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# On the Effect of Inquiry-based Learning Activities on Students' Attitudes Toward Science

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## Abstract

This research investigates the change in high school students' attitudes toward science following the implementation of inquiry-based learning activities in Physics. Conducted with a sample of 22 students from general high schools in Larissa region, Greece, the study explores how a series of inquiry-based learning influences students' attitudes toward science. Using a Greek-adapted version of the Test of Science-Related Attitudes (TOSRA), attitudes were measured across five scales: Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. Data were collected Pre- and Post- the intervention.

Statistical analysis demonstrated significant improvements in Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, and Enjoyment of Science Lessons, suggesting that inquiry-based activities positively impact these areas. However, no significant changes were found in Leisure Interest in Science and Career Interest in Science, indicating these attitudes might be less influenced by structured activities or were already high at the study's onset measurement. Gender had no influence on students' attitudes toward science. On the other hand, Grade influenced the research outcomes, with Grade 11 students demonstrating statistically significant higher mean values in Career Interest in Science scale demonstrating higher mean values than Grade 10 students.

The study highlights the effectiveness of inquiry-based learning in fostering positive attitudes towards science. Its findings underscore the importance of tailored educational approaches to nurturing students' scientific curiosity and long-term engagement with science.

**Keywords:** Inquiry-Based Learning; Attitudes Toward Science; High School Students; Science Education; TOSRA (Test of Science-Related Attitudes)

## Introduction

Attitudes in everyday life refer to the positive or negative psychological tendencies towards objects or events, which are stable over time and significantly influence daily actions and behaviors [1,2]. In education, attitudes are perceived as subjective emotional reactions indicating favor or disfavor towards events, objects, people, or school subjects, influenced by learning processes and cognitive factors [3].

Researchers consider two domains when discussing "attitudes towards science": cognitive and affective. Cognitive attitudes focus on processing information and constructing knowledge, while affective attitudes emphasize emotional responses during learning [4]. Attitudes toward science are influenced by emotions, beliefs, and personal values, reflecting a multifaceted view that includes cognitive processes, contextual influences, and individual differences. Osborne et al. [3] describe attitudes from a social-

cognitive perspective, viewing them as handling information to develop understanding and knowledge while also encompassing the feelings experienced during learning.

Klopfer's taxonomy [5], established in 1971, categorizes scientific understandings and skills and enriches the framework for educators in terms of attitudes toward science. Incorporating Klopfer's taxonomy into educational planning helps educators foster holistic and engaging learning environments, promoting scientific knowledge and positive attitudes toward science.

Many studies have explored attitudes toward science using assessment tools based on students' epistemic beliefs and perceptions of the social impact of science [6]. One notable tool is the Test of Science-related Attitudes (TOSRA) developed by Fraser [7], which includes seven scales: Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. TOSRA assesses secondary education students' attitudes toward science and remains relevant in recent studies [8,9]. Gkagkas & Hatzikraniotis [10] have translated an adapted version of TOSRA into Greek, consisting of a five-scale assessment.

In line with global trends, this study seeks to comprehend the behavior and interests of students in the field of science by examining the factors that influence their attitudes. Specifically, the study aims to explore how inquiry-based activities in school physics affect the attitudes of secondary education students toward science. It also aims to analyze the influence of social and demographic factors such as gender and grade level.

The research questions are:

1. How do high school students' attitudes toward science change after participating in inquiry-based learning activities in Physics?

2. Does gender or grade affect students' attitudes toward science when participating in inquiry-based learning activities in Physics?

## Materials and Methods

A series of inquiry-based interventions in Physics was originally developed and implemented over a four-month period (February-May 2023). The study included 18 sessions, each lasting 40-45 minutes, and engaged students in three types of inquiry-based learning (confirmatory, structured, and guided) [11]. The thematic area covered in the interventions was within the scientific field of "Newtonian Mechanics." The research involved N=22 students (5 girls and 17 boys) of the 10 & 11 Grades. All students attended General high schools (Lyceum) in Larissa. During the inquiry-based activities, students were divided into small groups of 3-4 and encouraged to work collaboratively.

Throughout their investigations, students utilized online simulations from PhET Interactive Simulations (https://phet.colorado.edu) alongside hands-on laboratory equipment such as Pasco wireless carts, mass sets, digital scales, and personal laptops. They designed and conducted controlled experiments, encompassing all the stages of scientific inquiry, namely, formulating investigable questions, developing hypotheses, designing, and executing investigations, collecting experimental measurements, processing data, and drawing conclusions. Support (scaffolding) for executing each inquiry stage was explicitly provided, both in writing through given worksheets and orally by the educator, following the principles of the Inquiry Continuum [12,13].

Data collection regarding students' attitudes was carried out through the Greek-adapted version of the Test of Science-Related Attitudes (TOSRA) [10], which was administered before and after the research. Five scales were tested with TORSA questionnaire: "Attitudes to Scientific Inquiry", "Adoption of Scientific Attitudes", "Enjoyment of Science Lessons", "Leisure Interest in Science" and "Career Interest in Science". The questionnaire was administered before (pre-) and after (post-) the four-month research period.

A paired samples t-test was implemented to study students' differences in mean values in pre- and post-inquiry-based learning activities. To determine the gain for the whole intervention, also the Hake Gain index was computed [14] using a formula proposed by Marx & Cummings [15], recommended for small samples [16]. IBM SPSS Statistics (ver. 28) and MS Excel (ver. 16) were used to perform all the statistical analyses.

## Results and Discussion

After implementing the inquiry-based learning activities, statistically significant improvements were observed in students' attitudes on the first three out of the five scales of the TOSRA questionnaire. Specifically, for the scale Attitude to Scientific Inquiry (I), it was found that at the end of the intervention, students' mean values for attitudes toward science (M=4.28, SD=.51) were higher than those before (M=3.39, SD=.66), t(7.056, 21), p=<.001, with a 95% confidence interval from .63 to 1.15. For the scale Adoption of Scientific Attitudes (A), it was found that at the end of the intervention, students' mean values for attitudes toward science (M=4.03, SD=.72) were higher than those before (M=3.59, SD=.60), t(4.093, 21), p=<.001, with a 95% confidence interval from .21 to .66. Finally, for the scale Enjoyment of Physics Lessons (E), it was found that at the end of the intervention, students' mean values for attitudes toward science (M=4.61, SD=.43) were higher than those before (M=4.03, SD=.57), t(4.207, 21), p=<.001, with a 95% confidence interval from .29 to .86. These improvements indicate the overall positive impact of the interventions on enhancing students' attitudes towards Scientific Inquiry (I), Adoption of Scientific Attitudes (A), and Enjoyment of Science Lessons (E).

However, no statistically observed enhancement in students' attitudes regarding Leisure Interest in Science (L) and Career Interest in Science (C) was observed. The mean values for scale (L) were Pre (M=3.35, SD=.86) and Post (M=3.37, SD=1.12), and for scale (C), were Pre (M=3.28, SD=.85) and Post (M=3.26, SD=.94). The latter finding may indicate that although students generally improved their attitudes toward science, their Leisure

engagement with science is predominantly limited inside education environments. Also, their Career engagement with science may be predominantly limited to general academic aspirations rather than practical or research-based interests in scientific fields. According to these findings, it could be further suggested that while the inquiry-based activities effectively fostered a positive attitude toward learning and exploring science within a structured environment, additional strategies might be necessary to inspire a deeper, more personal connection to science that extends into the students' future career considerations.

Further analysis revealed that girls demonstrated higher mean values on each TOSRA scale than boys. However, these differences were not statistically significant. This trend suggests that female students may have a more positive view of scientific inquiry and science lessons in general, emphasizing the potential influence of gender on science education outcomes. These findings partially align with previous studies utilizing the TOSRA instrument and often report increased positive attitudes toward science favoring female students [9,17].

Grade 11 high school students demonstrated higher mean values on each TOSRA scale than Grade 10 students. However, statistically significant differences were found in some scales at the research's beginning and end. These were a) at the initial measurement (Pre) where Grade 11 students had a higher mean value on Scale I (Attitudes to Scientific Inquiry) (M=3.91) compared to first-year students (M=3.24), t(2.217,20), p=.04 with a 95% confidence interval from 0.04 to 1.32, and b) after the implementation of the inquiry-based learning activities (Post) where Grade 11 students had a higher mean value on Scale C (M=4.33, SD=.38) compared to Grade 10 students (M=2.95, SD=.81), t(3.678, 20), p=.001 with a 95% confidence interval from .60 to 2.17.

The latter research finding indicates a trend where Grade 11 high school students demonstrate higher mean values than Grade 10 students after implementing various types of Inquiry-Based Learning. These results highlight a pronounced and consistent inclination toward science-related attitudes and interests among Grade 11 students compared to Grade 10 students. Therefore, Grade 11 students seem to have developed a deeper connection with science, displaying higher mean values than Grade 10 students on every scale pre- and post-research. This may be related to the students' characteristics because of the fact that all Grade 11 students were enrolled in a specific number of advanced placement courses in the "Science and Medical Studies category" at their General High Schools, meaning that some of them are planning to go through a highly competitive exam process to secure admission to Higher Education. Other studies report mixed results regarding the effect of grade level, which sometimes favors higher grades [17] and sometimes favors lower grades [9].

Subsequently, the Hake Gain (average of gains) was calculated. Based on the findings, for scales Attitude to Scientific Inquiry (I) and Adoption of Scientific Attitudes (A) there is a Proficient gain (Medium, M) between Pre- and Post- the research. The third scale, Enjoyment of Science Lessons (E), achieves a high gain over the entire research, indicating substantial improvement in students' enjoyment of science lessons. Finally, the gains in the fourth and fifth scales remain marginal (Low, L), suggesting that inquiry-based learning activities did not significantly enhance students' leisure and career interests in science.

## Conclusion

The current research investigated the effect of inquiry-based activities on 10th and 11th-grade students' attitudes toward science. The results demonstrated that students' attitudes improved. Statistically, significant differences were found between pre- and post-assessments in three out of the five scales of the Greek-adapted TOSRA questionnaire. These scales were "Attitudes to Scientific Inquiry," "Adoption of Scientific Attitudes," and "Enjoyment of Science Lessons," suggesting that the inquiry-based activities in which the students participated were effective in general fostering positive attitudes toward science. However, no statistically significant differences were found in the "Leisure Interest in Science" and "Career Interest in Science" scales. This finding may suggest two plausible explanations. Firstly, students' engagement with science during their leisure time and in terms of future careers may be tied more to general academic interests rather than specific practical or research-based interests. Secondly, it's possible that students' attitudes were already quite positive at the beginning of the inquiry-based interventions and thus remained consistently high throughout the research period.

These results indicate that while inquiry-based learning activities effectively improve certain attitudes toward science, they may not influence others, leading to several implications and additional tailored strategies for further research. So, future research could expose students to real-world applications and maybe career guidance during inquiry-based interventions to enhance students' leisure and career interests in science. These interventions could also include career talks and activities that align more with students' interests.

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## Conflict of Interest

No conflict of interest.

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