THE INFLUENCE OF THE APPLICATION OF GAME ELEMENTS ON STUDENT UNDERSTANDING OF THE CONCEPTS OF ENERGY, WORK AND MOMENTUM

Marija Gaurina
University of Split, Faculty of natural sciences and mathematics
Split, Croatia
mgaurina@pmfst.hr

Abstract **— Physics is one of the fundamental school subjects in preparing students for the challenges of the 21st century. Therefore, improving students' learning outcomes in physics is crucial for modern education. To this end, the clear formulation of positive educational goals, streamlined teaching process, and diversified teaching methods should eliminate routine, unproductive, and tedious practices. Moreover, lifelong physics learning requires more than basic knowledge and skills. It depends largely on the attitudes that students develop towards physics. To achieve goals like understanding science and technology issues, actively participating in discussions, and making responsible and informed decisions, games and gaming practices have great potential because they directly and strongly involve participants in developing and co-creating outcomes, both individually and collaboratively. Introducing game elements in non-game environments is called gamification, a broad term that includes many variations and applications. This complexity makes applying gamification in education challenging, especially in a education physics settings. Considering the fact that gamification elements were most frequently used in computer science, while other science, technologay, engeenering anf math (STEM) areas have been neglected in this regard, we are pointing to a wide area with a great educational potential that has not yet been explored in great extend.**

Keywords — Physics, education, gamification, energy, work, momentum

I. Introduction

We witness how with the rapid development of science and technology in the world, the importance of science in education has also increased because "knowledge of basic science contributes to technological progress and ensures sustainable development on Earth" (Fuchs, 2011; Uzunboylu & Aşıksoy, 2014). In secondary schools, physics is often one of the core subjects because knowledge of physics is the basis for understanding many other vocational subjects. Therefore, it is important to improve students' academic achievements in physics. "Routine, and thus boredom, must be avoided by combining different types of work, teaching methods, and skillful lesson design." (Braš Roth, 2017) Moreover, a lifelong commitment to science requires more than just knowledge and skills, and therefore depends largely on students' attitudes toward science. Science education should ensure that students completing elementary school understand and actively participate in discussions about topics related to science and technology and make responsible and informed decisions (Braš Roth, 2017).

In the Republic of Croatia, students are least interested in physics comparing to their interest for other STEM subjects like biology and chemistry, mainly because of its difficulty and connection to mathematics (Jokić, 2008; Marušić & Sliško, 2009). 50% of the surveyed students believe that it takes a lot of effort to master the content, and even more than 25% of them believe that the content is too much. In research from 2022 is stated that students found both biology and physics to be as intriguing as they had anticipated (Maltar Okun et al., 2022). This finding is surprising because, according to researches conducted in Croatia over the past 15 years (Marušić & Sliško, 2009; Šimičić & Pešut, 2021) physics is one of the least popular subjects, and students around the world frequently describe it as difficult, difficult to understand, and overly abstract (Stefan & Ciomos, 2010). Therefore, it is important to consider the personality, expertise, and passion of physics teachers when interpreting such results since they have a significant impact on students' views about physics (Maltar Okun et al., 2022). In research conducted 2015 it is claimed that the amount of content affects the quality of physics education (Ćosić, 2015). A lower number of students like physics and find the reason in the interestingness of the subject or give the teacher as the reason. Students with higher average of grades show more positive attitude towards physics (Jokić, 2008). Most of the surveyed students recognize physics as a subject that develops scientific thinking, focuses on the application of the scientific method, and conducts interesting experiments (Ćosić, 2015). Nevertheless, only a very small number of students choose this subject as a future profession. In research from 2010 is reported that girls perform better in physics than boys, although they do not tend to continue learning the subject, and that it is equally important for girls and boys to be successful in solving problems in physics (Jugović, 2010).

The 2015 PISA survey (Braš Roth, 2017) in the Republic of Croatia shows that 24.2% of students expect to study science at the age of 30, of which 26.8% are boys and 21.8% are girls.

Ultimately, students show negative attitudes towards physics due to the difficult, abstract and incomprehensible content associated with mathematics, which reinforces the negative attitude (Jokić, 2008). The same author states that the negative image of students towards science has not changed for decades, i.e., a continuous turning away of students from science can be observed.

Physics students also very often have difficulty learning scientific concepts because they have preconceived notions, usually called as misconceptions, alternative conceptions, or mental models. These types of alternative conceptions and mental models that students use before and after school (McDermott & Redish, 1999) are highly resistant to change. It is widely recognized that these beliefs and intuitions that students have about physical phenomena are mostly derived from their everyday experience and are usually not accepted by the scientific community (Novak & Gowin, 1984).

II. GAMIFICATION

Gamification is now a widely known term used in various areas of life such as business, health, entertainment, and even education. It is widely known that games appeal to students and stimulate their creativity. Therefore, it is important to include them in the educational process, especially in the field of physics education.

If we wanted to define the concept of gamification, we would probably face a bigger problem, but we can state that the generally accepted definition is: "the use of game elements in a non-gaming context" (Deterding et al., 2011). The use of game strategies, its mechanics and aesthetics to motivate and activate stakeholders is the main idea of gamification.

In education, gamification can be integrated into the mechanics themselves by introducing badges, points, rankings, levels, and rewards. This is a copy of the elements of the game, but adapted to an context that is not entertaining, in order to make the educational processes as interesting and dynamic as possible for students (Sandusky, 2015). Gamification is often confused with the term of serious games, which includes the application of the game as a whole, and game-based learning, which complements traditional teaching with the use of technology (Plantak Vukovac et al., 2018).

A. History of gamification

It is difficult to pinpoint the beginnings of gamification itself, but many cite 1912 as the first appearance on the mass market. In 1912, the American popcorn brand Cracker Jack began including a free prize with each bag. While this was not yet gamification in the modern sense, the introduction of fun and prizes hinted at elements of gamification. While Cracker Jack's implemented the first and most basic application of gamification in marketing, another well-known application came in education in the form of the Boy Scout movement in 1910, whose use of ranks and merit badges in various activities encouraged engagement and situational interest among children. Although the term gamification was used in early practice around the world, it had not yet been validated. The 1980s saw the first academic papers and commercial books on gamification that focused specifically on education, at a time when digital games were first entering classrooms in the era of CD-ROM. Adoption increased slowly but steadily. In the 1990s, however, numerous factors led to a distorted view of the market and, eventually, its consolidation into a few major players, which prevented gamification from adapting quickly to schools. The term gamification originated in the digital media industry. The first documented applications date back to 2008, while it did not become widely used and accepted until the second half of 2010, when it went viral thanks to the development of the Internet and videoconferencing DICE (Deterding et al., 2011).

In a survey conducted by the Joan Ganz Cooney Center, 32% of the teachers surveyed reported using digital games 2-4 times a week in their classrooms, with 18% used them daily (Millstone, 2012). Most of them use educational games, of which only 18% use commercial games adapted for classroom use (Millstone, 2012).

Considering its popularity, there has also been an increased interest in researching this concept among educators. On the topic of gamification, a systematic review of scientific papers was conducted in 2014 (Caponetto et al., 2014), which showed that the number of scientific papers has increased extraordinarily in the period from 2000 to 2014, especially in the last part of this period.

Another study was conducted in 2016, also in the form of a systematic review of the literature with the aim of identifying fundamental concepts and keywords related to the use of games in education (Martí-Parreño et al., 2016). The authors proposed gamification as a new approach in education and a new concept in research. Some authors focused their research on the concept of gamification in science in higher education. Through a review of the literature, a focused analysis of 30 academic papers, they concluded that gamification is implemented with mechanisms such as points, badges, and progress monitoring scales that have a positive impact on student activity. The application of gamification in higher education has been most commonly related to computer science (Ortiz Rojas et al., 2016).

De Byl and Hooper (2013) investigated the connection between gamification and curricula and its application as a tool in teaching. They conducted the research by applying a gamified curriculum. After implementation, they surveyed students to determine the impact of gamified instruction on their activity. In their analysis, they observed the correlation of activities with the dimension of gamification and an alternative approach. The result showed that the playfulness and alternative pedagogy categories showed the strongest association with student involvement. This positive connection shows that the students who were fun and valued learning with alternative pedagogies were the most engaged in the gamified classes. Researchers are pointing out that the characteristics of playfulness and pedagogy itself did not significantly correlate, demonstrating that the more playful students were not necessarily those who chose alternative pedagogies and vice versa (De Byl & Hooper, 2013).

B. Elements of gamification

When we talk about gamification, we make a direct connection to the concept of play, which is one of the best ways of development at early age. In order to facilitate children's learning, it is important to apply the game to the learning process itself and to include its most important elements. The use of game in education is not new, but we cannot call every use of game gamification (Deterding et al., 2011).

On the other hand, there is a difference between gamification and didactic games.

Didactic games are different from creative games played in kindergarten, when the instructor teaches concepts by narrating a tale and asking each student a question one at a time. This enhances student understanding. The games are quite different from this.

First and foremost, didactic games should be used to teach and must be done at a level that is engaging, fun, and ultimately intelligible for students. Children play the game with all of their heart, becoming accustomed to performing each assignment flawlessly, which boosts their motivation in completing didactic activities. Didactic games aid in a better understanding of each lesson's objectives as well as the key points and objectives of each activity (Mukhtoraliyevna, 2023).

Playing didactic games makes learning more visually appealing. As a result, the students are able to comprehend what the teacher is saying with ease and deliberately play the didactic game according to its rules. It is simple to analyze the behaviors of pupils thanks to the characteristics of the framework of educational games. Because of this, every child in elementary school participates in the game with a lot of enthusiasm (Mukhtoraliyevna, 2023).

In research conducted in 2020. by Susman and Pavlin results show that the use of didactic games as an instructional strategy is appropriate for elementary school students aged 12 to 14 years. Although the didactic games that were produced did not fully achieve all of the proposed learning objectives, authors still consider them suitable for teaching the topic of light. However, they also found that students enjoy this method of learning and retaining the learning information and that it is a motivating tool that arouses their interest in the subject. The evaluation showed that the didactic games need to be optimized. The results of the study will provide educators with a better understanding of the design and critical components that must be considered when developing a didactic game (Susman & Pavlin, 2020).

Back to the gamification, in their paper Nah et al. (2013) describes five basic principles of gamification, namely: goal orientation, success or achievement, encouragement, competition, and fun orientation (Nah et al., 2013).

Jane McGonigal, in her work Superbetter, which is about learning how to be playful in the face of extreme stress and personal challenges, talks about being gameful means bringing the psychological strengths you naturally exibit in play - such as optimism, creativity, courage and determination – and applying them to your real life. She also list seven basic principles of gamification, "seven rules to live by," namely: challenge yourself , collect and activate power-ups, find and battle the bad guys, seek and complete quests , recruit allies, adopt a secret identity, and strive for epic victory (McGonigal, 2015).

On the other hand, Chou constructs a complete framework for analyzing and developing strategies around the various systems that make games engaging. He notes that almost every successful game appeals to certain Core Drives within us and motivates us to make a variety of choices and engage in a variety of activities, and how different types of gaming techniques push people forward differently; some through inspiration and empowerment, others through manipulation and obsession. As a result of his work, he developed a gamification design framework called Octalysis, which derives its name from an octagonal shape with 8 Core Drives representing each side (Chou, 2019). Eight Core Drives reprezented in Octalysis are: Epic Meaning & Calling, Development & Accomplishment, Empowerment of Creativity & Feedback, Ownership & Possession, Social Influence & Relatedness, Scarcity & Impatience, Unpredictability (Chou, 2019).

Game design elements are the basic building blocks of gamification applications (Deterding et al., 2011; Werbach et al., 2012). For example, Reeves and Read ~~(Reeves & Read,~~ 2009) suggest “Ten Ingredients for Great Games”," which include self-expression, narrative context, feedback, competition, teams, avatars, time constrains, leaderboards, ranks and badges. Werbach and Hunter (2015) (Werbach & Hunter, 2015) identify 15 components, where they particularly emphasize what they call the “PBL triad”- the linking of points, badges, and leaderboards, which they see as characteristic of the use of gamification (Werbach et al., 2012).

In the educational context, gamification is used to enhance learning and problem solving. The mechanisms used are elements of the game and are adapted for the teaching process, which is considered an activity that is not a game. Therefore, it is assumed that students perceive it as something dynamic and entertaining (Kiryakova et al., 2014; McGrath & Bayerlein, 2013). In addition to gamification, there are several concepts related to games that can be implemented in the educational process, and it is necessary to distinguish between them. Concepts that are often identified with gamification are: free play (a game without strictly defined rules), a game with rules (a structure with rules and a specific goal), game-inspired design (a visual animation or image that resembles a game), and serious games (the creation of simulations of real events) (Al-Azawi, 2016; Garris et al., 2002).

When we use gamification, the teacher creates goals and progress monitoring mechanisms that allow them to evaluate student performance.

In their 2015 study, Dicheva et al. point out that the most common elements of game mechanics are those used to monitor progress. Among these elements, those that foster a competitive spirit and allow comparison between students stand out (Dicheva et al., 2015).

Different authors mention many game mechanics, the most commonly used are points, levels, challenges, badges, scales, awards, progress bars, stories, avatars, and feedback (Nah et al., 2013; Urías et al., 2016).

C. Research in gamified classroom

In this section we will present some research findings on gamified teaching.

In 2017, Jagušt et al. investigated the implementation of gamification in mathematics teaching. As part of the study, they used an application in which students solved mathematical problems independently to implement gamification elements in the repeated version of the application. Students were shown a countdown on the tablet while seeing a progress bar on the screen. When analyzing and interpreting the research results, they concluded that students were more motivated by using an application with gamification elements. On the other hand, the progress monitoring scale was demotivating for some students, so they did not perform well (Jagušt et al., 2017).

Laskowski and Borys investigated the level of teachers' familiarity with the gamification and serious games concepts and collected information about the application of certain concepts. The authors surveyed a group of higher education teachers in Poland about their use of and exposure to serious games and gamification, including how they use them, why they use them (or not), and when they use them. Analyzing the results, they found that respondents between the ages of 30 and 35 showed the greatest interest in using gamification in the classroom. "Most responses related to increasing student engagement and making the classroom more engaging." (Laskowski & Borys, 2016). Respondents cited current trends and the creation of materials as reasons why they would not use gamification in the classroom (Schrier, 2014).

In 2012, it was predicted that 70% of global companies would use gamification in some form in their operations (Christians, 2018). Jane McGonigal, in her book "Reality is Broken, introduces the idea of using gamification to encourage the world's population to engage in global change (McGonigal, 2011). Despite the opinion that gamification is just a trend, there are a growing number of online courses that award points for acquired knowledge (e.g., Udemy, Coursera) that still exist in a similar form today. Gamification has had various applications and forms since its inception. It took almost over 30 years for the application to receive the official name by which it is known today (Pofuk, 2020).

Reichelt (2015) examined the effects of gamification on achievement, motivation, and mastery in science. Students mastered the content of anatomy and physiology. The author found that "although the model increased the performance of excellent and non-excellent students, the non-excellent students benefited more from the implementation than the excellent students" and observed a change in motivation before and after the treatment (Reichelt, 2015).

Papastergiou (2009) examined the impact of learning through digital games. The aim was to observe how the treatment affected students' motivation and efficiency. The study involved 46 male and 42 female students who were randomly divided into two groups, an experimental group and a control group. The research showed that learning based on digital games effectively promotes students' conceptual knowledge of computer memory, and also motivates them to learn and work even more (Papastergiou, 2009).

In 2013, Dominguez's study focused on the practical effects and outcomes of the gamified experience for first- and second-year college students, who were also divided into two groups. The study found that students in the experimental group "performed better on all tasks related to the practical application of concepts." It also found that "gamification can have a great emotional and social impact on students, as reward systems and mechanisms of social competition seem to be motivating for them." (Domínguez et al., 2013).

Finally, in a 2015 study, Hanus and Fox measured student motivation, satisfaction, and academic performance at four time points during a sixteen-week study. The study showed the negative effects of gamification, i.e., student motivation, satisfaction, and empowerment tend to decrease in a gamified environment compared to a non-gamified environment, and participants in a gamified environment were "less intrinsically motivated and accordingly scored lower on tests than participants in a non-gamified environment.“ (Hanus & Fox, 2015).

In research conducted 2020 which aimed at investigating how gamification influences freshman engineering students' enthusiasm for physics. Experience points (XP), badges, leaderboards, and repeatable tasks were used to make the Physics for Engineers 2 course, which covers the fundamentals of electricity and magnetism, gamified. The Wilcoxon Signed Rank Test was used to assess student responses to the physics motivation questionnaire completed before and after implementation to determine if gamification had a significant impact on student motivation. Results showed significant improvement in each of the five motivational factors for physics students, including intrinsic motivation, self-efficacy, grade incentive, career motivation, and self-determination (Cruz et al., 2020).

One year later Ahmed and Asiksoy conducted research that examined how the Gamified Flipped Learning (GFL) technique affected students' inventiveness and physics self-efficacy in a virtual physics laboratory course. The study involved 70 first-year engineering students who were randomly separated into two groups. It was conducted using a true experimental design. The control group received training using the Classical Flipped Learning (CFL) approach, whereas the experimental group received training using the GFL method. A physics self-efficacy questionnaire, a questionnaire on inventive talents, and a form for semi-structured interviews were used to gather the data. The findings of the study demonstrated that, despite a little gain in students' self-efficacy brought about by gamified-flipped learning, the GFL approach had a beneficial effect on students' innovative skills. Additionally, the student interviews demonstrated a favorable opinion of gamification by identifying several significant components of the procedure that were very advantageous (Ahmed & Asiksoy, 2021).

The latest research from 2023 showed that gamified learning robots could significantly increase learning motivation by increasing students' interest in the appearance of the robot. The teaching robot provided instruction to students and prompted them to ask questions. This finding shows that a gamified learning robot has a better affinity with the students and can engage with them better because it lacks human characteristics such as gestures, voice, and facial expressions. The gamified learning robot gives students the opportunity to engage with real people while learning in an engaging way, which builds their confidence when they have questions. In summary, the gamified learning robot allows students to develop confidence in their ability to learn, as well as increase their engagement and motivation in the classroom so they can enjoy learning more (Chen et al., 2023).

D. Motivation and gamification

If we consider motivation from many aspects, it is a very complex phenomenon (Gardner, 1980). Student motivation can be both external (extrinsic) and internal (intrinsic). Extrinsic motivation generally consists of recognition and praise for good work, while intrinsic motivation generally consists of an internal desire to learn about a particular subject.

According to Vansteenkiste, et al. (2004), intrinsically motivated students process content such as reading material more intensively achieve better grades and show more persistence than extrinsically motivated students. Student motivation is widely considered to be a key factor influencing the pace and success of learning. There are many factors that can lead to students' lack of knowledge, and they can also be attributed to students' motivation for a particular subject (Vansteenkiste et al., 2004). McDonough (1983) believes that student motivation is still the most important factor influencing student success or failure. A better understanding of motivation itself can be of great benefit to curriculum designers in designing instructional programs that significantly influence student acceptance of particular subjects (McDonough, 1999).

Because of the above problems, Chou (2019) has worked over the past decade to create a complete framework for analysis and strategy development around the various systems that make games and their elements engaging and motivating. He concluded that almost every successful game can be described by a particular "core drive" (Core Drives) that moves and motivates us to make various decisions and engage in various activities (Chou, 2019).

As he explains in his book, everything is based on one or more basic drives. If none of them is behind the desired action, there is neither motivation nor action. In addition, each of the drives carries different natural powers. Some make people feel powerful but do not create pressure, while other triggers do, such as obsessions and even addictions, making people feel bad. Some are more extrinsically oriented in the short term, while others are intrinsically oriented in the long term. Thus, these eight basic drivers are drawn into the octagon not just for esthetic reasons, but because their position determines the type of motivation. The Octalisys framework is arranged so that the basic drives that focus on creativity, self-expression, and social dynamics are positioned on the right side of the octagon, which is why Chou (2019) calls them the basic drives of the right hemisphere. The basic drives commonly associated with logic, analytical thinking, and possession are located on the left side of the octagon and are called the main drives of the left hemisphere of the brain. As he notes, the left and right hemisphere of the brain are not to be taken literally in terms of actual brain geography, but merely a symbolic distinction between two different brain functions. Interestingly, left brain drives are usually based on extrinsic motivation – you are motivated because you want to achieve something, whether it is a goal, a good, or something you cannot achieve. Right hemisphere drives, on the other hand, are usually related to internal motivations - you do not' need a goal or a reward to use your creativity, to be with friends, or to feel uncertainty or unpredictability - the activity itself is rewarding.

There is another factor worth noting within the Cho's (2019) Octalisys framework, namely upper basic drivers in the octagon, which the author considers positive motivators, while the lower ones are considered negative motivators (Chou, 2019). The author also calls them "white hat gamification," while the techniques that use the lower part of the Octalisys framework are referred to as "black hat gamification". If something is attractive because it allows you to express your creativity, makes you feel successful by mastering skills, and gives you a sense of greater meaning, then you feel very good and strong. If, on the other hand, you are constantly doing something because you do not know what will happen next, because you are constantly afraid of losing something, or because you are struggling to achieve the unachievable, then this experience often leaves a bad taste in your mouth, even if you are consistently motivated to take these actions.

III. WHY TO EXPLORE CONCEPTS OF MECHANICAL ENERGY, WORK AND MOMENTUM?

The term "energy" holds significant importance in the daily lives of students. It refers to the vital abstract concept that powers various activities and processes around us. From the moment they wake up, students utilize energy to fuel their bodies and minds. Whether it's the energy derived from food that provides physical stamina or the mental energy required for learning and problem-solving, energy is a constant companion throughout their day.

In the classroom, students use their mental energy to concentrate, comprehend, and engage in lessons. They also employ energy in extracurricular activities, sports, and social interactions. Understanding the sources and conservation of energy becomes crucial as students grow, aiding them in making sustainable choices and managing their resources efficiently. In essence, the concept of energy is an ever-present concept that impacts every facet of a student's routine, reminding them of the dynamic interplay between their actions and the resources they expend.

Of all the areas of physics, students exhibited the most misconceptions in mechanics, which attracted the attention of researchers for this reason (Duit, 2009). Much research has been conducted on the concepts of force and motion. Although they are among the most fundamental concepts in physics, little research has been done on energy and the momentum.

Energy, as one of the fundamental topics of physics, has significant content and a wide range of applications both in science and in our daily lives. Inevitably, the concepts of energy in all respects occupy a rather important place in the teaching of physics in schools and universities. In fact, in many traditional mechanics courses, energy concepts, although of fundamental importance, are often introduced quite late in the course and are therefore considered by students to be secondary or even tertiary topics in the course. In addition, certain widely used physics textbooks, which initially attempted to reduce ideas of energy to real-world facts, sometimes contain inaccurate or inadequate information about energy. In response to these problems, research in physics education is attempting to update the subject matter to provide students with a contemporary understanding of the most fundamental ideas, such as energy (Ding, 2007).

The literature review shows that research in the field of conceptual understanding of energy and the momentum has also been studied modestly. On the other hand, some of them study the concepts separately. For example, research conducted in 1967, 1976, and 1996. studied the momentum as a separate topic with the aim of finding an effective method of conveying the concepts as well as describing the subconcepts leading to the understanding of the concept of the momentum (Raven, 1967; Williams, 1976)

In his 1967 study, Raven notes that children as young as five have an intuitive sense of the concept of momentum, regardless of the fact that they are unfamiliar with the concept and that their intuition does not depend on knowledge of the concepts of velocity or mass (Raven, 1967).

Singh and Rosengrant (2003) emphasize that many students lack a coherent understanding of the concepts of energy and momentum and point out that students have difficulty applying them in different situations. The authors also observed that students of mechanical engineering had significant problems applying the law of conservation of energy and momentum in many situations presented to them (Singh & Rosengrant, 2003).

A study on 10th grade students' misconceptions about momentum and impulse, in which a conceptual understanding test with 8 open-ended questions was administered to 139 students from 5 randomly selected secondary schools, revealed that 92.8% of the students could not explain the momentum conservation principle (MCP) at a scientifically acceptable level (Şekercıoğlu & Kocakülah, 2008).

In 2014 research using EMCS (Energy Momentum Conceptual Survey) researchers found that the average student score on the energy and momentum concept survey was 32.5%. It was found that most students did not recognize the importance of the relationship between energy and momentum and that they had difficulty qualitatively interpreting the basic principles of energy and momentum and applying them in physical situations. In addition, the authors of the research stated that there was no statistically significant difference between genders (Dalaklioğlu et al., 2015).

Liu and Fang (2017) investigated the misconceptions students have related to the concepts of work and mechanical energy. The authors identified a total of 23 misconceptions. As noted in the study, mechanical energy and work are high-level abstract concepts, so it is difficult for students to develop a correct understanding if they only learn them from textbooks. Students therefore use analogies and metaphors to help themselves, which in turn can easily go wrong because of the students' previous experiences. The authors also state that students' misconceptions are due to placing concepts into incorrect categories and suggest the use of Chi's Category Change Theory. Chi's theory emphasizes the dissociation of overly general categories by recognizing differences (Chi, 2008; Chi & Brem, 2009). They also note that students' misconceptions may also be caused by "vernacular misunderstandings," due to a student's insufficient or even deficient reading skills, or the lack of clarity of textbooks and other reading materials (Liu & Fang, 2016) meaning that students do not fully understand the textbook material (Liu & Fang, 2017).

In one of the most recent studies from 2022, the authors used five conceptual questions from the Energy Momentum Conceptual Survey (EMCS) on a sample of 66 high school students, which they adapted to meet the needs of the study. The results of the analysis showed that the percentage of students that showed understanding of the concept of energy and momentum in high school through the prism of correct answers was 54%. The item analysis results for each question on the concept of energy and momentum also showed that some students still misunderstand some of the concepts (Yana et al., 2022).

IV. METODOLOGY, QUESTIONS AND OBJECTIVES

The purpose of our future doctoral thesis is to investigate the influence of the application of gamification elements on students' understanding of the concepts of energy, work, and momentum, as well as the relationship between students' attitudes towards learning physics in relation to these concepts. It is assumed that students' attitudes towards learning physics as a subject are influenced by gamification elements, which then lead to different educational outcomes.

This leads to the assumption that students who use gamification elements have a more positive attitude towards learning than those who approach physics education traditionally, and therefore have a better understanding of energy, work, and momentum concepts.

Considering the above research objectives, the following hypotheses were formulated:

H1 Understanding of energy and momentum concepts will be statistically significantly better among students who used elements of gamification in class than among those who approached physics instruction in a traditional manner.

H2 Students' attitudes toward physics instruction who have used gamification elements in class will be statistically significantly more positive than those who approach physics instruction in a traditional manner.

H3 Attitudes toward learning physics of students who used only gamification elements in class will be statistically significantly more positive than those of students who approach physics instruction traditionally.

H4 Level of thinking skills of students who used only gamification elements in class will be statistically significantly higher than those of students who approach physics instruction traditionally

In preparation for a future doctoral dissertation, we would conduct a study of an appropriate sample of first grade secondary school students in the Republic of Croatia during the 2023/2024 school year. The sample would be determined based on convenience sampling.

The application of gamification elements would span the entire school year in order to effectively introduce students to gamification elements.

For each school (gymnasium and vocational school), there will be a control group and an experimental group that will be randomly selected. For teachers involved in the research process, we plan to prepare materials and lesson plans for teaching both the control and experimental groups. We will also ask teachers to take field notes after each lesson.

Data will be collected by the following instruments: EMCS (Energy Momentum Conceptual Survey), TOLT (Test Of Logical Thinking), summative assessments prepared for teachers, individual interviews and field notes of teachers.

Student performance on the summative assessment will be used to identify the impact of introducing gamification elements on concept understanding and problem solving. By administering a pretest and a posttest EMCS (Energy momentum conceptual survey), we would examine the effects of the gamification elements specifically on understanding the concepts of energy and momentum. The EMCS consists of 25 multiple-choice questions was introduced by Singh and Rosengrant (2003). It is designed to cover topics related to work and energy, conservation of energy and momentum, and collisions in one dimension (Singh & Rosengrant, 2003). For the purpose of our research, it will be translated to Croatian language and piloted.

The TOLT provides a reliable method for assessing formal thinking skills. The ten-item test has a high degree of internal consistency, and several subtests show sufficient reliability to allow subtest-level decisions. The test can be used for diagnostic assessment, in a research context, or in studies designed to promote specific formal thinking skills, as the reliability coefficients are of a magnitude that makes them suitable for use in these contexts (Capie, 1981).

Individual interviews will be done by randomly selected students in the experimental groups. By triangulating the summative test scores, the EMCT test, with the responses of the TOLT test and the responses of the interview samples, we will attempt to determine, from both quantitative and qualitative perspectives, the effects of gamification on secondary school students' understanding of the concepts of conservation of energy and momentum. We also plan to have each teacher keep an observation diary with prepared rubrics to observe the impact of the introduction of gamification on teachers.

The research methodology will be submitted to the Ministry of Science, Education and Sports of the Republic of Croatia and the Agency for Education to obtain approval from the relevant institutions.

V. CONCLUSION

The use of gamification can be beneficial at many levels of education, from school to university, according to the comprehensive literature review. Through the systematic review we found that gamified learning has a number of benefits for students, including increasing their motivation, engagement, and academic achievement. The main gamification components used in education are points, medals, leaderboards, and stories. It is believed that the impact on student motivation is lower or even negative when only one or two gamification components such as points or badges are used. On the other hand, energy is one of the fundamental concepts of physics, encompassing a considerable amount of content and a variety of applications in both the physical sciences and daily life. Inevitably, energy concepts occupy a relatively significant place in both secondary and university education. In many traditional mechanics courses, energy concepts are taught relatively late, although they are fundamental, so students consider them secondary or even tertiary topics in the course.

We believe that the proposed research will fill the research gap in evaluating physics teaching strategies and that the results will be useful both for physics teachers to apply the conclusions in developing new educational strategies using gamification and for the broader scientific community to use as a starting point for new research in physics education. We can also conclude that in a wide range of research, the notion of gamification is being replaced by the notion of GBL and serious games, often ignoring what gamification really is. In general, according to the previous research and scientific papers, gamification has positive effects on students' motivation, engagement and academic achievement, while on the other hand we can say that it is either little used or little researched in educational physics, which indicates a wide area to be explored.

References

Ahmed, H. D., & Asiksoy, G. (2021). The effects of gamified flipped learning method on student's innovation skills, self-efficacy towards virtual physics lab course and perceptions [Article]. *Sustainability (Switzerland)*, *13*(18), Article 10163. https://doi.org/10.3390/su131810163

Al-Azawi, R., Fatma Al-Faliti, i Mazin Al-Blushi. (2016). Educational Gamification Vs. Game Based Learning:Comparative Study. *International Journal of Innovation, Management and Technology 7*.

Braš Roth, M., Markočić Dekanić, A. i Markuš Sandrić, M. (2017). PISA 2015. Prirodoslovne kompetencije za život. *Nacionalni centar za vanjsko vrednovanje obrazovanja – PISA centar*.

Capie, T. a. (1981). The Development and Validation of a Group Test of Logical Thinking. *Educational and Psychological Measurement 1981; 41; 413*. https://doi.org/10.1177/001316448104100220

Caponetto, I., Earp, J., & Ott, M. (2014, Oct 09-10). Gamification and Education: A Literature Review.*Proceedings of the European Conference on Games-Based Learning* [Proceedings of the 8th european conference on games based learning (ecgbl 2014), vols 1 and 2]. 8th European Conference on Games Based Learning (ECGBL), Univ Appl Sci, Res & Training Ctr Culture & Comp Sci, Berlin, GERMANY.

Chen, T.-I., Lin, S.-K., & Chung, H.-C. (2023). Gamified Educational Robots Lead an Increase in Motivation and Creativity in STEM Education. *Journal of Baltic Science Education*, *22*(3), 427-438.

Chi, M. T. (2008). Three types of conceptual change: Belief revision, mental model transformation, and categorical shift. *International handbook of research on conceptual change*, *61*, 82.

Chi, M. T., & Brem, S. K. (2009). Contrasting Ohlsson's resubsumption theory with Chi's categorical shift theory. *Educational Psychologist*, *44*(1), 58-63.

Chou, Y.-k. (2019). *Actionable gamification: Beyond points, badges, and leaderboards*. Packt Publishing Ltd.

Christians, G. (2018). The origins and future of gamification.

Cruz, M. K. B. d., Tolentino, A. N., & Roleda, L. S. (2020). *Increasing Student Motivation in College Physics with Gamified Instruction* Proceedings of the 2020 11th International Conference on E-Education, E-Business, E-Management, and E-Learning, Osaka, Japan. https://doi.org/10.1145/3377571.3377623

Ćosić, A. (2015). *Analiza stavova učenika osječkih srednjih škola o nastavi fizike i informatike* Josip Juraj Strossmayer University of Osijek. Department of Physics. The …].

Dalaklioğlu, S., Demirci, N., & Şekercioğlu, A. (2015). Eleventh grade students' difficulties and misconceptions about energy and momentum concepts. *International Journal of New Trends in Education and Their Implications*, *6*(1), 13-21.

De Byl, P., & Hooper, J. (2013). Key attributes of engagement in a gamified learning environment. ASCILITE-Australian Society for Computers in Learning in Tertiary Education Annual Conference,

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: defining" gamification". Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments,

Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). Gamification in Education: A Systematic Mapping Study. *Educational Technology & Society*, *18*(3), 75-88. <Go to ISI>://WOS:000358994600006

Ding, L. (2007). Designing an energy assessment to evaluate student understanding of energy topics.

Domínguez, A., Saenz-de-Navarrete, J., De-Marcos, L., Fernández-Sanz, L., Pagés, C., & Martínez-Herráiz, J.-J. (2013). Gamifying learning experiences: Practical implications and outcomes. *Computers & Education*, *63*, 380-392.

Duit, R. (2009). Bibliography–STCSE. *Students' and Teachers' Conceptions and Science*

Education (http://www. ipn. uni-kiel. de/aktuell/stcse/download_stcse. html).
Fuchs, R. (2011). Nacionalni okvirni kurikulum za predškolski odgoj i obrazovanje te opće obvezno i srednjoškolsko obrazovanje. (Ministarstvo znanosti, športa i obrazovanja).
Gardner, R. C. (1980). On the validity of affective variables in second language acquisition: conceptual, contextual, and statistical considerations 1. *Language learning*, *30*(2), 255-270.
Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, Motivation, and Learning: A Research and Practice Model. *Simulation & Gaming*, *33*(4), 441-467. https://doi.org/10.1177/1046878102238607
Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education*, *80*, 152-161.
Jagušt, T., Boticki, I., Mornar, V., & So, H.-J. (2017). Gamified digital math lessons for lower primary school students. 2017 6th IIAI international congress on advanced applied informatics (IIAI-AAI),
Jokić, B. (2008). *Science and Religion in Croatian Elementary Education. Pupils' Attitudes and Perspectives. University of Cambridge, Faculty of Education* doctoral dissertation].
Jugović, I. (2010). Uloga motivacije i rodnih stereotipa u objašnjenju namjere odabira studija u stereotipno muškom području. *Sociologija i prostor: časopis za istraživanje prostornoga i sociokulturnog razvoja*, *48*(1 (186)), 77-98.
Kiryakova, G., Angelova, N., & Yordanova, L. (2014). Gamification in education. Proceedings of 9th international Balkan education and science conference,
Laskowski, M., & Borys, M. (2016). The student, the professor and the player: usage for gamification and serious games in academic education–a survey. EDULEARN16 Proceedings,
Liu, G., & Fang, N. (2016). Student misconceptions about force and acceleration in physics and engineering mechanics education. *International Journal of Engineering Education*, *32*(1), 19-29.
Liu, G., & Fang, N. (2017). Student misconceptions of work and energy in engineering dynamics. Proceedings of the 2017 ASEE Gulf-Southwest Section Annual Conference,
Maltar Okun, T., Rijavec, M., & Caleta, M. (2022). Association between Attitudes towards Science Subjects and Grades: The Mediation Role of Learning Strategies. *Problems of Education in the 21st Century*, *80*(4), 547-564.
Martí-Parreño, J., Méndez-Ibáñez, E., & Alonso-Arroyo, A. (2016). The use of gamification in education: a bibliometric and text mining analysis. *Journal of computer assisted learning*, *32*(6), 663-676.
Marušić, M., & Sliško, J. (2009). Postoje li» muški «i» ženski «stavovi o učenju fizike, o fizici kao znanosti i fizici kao struci? *Metodički ogledi: časopis za filozofiju odgoja*, *16*(1-2), 87-111.
McDermott, L. C., & Redish, E. F. (1999). Resource letter: PER-1: Physics education research. *American Journal of Physics*, *67*(9), 755-767.
McDonough, S. H. (1999). Learner strategies. *Language teaching*, *32*(1), 1-18.
McGonigal, J. (2011). *Reality is broken: Why games make us better and how they can change the world*. Penguin.
McGonigal, J. (2015). *SuperBetter: A revolutionary approach to getting stronger, happier, braver and more resilient*. Penguin.
McGrath, N., & Bayerlein, L. (2013). Engaging online students through the gamification of learning materials: The present and the future. ASCILITE-Australian Society for Computers in Learning in Tertiary Education Annual Conference,
Millstone, J. (2012). Teacher attitudes about digital games in the classroom. The Joan Ganz Cooney Center at Sesame Workshop,
Mukhtoraliyevna, Z. S. (2023). Educational Importance Of Using Didactic Games. *Journal of Pedagogical Inventions and Practices*, *19*, 104-107.

Nah, F. F.-H., Telaprolu, V. R., Rallapalli, S., & Venkata, P. R. (2013). Gamification of education using computer games. Human Interface and the Management of Information. Information and Interaction for Learning, Culture, Collaboration and Business, 15th International Conference, HCI International 2013, Las Vegas, NV, USA, July 21-26, 2013, Proceedings, Part III 15,

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. cambridge University press.

Ortiz Rojas, M. E., Chiluiza, K., & Valcke, M. (2016). Gamification in higher education and stem: A systematic review of literature. 8th International Conference on Education and New Learning Technologies (EDULEARN),

Papastergiou, M. (2009). Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education*, *52*(1), 1-12.

Plantak Vukovac, D., Škara, M., & Hajdin, G. (2018). Korištenje i stavovi nastavnika o igrifikaciji u osnovnim i srednjim školama. *Zbornik Veleučilišta u Rijeci*, *6*(1), 181-196.

Pofuk, A. (2020). *Primjena igrifikacije u srednjoškolskoj nastavi* University of Zagreb. Faculty of Organization and Informatics. Department of …].

Raven, R. J. (1967). The development of the concept of momentum in primary school children. *Journal of Research in Science Teaching*, *5*(3), 216-223.

Reeves, B., & Read, J. L. (2009). *Total engagement: How games and virtual worlds are changing the way people work and businesses compete*. Harvard Business Press.

Reichelt, A. L. (2015). Effects of gamification: analyzing student achievement, mastery, and motivation in science classrooms.

Sandusky, S. (2015). Gamification in education.

Schrier, K. (2014). *Learning, education and games. Volume one: Curricular and design considerations*. Carnegie Mellon University.

Şekercıoğlu, A. G., & Kocakülah, M. S. (2008). Grade 10 Students' Misconceptions about Impulse and Momentum. *Journal of Turkish Science Education (TUSED)*, *5*(2).

Singh, C., & Rosengrant, D. (2003). Multiple-choice test of energy and momentum concepts. *American Journal of Physics*, *71*(6), 607-617.

Stefan, M., & Ciomos, F. (2010). The 8th and 9th Grades Students' Attitude towards Teaching and Learning Physics. *Acta Didactica Napocensia*, *3*(3), 7-14.

Susman, K., & Pavlin, J. (2020). Improvements in Teachers' Knowledge and Understanding of Basic Astronomy Concepts through Didactic Games. *Journal of Baltic Science Education*, *19*(6), 1020-1033.

Šimičić, S., & Pešut, M. (2021). Stavovi učenika sedmih i osmih razreda osnovne škole o nastavnim predmetima Matematika i Kemija. *Poučak: časopis za metodiku i nastavu matematike*, *22*(85), 32-41.

Urías, M. V., Chust, A. C., & Carrasco, O. L. (2016). How to gamify an online technical subject in higher education. EDULEARN16 Proceedings,

Uzunboylu, H., & Aşıksoy, G. (2014). Research in physics education: A study of content analysis. *Procedia-Social and Behavioral Sciences*, *136*, 425-437.

Vansteenkiste, M., Simons, J., Lens, W., Soenens, B., Matos, L., & Lacante, M. (2004). Less is sometimes more: Goal content matters. *Journal of educational psychology*, *96*(4), 755.

Werbach, K., & Hunter, D. (2015). *The gamification toolkit: dynamics, mechanics, and components for the win*. University of Pennsylvania Press.

Werbach, K., Hunter, D., & Dixon, W. (2012). *For the win: How game thinking can revolutionize your business* (Vol. 1). Wharton digital press Philadelphia.

Williams, D. J. (1976). *A Study of Some Aspects of the Growth in GCE'O'Level Candidates of the Concept of Momentum* University of Leeds (School of Education)].

Yana, A., Koes-H, S., Taufiq, A., & Kusairi, S. (2022). Online-Based Assessment of Students' Conceptual Understanding of

Energy and Momentum Using Quizizz. Journal of Physics: Conference Series