European Journal of Science and Mathematics Education, 2024, **12**(2), 200-210
ISSN: 2301-251X (Online)

OPEN ACCESS

**Research Article**

# Effect of didactic intervention in Einsteinian physics on students' interest in physics

**Georgia Vakarou** [1*]
0009-0001-1235-8275

**Georgios Stylos** [1]
0000-0001-8036-8427

**Konstantinos T. Kotsis** [1]
0000-0003-1548-0134

[1] Department of Primary Education, University of Ioannina, Ioannina, GREECE
[*] Corresponding author: vakaroug@gmail.com

**Citation:** Vakarou, G., Stylos, G., & Kotsis, K. T. (2024). Effect of didactic intervention in Einsteinian physics on students' interest in physics. *European Journal of Science and Mathematics Education, 12*(2), 200-210. https://doi.org/10.30935/scimath/14303

**ARTICLE INFO**

Received: 6 Dec 2023

Accepted: 8 Feb 2024

**ABSTRACT**

To investigate students' interest in physics, this study explores the impact of a brief teaching intervention on the increase of interest. The intervention focused on modern physics, specifically exploring Einstein's theory of gravity and the dual nature of light. A total of 325 Greek students participated in the survey, comprising 83 students in the 6$^{th}$ grade (11-12 years old), 116 students in the 9$^{th}$ grade (14-15 years old), and 126 students in the 11$^{th}$ grade (16-17 years old). Participants completed a questionnaire, which helped determine the average level of interest before and after the teaching. The findings indicate that teaching modern physics concepts contributes to the development of students' interest. However, there is an observed decline in interest as the educational level advances, a pattern persisting despite the introduction of Einsteinian physics concepts.

**Keywords:** interest in physics, Einsteinian physics, educational level

## INTRODUCTION

Despite the increasing significance of science in our daily lives, research indicates a consistent decline in the number of students opting for scientific subjects in high school and pursuing scientific careers after that (Kaleva et al., 2023; Osborne et al., 2003; Salmela-Aro, 2020). The same authors underscore the crucial role of a positive attitude towards science, emphasizing its substantial impact on motivation for learning both within the school environment and in other educational frameworks.

Examining students' interest in science is a crucial research focus within the educational community. The demand for scientific interest among young individuals is substantial, given that a nation's literacy and economic vitality hinge on science and technology (Swarat et al., 2012). Blankenburg et al. (2015) elucidated that interest is a dynamic interplay between an individual and an object, subject, activity, or idea. The same authors report that young students may not actively engage with science and technology, posing potential challenges in the labor market. Notably, interest correlates directly with success and commitment to a goal. Besides, successful learning occurs when students have significant exposure to knowledge and ample time to grasp each concept, an achievement hindered in the absence of interest (Baram-Tsabari & Yarden, 2009).

Undoubtedly, the education system profoundly impacts students' interest in science. As van Griethuijsen et al. (2015) highlight, students exhibit substantial scientific interest up to the age of 10. The critical period spans from 10 to 14, during which interest either sustains or experiences a significant decline, ultimately solidifying a child's perspective on science. Children tend to gravitate toward fields like zoology and astrophysics in their early years. However, as school grades advance, exposure to more abstract concepts and higher mathematics often leads to a gradual waning of interest (Anderhag et al., 2016; Baram-Tsabari & Yarden, 2009).

This study aims to assess students' interest in science, specifically in physics, seeking to characterize their physics education experiences. One specific element under examination is the role of intervention regarding modern physics and its potential impact on students' interests. By exploring this factor, the study aims to contribute valuable insights into the dynamics that shape students' interest in physics. Our primary emphasis in this study lies within the realm of science education. Our objective is to comprehend phenomena associated with physics education rather than actively contributing to the theoretical discourse on the concept of interest (Hasni & Potvin, 2015).

## Science Education in Greek Schools

In the Greek educational system, science education is integral to compulsory education. The science curriculum includes topics from various scientific fields, including life science, material science, earth science, and technology. These subjects illustrate the intricate connections among science, technology, and human society, addressing environmental concerns, energy production, etc. The physics curriculum covers a range of fundamental scientific concepts and terms, such as the definition of matter, energy, force and Newton's laws. Also, students delve into the basics of electric circuits, optics, and heat.

Elementary school students are taught all the aforementioned subjects either in sixth or fifth grade. Advancing through the academic progression, middle school seniors delve into the core details of electricity, while high school students encounter a division in their curriculum. While all students receive instruction in electricity, those opting for a scientific career undertake a more profound exploration of the dynamic motions of bodies.

Besides that, the teaching of modern physics remains limited. The chosen approach is either to omit the teaching of modern physics altogether or to provide only a brief mention of it, typically shortly before students' transition to higher education, once classical perspectives have firmly established themselves in their consciousness (Choudhary et al., 2020; Gkiolmas et al., 2021; Kaur et al., 2017c; Velentzas & Halkia, 2013).

## Interest in Science & Didactic Interventions

Motivation and intrinsic interest in science have been focal points in educational research for several decades (Agranovich & Assaraf, 2013; Brophy, 2004; Osborne et al., 2003; Palmer, 2005). Logan and Skamp (2008) report that survey findings indicate that students generally hold positive attitudes towards "science in society" despite their negative perceptions of "school science". It is worth noting, however, that certain studies have identified a significant correlation between interest in school science and an overall positive perception of science in society (Osborne et al., 2003).

"School science" primarily concerns the systematic instruction of scientific subjects within recognized educational establishments, employing a structured curriculum to instill fundamental knowledge. In contrast, "science in society" extends the conversation beyond traditional classroom boundaries, embracing the dynamic interplay between scientific progress and the wider social landscape. This includes a conscientious examination and resolution of ethical, social, and cultural consequences stemming from scientific advancements (Allchin, 2011; National Academies of Sciences, Engineering, and Medicine, 2018).

Studies examining children's satisfaction with their science classes reveal that both their satisfaction and motivation to learn science are influenced by instructional methods (Agranovich & Assaraf, 2013). Children have identified that using diverse teaching approaches and engaging them in active learning positively impacts their attitude toward science in both school and general contexts (Osborne & Collins, 2001).

Another factor affecting motivation and attitudes toward science is the recognition of science as something significant and valuable. Research findings suggest that students experience diminished interest in learning due to the memorization requirements associated with scientific subjects (Gitatenia & Lasmawan, 2022). A strong interest in learning significantly impacts student success, while a lack of interest can profoundly affect academic achievement. However, a distinct decline in interest in science during school has been shown, starting in junior high and intensifying in high school (Reiss, 2004; Sorge, 2007). Agranovich and Assaraf's (2013) research included 1,298 primary students in grade 4grade 6 who responded to a Likert-type questionnaire, revealing that students preferred experiments and class discussions as a stimulating source of interest.

Interest in science can be broadly categorized into general or specific. In the former, science interest encompasses the entire spectrum of science-related subjects known to an individual. Conversely, at a more specific level, one may consider that a person's science interest could be confined to a particular school subject. To differentiate between various types of science interests, it is logical to reference the structure of school subjects (Krapp & Prenzel, 2011).

The importance of didactic interventions is generally recognized to foster interest in physics. Institutions and teachers should allocate significant attention to the teaching strategies employed, as their role in fostering positive attitudes towards science appears highly relevant (Tolstrup et al., 2014). Anderhag et al. (2016) report that although students seem interested in science experiments, there is little to suggest what experiments they like or why they have these preferences. The only guideline researchers should consider is that the objects studied for their effects on students' interest should have consequences for establishing continuity between school levels.

Despite the extensive range of didactic strategies available, the better approaches for increasing interest seem to be inquiry-based, context-based and model-based teaching (Aguilera & Perales-Palacios, 2020). Specifically, teaching using models and analogies enhances students' comprehension of scientific content. A model is commonly perceived as a representation of something. Children engage with this concept early on by playing with soft toys and miniatures, visiting museums, and playing games. The situation is analogous in education, as models or representations are frequently employed to explain, illustrate, or describe theoretical and/or practical content (Aguilera & Perales-Palacios, 2020).

The most commonly utilized models in science teaching encompass drawings, models, simulations, and analogies (Aguilera & Perales-Palacios, 2020). Recognizing the efficacy of model-based teaching in science education, researchers like Clement and Rea-Ramirez (2008) underscore its importance in fostering scientific literacy. The positive impact of the modelling process encouraged us to apply a didactic intervention to teach children Einsteinian physics concepts.

In a study by Agranovich and Assaraf (2013), 1,298 primary students (grade 4-grade 6) answered a Likert-type questionnaire containing open-ended questions. The study demonstrated that students liked experiments and saw discussions in class as a source of interest.

## Einsteinian Physics

The 20th century is a pivotal era in physics, witnessing the formulation of some of its most crucial theories that revolutionized our perception of the natural world. Albert Einstein played a pivotal role in this, introducing concepts like the general theory of relativity and explaining the photoelectric effect (Choudhary et al., 2020; Kaur et al., 2017a; Vakarou et al., 2024). His perspectives serve as a cornerstone in the trajectory of science and technological progress. Consequently, students should be taught Einstein's theories to encounter new knowledge and witness the progressive developments in physics. Engaging students in the exploration and comparison of classical physics with its modern counterpart not only fosters motivation and interest but also enhances their comprehension and scientific literacy (Choudhary et al., 2020; Dua et al., 2020; Foppoli et al., 2019; Levrini, 2014; Postiglione & Angelis, 2021; Vakarou et al., 2024). This observation pertains to students from year 7 as mentioned in Choudhary et al. (2020) but Foppoli et al. (2019) found in their research that a considerable number of educators participating in the study express the view that introducing modern physics could commence as early as age eight-age nine (grade 3) and beyond. The research also indicates a positive reception from both parents and students regarding the incorporation of these innovative concepts. Also, research on introducing modern physics in schools aims to raise school standards (Olsen, 2002).

According to Choundary et al. (2020), Einsteinian physics includes Einstein's work in the theory of relativity and his contribution to quantum physics. Einstein formulated a groundbreaking theory of gravity, proposing that gravity can be understood as a geometric phenomenon since it is the curvature of the four-dimensional spacetime caused by the presence of mass in the universe. This innovative concept is the cornerstone of the general theory of relativity, arguably Einstein's most renowned work. The implications of this theory can explain phenomena such as the existence of black holes, the big bang theory, and the expansion of the universe (Dua et al., 2020; Günther & Müller, 2020; Kavanagh & Sneider, 2006; Postiglione & Angelis, 2021; Zeidler, 2016).

Moreover, Einstein achieved a significant scientific breakthrough by asserting that light is not solely propagated as waves but is also composed of discrete units of energy known as photons. Einstein's revolutionary concept regarding the particle nature of light provided a groundbreaking interpretation of the photoelectric effect experiment (Rablau et al., 2019; Vakarou et al., 2024).

## METHODOLOGY

### Present Study

#### *Research objectives*

The purposes of the current research are, as follows:

1. Investigate whether the intervention could change students' interest in physics.
2. Compare students' interest in physics between primary education (grade 6), lower secondary education (grade 9), and upper secondary education (grade 11).

The research questions (**RQ**) are the following:

**RQ1.** Is there any difference in student's interest in physics in terms of their school level?

**RQ2.** Does the EP intervention impact students' change in interest?

#### *Participants*

A total of 325 students (147 girls and 178 boys) from primary and secondary education participated in the study. The sample was selected by convenient sampling, including students from schools across the Regional Unit of Ioannina, Greece. The sample included 83 students from 6$^{th}$ grade (11-12 years old), 126 students from 9$^{th}$ grade (14-15 years old), and 116 students from 11$^{th}$ grade (16-17 years old).

#### *The study*

The study implemented a face-to-face teaching intervention focused on Einstein's theory of gravity and the dual nature of light. These EP concepts, identified in the study by Choundary et al. (2020, p. 308), were selectively taught due to time constraints, aligning with the Greek curriculum. The program was delivered by a science educator–physicist who is the first author of this paper. We used diverse elements during teaching, including PowerPoint presentations, videos, questionnaires, and activities, following an activity-based learning strategy (Kavanagh & Sneider, 2006; Vakarou et al., 2024). The teaching methods were uniform across all classes. In the general framework of this study, three sets of questionnaires were employed; the conceptual and attitudinal results are published in another paper, turning the scientific interest of this paper into students' interest in physics before and after a teaching intervention in modern physics. Students completed questionnaires both before (pre-test) and after the teaching intervention (post-test). Notably, the post-test questionnaires mirrored the pre-test versions precisely. All students responded to every section, eliminating the need to categorize blank responses.

#### *Instrument*

All participants completed a questionnaire about interest in physics, consisting of eight questions. This questionnaire was found in similar studies (Cetinkaya & Tas, 2015; Chen et al., 2016; Deci et al., 1994; Koka & Hein, 2003; Pantazis et al., 2021). The questions were on the 5-point Likert scale with the following options: 1=strongly disagree; 2=disagree; 3=neutral-uncertain; 4=agree; and 5=strongly agree. The only change that has been made is the term "science", which became "physics".

**Figure 1.** Spacetime simulator experiment conducted in a classroom (Photo by authors)

### *Questionnaire validity*

The questions were validated based on the fact that they were selected from the literature (Cetinkaya & Tas, 2015; Chen et al., 2016; Deci et al., 1994; Koka & Hein, 2003; Novak & Wisdom, 2018; Pantazis et al., 2021) as well as a panel of four science educators and physicists assessed them to make it comprehensible. The questionnaire translation was performed by the authors.

## Pilot Study

A pilot study was conducted with 15 students across all educational levels of the target population. The translated version of the questionnaire was examined for age and language stability. Furthermore, the time required to complete the questionnaire was considered. According to the pilot study's findings, participants required less than five minutes to complete the questionnaire.

## About Teaching Intervention

We implemented a three-lesson program centered on the effective use of models, specifically employing the space-time simulator model to elucidate Einstein's concept of gravity. This model, constructed with an elastic fabric membrane symbolizing the universe and various-mass balls representing celestial objects, enhanced student engagement and interest (Foppoli et al., 2019; Kaur et al., 2017a; Kersting & Steier, 2018). For instance, the sun was represented by a large ball, while more petite balls depicted planetary movements around it. The membrane, made of lycra, featured a centrally positioned heavy mass, causing distortions that influenced the trajectories of the balls (Dua et al., 2020; Kersting et al., 2020). **Figure 1** shows spacetime simulator experiment conducted in a classroom.

Einstein's concept of light was briefly addressed, focusing primarily on the photoelectric effect (Foppoli et al., 2019). Utilizing a photon analogue, small projectiles fired from Nerf toy weapons represented photons. Materials involved in this experiment included Nerf guns, small-diameter bullets, identical ping pong balls, and bowls of various depths, aligning with the principles of the photoelectric effect, where electrons are ejected from a metal surface upon exposure to light. The analogue was addressed in the paper of Kaur et al. (2017b), where more details could be found. **Figure 2** shows photoelectric effect experiment conducted in a classroom.

The lessons of the program have had one hour duration each. The three lessons spaced one week apart. The first session involved the distribution of pre-test questionnaires along with a theoretical introduction to the topics, while post-teaching intervention questionnaires were administered to the students two weeks after the conclusion of the instructional sessions.

**Figure 2.** Photoelectric effect experiment conducted in a classroom (Photo by authors)

**Table 1.** Analysis of students' scores about interest in physics

| Statements | PE (11-12 years) | | LSE (14-15 years) | | HSE (16-17 years) | |
|---|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | Pre | Post |
| 1. I do my physics homework without getting bored, with pleasure. | 3.14 | 3.18 | 2.65 | 2.81 | 2.52 | 2.70 |
| 2. Physics is one of the lessons that I love. | 3.37 | 3.54 | 3.02 | 3.18 | 2.79 | 3.07 |
| 3. I am comfortable in the physics class. | 3.49 | 3.66 | 3.16 | 3.33 | 3.28 | 3.40 |
| 4. I love class studies & activities in physics lessons. | 3.23 | 3.42 | 2.94 | 3.08 | 2.98 | 3.17 |
| 5. I would like number of hours assigned to physics lessons to be increased. | 2.80 | 2.84 | 2.28 | 2.56 | 2.35 | 2.55 |
| 6. I find everything about physics interesting. | 2.99 | 3.17 | 2.65 | 2.82 | 2.56 | 2.72 |
| 7. I like reading books about science. | 2.69 | 2.70 | 2.50 | 2.75 | 2.46 | 2.53 |
| 8. I feel important when I work with science tools. | 3.18 | 4.11 | 3.05 | 3.75 | 3.22 | 3.84 |

Note. PE: Primary education; LSE: Lower secondary education; & HSE: Higher secondary education

### Statistical Data Analysis

Data collection was processed using SPSS and Excel software. Individual student scores were calculated by combining data for positive responses based on the Likert scale. Statistical tests, including paired samples t-test and one-way ANOVA test, were employed to compare students' interest in physics across three school levels. The significance level was set at $p=.05$, and in each case, p-values for all tests were above .05. The internal consistency of the evaluation measure was also examined. The alpha reliability test (Cronbach's alpha coefficients) examined internal consistency; the value was 0.897.

## RESULTS

### Descriptive Statistics

Calculating students' mean scores for statements in the questionnaire regarding interest is important. **Table 1** shows the calculated results before and after the intervention. The results could be evaluated according to Sozen and Guven (2019), categorizing them, as follows: mean score between 1-1.80 refers to "strongly disagree", range between 1.81-2.60 refers to "disagree", range between 2.61-3.40 refers to "neutral", range between 3.41-4.20 refers to "agree" and range between 4.21-5.00 refers to "strongly agree".

For example, the second statement of **Table 1** is noteworthy, where most primary school students initially exhibited a neutral stance (3.37) before the intervention. After the intervention, a notable shift occurred, with the majority agreeing (3.54). This illustrates the transformative impact of the teaching approach, indicating a positive change in students' interest in the physics lesson.

**Table 2.** A comparison between students' mean scores about interest at three school levels

| Primary education | | Lower secondary education | | Upper secondary education | |
|---|---|---|---|---|---|
| Pre | Post | Pre | Post | Pre | Post |
| 3.1114 | 3.3283 | 2.7808 | 3.0337 | 2.7694 | 2.9720 |

### Statistical Analysis

To observe if the intervention improved the scores regarding interest, the parametric paired samples t-test applied. The test indicated that post-test ranks (mean [M]=3.3283, standard deviation [SD]=0.09047) were statistically significantly higher in primary education than pre-test ranks (M=3.1114, SD=0.10057), t=-2.063, p=.042. Also, in lower secondary education, the results indicate a statistically significant improvement, t=-2.783, p=.006 as before the intervention students' scores (M=2.7808, SD=0.08208) were lower than after the intervention (M=3.0337, SD=0.07853). In upper secondary education, t=-2.823, p=.006, there was an improvement, too, with the mean scores being M=2.7694, SD=0.08130 before the intervention and M=3.1114, SD=0.07268 after the intervention (**Table 2**).

Also, one-way ANOVA test was conducted to determine if there was any difference between interests in terms of students' school level. Before the intervention, the test indicated a statistically significant difference, F (2, 322)=4.277, p=.015. Specifically, multiple comparisons comparing the school grades in pairs give, in each case, a statistically significant result–i.e., the interest of the students differs between the grades–except for the comparison between middle school and high school, where there is no statistically significant result (p>.05). Furthermore, the same test repeated after the intervention, where there was also a statistically significant difference, F (2, 322)=4.849, p=.008.

## DISCUSSION

The statistical analysis revealed that students initially demonstrated a neutral stance regarding interest in physics. This may be explained by the fact that the educational curriculum is falling short of satisfying children's innate curiosity about the world. However, following the teaching intervention, a statistically significant improvement was observed, indicating a positive impact of the instruction on students' interest.

The exploration of modern physics encourages students to engage with theories that elucidate phenomena previously lacking scientifically accepted explanations. Some results support what we already know, like how students like activities that are both fun and make them think (Palmer, 2009). Doing experiments is a big reason why students get more interested in science. So, when students learn about Einstein's important theories from the past century, their interest in physics goes up, no matter what grade they're in.

Significantly, an inverse relationship between "school grade" and "interest" persisted both before and after the intervention. The data indicates a concentration of interest in primary school surpassing that in lower secondary school, with higher secondary school students registering the lowest final scores. This aligns with prior research by Hasni and Potvin (2015), Osborne et al. (2003), and van Griethuijsen et al. (2015). The observed progressive decline in interest is suggested to be influenced by curricular structures and educational methodologies.

It's noteworthy that the primary student sample, drawn from the 6th grade, raises the possibility that these children may have already encountered various physics concepts, potentially impacting their interest. Additionally, the small two-year difference between 9$^{th}$ and 11$^{th}$ grade may not be sufficient to discern a significant decline in interest, potentially explaining the absence of a statistically significant difference between middle and high school students' interest.

It is plausible that the absence of a statistically significant difference in interest between middle and high school students could be attributed to the similarity in courses and content covered within the curricula outlined by the study. This suggests that the educational environment and content alignment may contribute more significantly to the observed patterns than the age difference per se.

## CONCLUSIONS

In this paper, results derived from a five-point Likert scale questionnaire regarding interest in physics are presented. The questionnaire was distributed to 325 students in the $6^{th}$, $9^{th}$, and $11^{th}$ grades across schools in Ioannina, Greece. The primary objective of this study is to explore if students have an inherent interest in physics as well as if a didactic intervention regarding Einsteinian physics can shift their interest. To attain this aim, we endeavored to incorporate Einstein's theories on gravity and light into pedagogical tools. Our intervention was based on the use of models as teaching techniques.

The findings suggest that cultivating students' interest in physics involves teaching modern physics to enhance scientific literacy and awareness of the latest theories. This may encourage future citizens to engage more actively in scientific activities. Moreover, there is an observed decrease in interest with students' increasing age, emphasizing the necessity of addressing this issue for the improvement of the education system.

This study serves as a valuable contribution to the ongoing discourse on effective pedagogical strategies and the cultivation of enduring interest in physics among students. Moreover, the findings of this study underscore the importance of integrating real-world applications of Einsteinian physics into educational resources, offering educators valuable insights for improving students' interaction with intricate scientific ideas. In the dynamic realm of science education, this study contributes meaningful perspectives to guide educators in developing innovative approaches that captivate students' curiosity and sustain their interest in physics over time.

### Limitations & Further Research

The methodology employed in this research possesses some limitations. First of all, the selection of the student sample was not random as we collaborated only with students coming from a specific geographical area, from schools that were easily accessible. Future studies are recommended to broaden their student sample and extend the teaching intervention to encompass additional school grades.

Furthermore, forthcoming researchers might consider the examination of general interest in physics from the examination of interest in physics within the framework of a school program. Conducting an extended investigation into the effects of a teaching intervention on students' interests and its correlation with the decision to pursue a career in science would also hold significance.

**Author contributions:** All authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. All authors approved the final version of the article.

**Funding:** The authors received no financial support for the research and/or authorship of this article.

**Ethics declaration:** The authors declared that the study did not require formal ethics approval since the data was completely anonymous, with no personal information collected (apart from age and sex). Informed consents were obtained from the research participants.

**Declaration of interest:** The authors declared no competing interest.

**Data availability:** Data generated or analyzed during this study are available from the authors on request.

## REFERENCES

Agranovich, S., & Assaraf, O. B. Z. (2013). What makes children like learning science? An examination of the attitudes of primary school students towards science lessons. *Journal of Education and Learning, 2*(1), 55-69. https://doi.org/10.5539/jel.v2n1p55

Aguilera, D., & Perales-Palacios, F. (2020). What effects do didactic interventions have on students' attitudes towards science? A meta-analysis. *Research in Science Education, 50*, 573-597. https://doi.org/10.1007/s11165-018-9702-2

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. *Science Education, 95*(3), 518-542. https://doi.org/10.1002/sce.20432

Anderhag, P., Wickman, P. O., Bergqvist, K., Jakobson, B., Hamza, K. M., & Säljö, R. (2016). Why do secondary school students lose their interest in science? Or does it never emerge? A possible and overlooked explanation. *Science Education, 100*(5), 791-813. https://doi.org/10.1002/sce.21231

Baram-Tsabari, A., & Yarden, A. (2009). Identifying meta-clusters of students' interest in science and their change with age. *Journal of Research In Science Teaching, 46*(9), 999-1022. https://doi.org/10.1002/tea.20294

Blankenburg, J. S., Hoffler, T. N., & Parchmann, I. (2015). Fostering today what is needed tomorrow: Investigating students' interest in science. *Science Education, 100*, 364-391. https://doi.org/10.1002/sce.21204

Brophy, J. (2004). *Motivating students to learn*. Routledge. https://doi.org/10.4324/9781410610218

Cetinkaya, M., & Tas, E. (2015). Developing, implementing, evaluation of an attitude scale for towards science and technology education. *Journal of Education and Human Development, 4*(2), 152-158. https://doi.org/10.15640/jehd.v4n2a18

Choudhary, R., Foppoli, A., Kaur, T., Blair, D., Burman, R. R., & Zadnik, M. G. (2020). A comparison of short and long Einsteinian physics intervention programs in middle school. *Research in Science Education, 52*, 305-324. https://doi.org/10.1007/s11165-020-09944-8

Clement, J. J., & Rea-Ramirez, M. A. (2008). *Model based learning and instruction in science.* Springer. https://doi.org/10.1007/978-1-4020-6494-4

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: The self-determination theory perspective. *Journal of Personality, 62*(1), 119-142. https://doi.org/10.1111/j.1467-6494.1994.tb00797.x

Dua, Y. S., Blair, D. G., Kaur, T., & Choudhary, R. K. (2020). Can Einstein's theory of general relativity be taught to Indonesian high school students? *Jurnal Pendidikan IPA Indonesia* [*Indonesian Journal of Science Education*]*, 9*(1), 50-58. https://doi.org/10.15294/jpii.v9i1.22468

Foppoli, A., Choudhary, R., Blair, D., Kaur, T., Moschilla, J., & Zadnik, M. (2019). Public and teacher response to Einsteinian physics in schools. *Physics Education, 54*, 015001. https://doi.org/10.1088/1361-6552/aae4a4

Gitatenia, I. D. A. I., & Lasmawan, I. W. (2022). The relationship of curiosity, confidence, and kinesthetic learning styles with interest in science learning. *MIMBAR PGSD Undiksha, 10*(2), 190-200. https://doi.org/10.23887/jjpgsd.v10i2.47551

Gkiolmas, A., Stoumpa, A., Lazos, P., Skordoulis, C., Chalkidis, A., Michalopoulos, V., & Balwit, J. (2021). An instructional method, based on POE (predict-observe-explain), for teaching two basic wave properties and the wave nature of light. *Journal of Physics: Conference Series, 1929*, 012086. https://doi.org/10.1088/1742-6596/1929/1/012086

Günther, H., & Müller, V. (2020). *The special theory of relativity: Einstein's world in new axiomatics.* Springer. https://doi.org/10.1007/978-981-13-7783-9

Hasni, A., & Potvin, P. (2015). Student's interest in science and technology and its relationships with teaching methods, family context and self-efficacy. *International Journal of Environmental & Science Education, 10*(3), 337-366.

Kaleva, S., Celik, I., Nogueiras, G., Pursiainen, J., & Muukkonen, H. (2023). Examining the predictors of STEM career interest among upper secondary students in Finland. *Educational Research and Evaluation, 28*(1-3), 3-24. https://doi.org/10.1080/13803611.2022.2161579

Kaur, T., Blair, D., Moschilla, J., & Zadnik, M. (2017b). Teaching Einsteinian physics at schools: Part 2, models and analogies for quantum physics. *Physics Education, 52*(6) 065013. https://doi.org/10.1088/1361-6552/aa83e1

Kaur, T., Blair, D., Moschilla, J., Stannard, W., & Zadnik, M. (2017a). Teaching Einsteinian physics at schools: Part 1, models and analogies for relativity. *Physics Education, 52*(6) 065012. https://doi.org/10.1088/1361-6552/aa83e4

Kaur, T., Blair, D., Moschilla, J., Stannard, W., & Zadnik, M. (2017c). Teaching Einsteinian physics at schools: Part 3, review of research outcomes. *Physics Education, 52*(6) 065014. https://doi.org/10.1088/1361-6552/aa83dd

Kavanagh, C., & Sneider, C. I. (2006). Learning about gravity II. Trajectories and orbits: A guide for teachers and curriculum developers. *Astronomy Education Review, 5*(2), 53-102. https://doi.org/10.3847/AER2006019

Kersting, M., & Steier, R. (2018). Understanding curved spacetime–The role of the rubber sheet analogy in learning general relativity. *Science & Education, 27*, 793-623. https://doi.org/10.1007/s11191-018-9997-4

Kersting, M., Toellner, R., Blair, D., & Burman, R. (2020). Gravity and warped time–Clarifying conceptual confusions in general relativity. *Physics Education, 55*(1) 015023. https://doi.org/10.1088/1361-6552/ab56d7

Koka, A., & Hein, V. (2003). Perceptions of teacher's feedback and learning environment as predictors of intrinsic motivation in physical education. *Psychology of Sport and Exercise, 4*(4), 333-346. https://doi.org/10.1016/S1469-0292(02)00012-2

Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education, 33*(1), 27-50. https://doi.org/10.1080/09500693.2010.518645

Levrini, O. (2014). The role of history and philosophy in research on teaching and learning of relativity. In M.R. Matthews (Eds.), *International handbook of research in history, philosophy and science teaching* (pp. 157-181). Springer. https://doi.org/10.1007/978-94-007-7654-8_6

Logan, M., & Skamp, K. (2008). Engaging students in science across the primary secondary interface: Listening to the students' voice. *Research in Science Education, 38*, 501-527. https://doi.org/10.1007/s11165-007-9063-8

National Academies of Sciences, Engineering, and Medicine. (2018). *Science and engineering for grades 6-12: Investigation and design at the center.* National Academies Press. https://doi.org/10.17226/25216

Osborne, J., & Collins, S. (2001). Pupils' views of the role and value of the science curriculum: A focus-group study. *International Journal of Science Education, 23*(5), 441-467. https://doi.org/10.1080/09500690010006518

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079. https://doi.org/10.1080/0950069032000032199

Palmer, D. (2005). A motivational view of constructivist-informed teaching. *International Journal of Science Education, 27*, 1853-1881. https://doi.org/10.1080/09500690500339654

Palmer, D. (2009). *Student interest generated during an inquiry skills lesson. Journal of Research in Science Teaching, 46*(2), 147-165. https://doi.org/10.1002/tea.20263

Pantazis, S., Stylos, G., Kotsis, K. T., & Georgopoulos, K. (2021). The effect of 3D printing technology on primary school students' content knowledge, anxiety and interest toward science. *International Journal of Educational Innovation, 3*(1), 38-50.

Postiglione, A., & Angelis, I.D. (2021). Students' understanding of gravity using the rubber sheet analogy: An Italian experience. *Physics Education, 56*, 025020. https://doi.org/10.1088/1361-6552/abd1c4

Rablau, C. I., Ramabadran, U. B., Book, B., & Cunningham, R. (2019). The photoelectric effect: Project-based undergraduate teaching and learning optics through a modern physics experiment redesign. In *Proceedings of the 15th Conference on Education and Training in Optics and Photonics*. https://doi.org/10.1117/12.2523860

Reiss, M. J. (2004). Students' attitudes towards science: A long term perspective. *Canadian Journal of Science, Mathematics and Technology Education, 4*, 97-109. https://doi.org/10.1080/14926150409556599

Salmela-Aro, K. (2020). The role of motivation and academic wellbeing–The transition from secondary to further education in STEM in Finland. *European Review, 28*(S1), S121-S134. https://doi.org/10.1017/S1062798720000952

Sorge, C. (2007). What happens? Relationship of age and gender with science attitudes from elementary to middle school. *Science Educator, 16*(2), 33-37.

Sozen, E., & Guven, U. (2019). The effect of online assessments on students' attitudes towards undergraduate level geography courses. *International Education Studies, 12*(10), 1-8. https://doi.org/10.5539/ies.v12n10p1

Swarat, S., Ortony, A., & Revelle, W. (2012), Activity matters: Understanding student interest in school science. *Journal of Research in Science Teaching, 49*(4), 515-537. https://doi.org/10.1002/tea.21010

Tolstrup, H., Møller, L., & Ulriksen, L. (2014). To choose or not to choose science: Constructions of desirable identities among young people considering a STEM higher education program. *International Journal of Science Education, 36*(2), 186-215. https://doi.org/10.1080/09500693.2012.749362

Vakarou, G., Stylos, G., & Kotsis, K. T. (2024). Probing students' understanding of Einsteinian physics concepts: A study in primary and secondary Greek schools. *Physics Education, 59*(2), 025004. https://doi.org/10.1088/1361-6552/ad1768 van Griethuijsen, R. A. L. F., van Eijck, M. W., Haste, H., den Brok, P. J., Skinner, N. C., Mansour, N., Gencer, A. S., & BouJaoude, S. (2015). Global patterns in students' views of science and interest in science. *Research in Science Education, 45*, 581-603. https://doi.org/10.1007/s11165-014-9438-6

Velentzas, A., & Halkia, K. (2013). The use of thought experiments in teaching physics to upper secondary level students: Two examples from the theory of relativity. *International Journal of Science Education, 35*(18), 3026-3049. https://doi.org/10.1080/09500693.2012.682182

Zeidler, E. (2016). *Phenomenology of the standard model for elementary particles. Quantum field theory I: Basics in mathematics and physics: A bridge between mathematicians and physicists*. Springer. https://doi.org/10.1007/978-3-540-34764-4