–82. https://doi.org/10.33225/jbse/23.22.73

Radulovic, B., Zupanec, V., Stojanović, M., & Budic, S. (2022). Gender motivational gap and contribution of different teaching approaches to female students' motivation to learn physics. *Scientific Reports, 12*, 9. https://doi.org/10.1038/s41598-022-23151-7

Rajović, R. (2012a). *Kako uspešno razvijati IQ deteta kroz igru* [How to successfully develop your child's IQ through play]. Smart production.

Rajovic, R. (2012b). *NTC sistem ucenja – metodicki prirucnik za primenu programa.* [The NTC System of Learning – Methodological guide for implementing the program]. Smart Production.

Rajovic, R. (2012c). *NTC sistem ucenja: Metodicki prirucnik za ucitelje Ucenje je igra.* [NTC system of learning: Methodological guide for teachers. Learning is a game]. Ministarstvo prosvjete i kulture Republike Srpske.

Rajovic, R. (2016). *Kako uspešno razvijati IQ deteta kroz igru – NTC sistem učenja.* [How to successfully develop your child's IQ through play – the NTC System of Learning*]*. Smart Production.

Rajovic, R., Debeljuh, A., & Baf, M. R. (2018). NTC learning system and ICT for kids' analysis of a contemporary innovative learning methodology. *TEM Journal (Technology, Education, Management, Informatics), 7*(4), 886–891. https://doi.org/10.18421/TEM74-29

Rajovic, R., Rakic, J. D., Rajovic, V., & Rajovic, I. (2020). Popularity of school subjects among older elementary school student. *13th annual International Conference of Education, Research and Innovation* (pp. 8830–8840). ICERI2020 Proceedings. https://doi.org/10.21125/iceri.2020.1957

Ratey, J. J. (2008). *Spark: the revolutionary new science of exercise and the brain.* Little Brown.

Rieber, L. P., & Noah, D. (2008). Games, simulations, and visual metaphors in education: Antagonism between enjoyment and learning. *Educational Media International, 45*(2), 77–92. https://doi.org/10.1080/09523980802107096

Romine, X. (2004). Using games in the classroom to enhance motivation, participation, and retention: A pre–test and post–test evaluation. In Bothman, A. (Ed.), *Culminating Experience Action Research Projects, 5*, 286–289. https://files.eric.ed.gov/fulltext/ED490030.pdf

Schultz, W. (1998). Predictive reward signal of dopamine neurons. *Journal of Neurophysiology, 80*(1), 1–27. https://doi.org/10.1152/jn.1998.80.1.1

Schulz, K. F., Altman, D. G., Moher, D., & Group, T. C. (2010). CONSORT 2010 Statement: Updated guidelines for reporting parallel group randomised trials. *BMC Medicine, 8*(18), 1741–7015. https://doi.org/10.1186/1741-7015-8-18

Steinkuehler, C., & Duncan, S. (2008). Scientific habits of mind in virtual worlds. *Journal of Science Education and Technology, 17*(6), 530–543. https://doi.org/10.1007/s10956-008-9120-8

Tobias, S. E., & Fletcher, J. D. (2011). *Computer games and instruction.* Charlotte.

Tuan, H.-L., Chin, C.-C., & Shieh, S.-H. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International Journal of Science Education, 27*(6), 639–654. https://doi.org/10.1080/0950069042000323737

Wise, R. A. (2004). Dopamine, learning and motivation. *Nature Reviews. Neuroscience*. https://doi.org/10.1038/nrn1406

Wolters, C. A. (2003). Understanding procrastination from a self–regulated learning perspective. *Journal of Educational Psychology, 95*(1), 179–187. https://doi.org/10.1037/0022-0663.95.1.179

Yildiz, İ., Topçu, E., & Kaymakci, S. (2021). The effect of gamification on motivation in the education of pre–service social studies teachers. *Thinking Skills and Creativity, 42*(21). https://doi.org/10.1016/j.tsc.2021.100907

Zhang, L., & Shang, J. (2015). How video games enhance learning: A discussion of James Paul Gee's views in his book what video games have to teach us about learning and literacy. *International Conference on Hybrid Learning and Continuing Education.* https://doi.org/10.1007/978-3-319-20621-9_34

Zimmerman, B. J. (2000). Self–efficacy: An essential motive to learn. *Contemporary Educational Psychology, 25*, 82–91. https://doi.org/10.1006/ceps.1999.1016

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Appendix A: The SMTLP questionnaire (The students' motivation toward learning physics)

Number of items	Questions	I don't agree at all	I mostly disagree	I'm not sure	I mostly agree	I totally agree
	1. Self–efficacy					
1.	Regardless of whether the physics material is difficult or easy, I am sure that I will understand it.	1	2	3	4	5
2.	I can understand difficult physics concepts.	1	2	3	4	5
3.	I am sure that I can get a good grade on the physics test.	1	2	3	4	5
4.	No matter how hard I try, I can't learn physics material. (R)	1	2	3	4	5
5.	When physics tasks are too difficult, I often give up or do only the easier parts. (R)	1	2	3	4	5
6.	While learning physics, I prefer to ask for answers from others rather than think for myself. (R)	1	2	3	4	5
7.	If I find a physics subject difficult, I don't try to learn it. (R)	1	2	3	4	5
	2. Active learning strategy					
8.	When I learn new concepts in physics, I try to understand them.	1	2	3	4	5
9.	When I learn new concepts in physics, I connect them with previous knowledge and experience.	1	2	3	4	5
10.	When I don't understand a physical term, I use other sources (additional literature, internet).	1	2	3	4	5
11.	When the material in physics is unclear to me, I try to understand it through a conversation with the teacher or other students.	1	2	3	4	5
12.	When studying, I try to connect different parts of the material.	1	2	3	4	5
13.	When I make a mistake, I try to understand where I went wrong.	1	2	3	4	5
14.	Even if I don't understand the physics material, I will still try to learn it.	1	2	3	4	5
15.	When new physics material I'm learning doesn't agree with my previous knowledge, I try to understand why.	1	2	3	4	5
	3. Physics learning value					
16.	I think that learning physics is important because it can be useful in my everyday life.	1	2	3	4	5
17.	I think studying physics is important because it makes me think.	1	2	3	4	5
18.	I think that in physics it is important to learn how to solve problems.	1	2	3	4	5
19.	I think it is important to participate in research activities in physics.	1	2	3	4	5

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Number of items	Questions	I don't agree at all	I mostly disagree	I'm not sure	I mostly agree	I totally agree
20.	It is important for me to satisfy my curiosity in learning physics.	1	2	3	4	5
	4. Achievement goal					
21.	I study physics to get a good grade. (R)	1	2	3	4	5
22.	I study physics with the aim of being better than other students. (R)	1	2	3	4	5
23.	I study physics so that other students think I'm smart. (R)	1	2	3	4	5
24.	I study physics so that the teacher will pay attention to me. (R)	1	2	3	4	5
	5. Performance goal					
25.	I feel satisfaction when I get a good result on a control task in physics.	1	2	3	4	5
26.	I feel satisfaction when I am confident in my knowledge.	1	2	3	4	5
27.	I feel satisfaction when I can solve a difficult problem in physics.	1	2	3	4	5
28.	I feel satisfaction when my physics teacher accepts my ideas.	1	2	3	4	5
29.	I feel satisfaction when students accept my ideas.	1	2	3	4	5
	6. Learning environmental stimulation					
30.	I am active in physics classes because the teacher uses different teaching methods.	1	2	3	4	5
31.	I am active in physics classes because the teacher does not put any pressure on me.	1	2	3	4	5
32.	I am active in physics classes because the teacher pays attention to me.	1	2	3	4	5
33.	I am active in physics classes because other students also participate in discussions.	1	2	3	4	5
34.	I am active in physics classes because the content is interesting, and we always learn something new.	1	2	3	4	5
35.	I am active in physics classes because the classes are very interesting.	1	2	3	4	5

R – Questions marked with (R) are reversed analyzed

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

Appendix B: Correlation between six measures of motivation

		Students' motivation for learning physics on initial testing						Students' motivation for learning physics on the final test					
		1	2	3	4	5	6	1	2	3	4	5	6
E group	1	1	.541**	.483**	.095*	.455**	.384**	.819**	.500**	.413**	.097*	.430**	.334**
	2	.541**	1	.632**	.165**	.508**	.451**	.499**	.853**	.581**	.147**	.433**	.383**
	3	.483**	.632**	1	.195**	.541**	.494**	.434**	.562**	.823**	.213**	.468**	.378**
	4	.095*	.165**	.195**	1	.158**	.195**	.029	.149**	.185**	.843**	.133**	.241**
	5	.455**	.508**	.541**	.158**	1	.502**	.387**	.456**	.494**	.135**	.829**	.293**
	6	.384**	.451**	.494**	.195**	.502**	1	.363**	.406**	.480**	.192**	.429**	.632**
	1	.819**	.499**	.434**	.029	.387**	.363**	1	.484**	.404**	.043	.382**	.329**
	2	.500**	.853**	.562**	.149**	.456**	.406**	.484**	1	.570**	.142**	.426**	.409**
	3	.413**	.581**	.823**	.185**	.494**	.480**	.404**	.570**	1	.203**	.473**	.384**
	4	.097*	.147**	.213**	.843**	.135**	.192**	.043	.142**	.203**	1	.143**	.247**
	5	.430**	.433**	.468**	.133**	.829**	.429**	.382**	.426**	.473**	.143**	1	.311**
	6	.334**	.383**	.378**	.241**	.293**	.632**	.329**	.409**	.384**	.247**	.311**	1
C group	1	1	.553**	.512**	.066	.543**	.429**	.852**	.568**	.534**	.069	.515**	.454**
	2	.553**	1	.597**	.069	.560**	.493**	.511**	.903**	.591**	.077*	.529**	.512**
	3	.512**	.597**	1	.137**	.580**	.582**	.465**	.587**	.874**	.116**	.503**	.514**
	4	.066	.069	.137**	1	.102**	.227**	.061	.070	.141**	.827**	.065	.213**
	5	.543**	.560**	.580**	.102**	1	.492**	.511**	.559**	.568**	.077*	.885**	.476**
	6	.429**	.493**	.582**	.227**	.492**	1	.383**	.487**	.571**	.198**	.447**	.806**
	1	.852**	.511**	.465**	.061	.511**	.383**	1	.548**	.511**	.076*	.516**	.435**
	2	.568**	.903**	.587**	.070	.559**	.487**	.548**	1	.590**	.083*	.534**	.511**
	3	.534**	.591**	.874**	.141**	.568**	.571**	.511**	.590**	1	.139**	.539**	.558**
	4	.069	.077*	.116**	.827**	.077*	.198**	.076*	.083*	.139**	1	.073	.196**
	5	.515**	.529**	.503**	.065	.885**	.447**	.516**	.534**	.539**	.073	1	.474**
	6	.454**	.512**	.514**	.213**	.476**	.806**	.435**	.511**	.558**	.196**	.474**	1

1= Self–efficacy, 2= Active learning strategies, 3= Physics learning value, 4= Achievement goal, 5= Performance goal, 6= Learning environmental stimulation.

Pearson Correlation are shown.
**. Correlation is significant at the .01 level (2–tailed).
*. Correlation is significant at the .05 level (2–tailed).

https://doi.org/10.33225/jbse/24.23.331

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Received: *December 31, 2023* Revised: *February 13, 2024* Accepted: *April 04, 2024*

Cite as: Lazarevic, B., Stojanovic, M., Pisarov, J., & Bojanic, N. (2024). Evaluating the impacts of NTC learning system on the motivation of students in learning physics concepts using card–based learning approaches. *Journal of Baltic Science Education*, *23*(2), 331–351. https://doi.org/10.33225/jbse/24.23.331

Bojan Lazarevic
(Corresponding author)
Senior Physics Laboratory Instructor, College of Engineering and Technology, American University of the Middle East, Egaila 54200, Kuwait.
E-mail: bojan.lazarevic@aum.edu.kw
ORCID: https://orcid.org/0000-0002-3844-3523

Maja Stojanovic
Professor, Department of Physics, Faculty of Sciences, University of Novi Sad, Republic of Serbia.
E-mail: maja.stojanovic@df.uns.ac.rs
ORCID: https://orcid.org/0000-0002-0440-9677

Jelena Pisarov
PhD Student, Teacher of Physics and IT in Nikola Tesla, Primary and High School, Budapest, Hungary.
E-mail: jelena.pisarov@gmail.com
ORCID: https://orcid.org/0000-0003-2757-9780

Nemanja Bojanic
PhD, Assistant Professor, Faculty of Technology, University of Novi Sad, Republic of Serbia.
E-mail: bojanic.nemanja91@gmail.com
ORCID: https://orcid.org/0000-0003-0474-5387