

Article

Attitudes and Interest of Greek Students Towards Science

Vasileios Gkagkas , Eleni Petridou  and Euripides Hatzikraniotis

Physics Department, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece; elepet@auth.gr (E.P.); evris@physics.auth.gr (E.H.)

* Correspondence: vgkagk@auth.gr

Abstract

Understanding students' attitudes toward science is vital for fostering engagement in scientific fields. This study aimed to adapt and validate the Test of Science-Related Attitudes (TOSRA) for Greek upper-secondary Physics classrooms and explore how attitudes vary by gender, grade, and school location. A translated and culturally adapted version of TOSRA was administered to 662 students (grades 10–11) from urban and rural schools. Five of the original seven factors were retained. Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) tested the factor structure and reliability. Group comparisons were conducted using *t*-tests. A 32-item, five-factor structure showed good fit (CFI = 0.969, TLI = 0.966, RMSEA = 0.064) and high internal consistency ($\alpha = 0.89$ overall). Students reported stronger acceptance of inquiry and enjoyment-related factors compared with leisure and career interest. Boys scored higher on Leisure, 11th graders on Adoption of Scientific Attitudes, and rural students on Career Interest. The Greek TOSRA-Physics is a valid and reliable instrument for assessing science attitudes and evaluating inquiry-based programs.

Keywords: TOSRA questionnaire; attitudes toward science; secondary education



Academic Editor: Andrea C. Borowczak

Received: 1 July 2025

Revised: 1 September 2025

Accepted: 5 September 2025

Published: 7 September 2025

Citation: Gkagkas, V., Petridou, E., & Hatzikraniotis, E. (2025). Attitudes and Interest of Greek Students Towards Science. *Education Sciences*, 15(9), 1171. <https://doi.org/10.3390/educsci15091171>

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1. Introduction

Social psychology views attitudes as positive or negative evaluations of an object or event, characterized by their persistence over time. When combined with beliefs, which involve stable knowledge about an object or event, attitudes influence nearly all daily actions (Schacter et al., 2011). In education, attitudes toward science are seen as subjective emotional responses that reflect favor or disfavor toward events, objects, people, or even school subjects (Albarracín et al., 2014; Osborne et al., 2003). To clarify these definitions and link them to everyday school contexts and practices, attitudes guide students on “what” to do, while beliefs indicate “how” they should do it (Schacter et al., 2011).

An example of a positive attitude is the statement, “I enjoy attending Physics class” while an example of a negative attitude is, “I do not like Physics class”. Further specifying attitudes, they consist of both cognitive and affective components. The cognitive component is shaped by mental information processing aimed at constructing meaning and knowledge. In contrast, the affective component is influenced by the emotions evoked in students, which are generated collectively through the learning process (Osborne et al., 2003). Various studies investigating the impact of the learning process on students' attitudes support this conclusion. Specifically, Anghelache (2013) found that students' attitudes are influenced by participation, purpose, and achievement, while Winberg and Hedman (2008) further emphasized that students' prior knowledge and the type of education can interact with their emotional responses, affecting their attitudes.

A clear distinction among attitudes is the differentiation between scientific attitudes and attitudes toward science (Gardner, 1975). The former is grounded in honesty, scientific thinking, skepticism, and practices that emphasize the quest for knowledge and understanding by validating scientific claims with data. The latter pertains to students' dispositions regarding science, the scientific tools they utilize, and the influence of science on society (Osborne et al., 2003). Consequently, some researchers categorize attitudes within the affective domain, while others place them in the cognitive domain, and some use the terms interchangeably (Aydeniz & Kotowski, 2014).

Klopfer (1971) presented a taxonomy regarding students' attitudes and interests toward the natural sciences, based on Krathwohl's taxonomy. This taxonomy incorporates all three domains of student behavior, cognitive, affective, and psychomotor, along with the methodology of the natural sciences. The categorization he introduced, titled "Attitudes and Interests," positions attitudes within the affective domain as follows:

- Manifestation of favorable attitudes toward science and scientists;
- Acceptance of scientific inquiry as a way of thought;
- Adoption of "scientific attitudes";
- Enjoyment of science learning experiences;
- Development of interests in science and science-related activities;
- Development of interest in pursuing a career in science.

Numerous studies have been conducted globally to develop questionnaires that explore attitudes toward science. The various tools identified in the literature aim to examine different aspects of these attitudes, including beliefs about the nature of science (Chen, 2006) and perceptions of the social impact of science (Xiao & Sandoval, 2017). One notable tool is Fraser's Test of Science-Related Attitudes (TOSRA), which utilizes Klopfer's taxonomy, "Attitudes and Interests in the Natural Sciences" (Klopfer, 1971) and is designed to measure the attitudes of secondary education students toward science (Fraser, 1978, 1981). Fraser (1978) divided the first element of Klopfer's taxonomy into two factors, "Social Implications of Science" and "Normality of Scientists," resulting in a questionnaire that assesses a total of seven attitudes of secondary education students related to science. The TOSRA questionnaire comprises 70 items (questions) divided into 7 factors (scales) that evaluate (a) Social Implications of Science (S; students' attitudes towards the social benefits and problems of science), (b) Normality of Scientists (N; perceptions of scientists as ordinary individuals with normal lives), (c) Attitude to Scientific Inquiry (I; acceptance of experimentation and inquiry as ways of understanding the natural world), (d) Adoption of Scientific Attitudes (A; open-mindedness and willingness to change views when presented with evidence), (e) Enjoyment of Science Lessons (E; students' enjoyment and interest in science classes and laboratory activities), (f) Leisure Interest in Science (L; interest in science-related hobbies and extracurricular activities), and (g) Career Interest in Science (C; willingness to pursue a science-related career).

The development and use of validated and standardized research instruments for measuring attitudes towards science are essential, as they ensure the validity of comparisons between different groups and enable the conduct of reliable international and cross-cultural studies (Tai et al., 2022). These instruments enable researchers to evaluate differences in educational practices, track changes in students' attitudes over time, and assess the effectiveness of educational interventions. In this way, they enhance international education research and contribute to the creation of scientifically informed educational policies.

Methodological validity is a crucial requirement for accurately measuring and evaluating students' attitudes toward science (Tai et al., 2022). It is essential to ensure the validity and reliability of research tools used to assess students' attitudes and perceptions in science education. Particular care is necessary when adapting questionnaires cross-culturally to

preserve the conceptual equivalence of the items and to confirm that the instrument is suitable and valid within the new linguistic and educational environment (Chen, 2006).

The first factor, Social Implications of Science (S), assesses the expression of positive attitudes toward science and scientists. It includes items about students' perceptions regarding the societal advantages and challenges associated with scientific research and progress. Examples of items include "Money spent on science is well worth spending" and "Scientific discoveries are doing more harm than good".

The second factor, Normality of Scientists (N), explores students' perceptions of whether scientists are typical individuals or eccentric personalities. It investigates how students view scientists as individuals and their opinions on whether scientists lead a conventional lifestyle. Examples of items include "Scientists like sport as much as other people do" and "Scientists are just as interested in art and music as other people are".

The third factor, Students' Attitudes toward Scientific Inquiry (I), examines whether students embrace scientific inquiry as a mode of thinking. Specifically, it evaluates students' attitudes toward scientific experimentation and their acceptance of investigation as a method for gathering information about the natural world. Examples of items include "I would prefer to find out why something happens by doing an experiment than by being told" and "I would rather solve a problem by doing an experiment than be told the answer".

The fourth factor, Adoption of Scientific Attitudes (A), examines the degree to which students are open-minded and their willingness to revise their views in response to scientific evidence. Examples of items include "I am unwilling to change my ideas when evidence shows that the ideas are poor" and "I enjoy reading about things which disagree with my previous ideas."

The fifth factor, Enjoyment of Science Lessons (E), examines the enjoyment students experience in scientific laboratories and, more broadly, in science classes. Examples of items include "Science lessons are fun" and "Science lessons are a waste of time".

The sixth factor, Leisure Interest in Science (L), aims to reflect students' interests in their hobbies and extracurricular activities associated with science. Examples of items include "I would like to belong to a science club" and "I dislike reading books about science during my holidays".

Finally, the seventh factor, Career Interest in Science (C), aims to assess students' interest in pursuing careers related to science. Some example items are "I would dislike being a scientist after I leave school" and "I would dislike a job in a science laboratory after I leave school".

The TOSRA is an internationally recognized tool utilized in numerous studies in secondary education (Agunbiade, 2021; Naiker et al., 2020; Sharma et al., 2021). Many studies have been conducted globally using this questionnaire (Welch, 2010). TOSRA provides unique theoretical and practical advantages over other tools, owing to its foundation in Klopfer (1971)'s taxonomy. Its multidimensional framework enables the evaluation of various aspects of students' attitudes, including enjoyment, career interest, and acceptance of scientific methods (Fraser, 1978). Practically, its straightforward structure and ease of use make it ideal for comparative research, assessing educational interventions, and application in various educational and cultural environments.

A consistent need has been recognized for validated tools that measure secondary students' attitudes toward science in Greece. Because inquiry and experiment-based instruction are central to recent curricula changes, a suitable measure is needed to support the assessment of classroom methods and programs. This gap limits the ability to evaluate and improve educational practices, hindering the development of effective, evidence-based instructional strategies. This study aims to address this issue by adapting and validating the TOSRA for the Greek educational context, thereby significantly enhancing

the methodological framework for researching students' attitudes towards physics. In the Greek context, the TOSRA could function as an evaluation tool for both teaching interventions implemented in the classroom and the new science curricula, which adopt constructivist approaches that emphasize inquiry-based learning (<https://iep.edu.gr/en/>, accessed on 1 June 2025). Since the TOSRA was developed in English, it needs to be translated and adapted into the Greek language for use with Greek students. This study describes the process of adapting the TOSRA questionnaire into Greek and specifically into the educational context of Physics for secondary education students attending General Lyceums. This adaptation was not limited to a direct translation of the original factors but also included the removal of factors that did not align with the objectives of the study and modifications in the wording of certain items. These changes aimed to better reflect the scientific field of Physics and the experimental activities conducted within the Greek school environment.

Despite TOSRA's widespread international use, a validated Greek version tailored for upper-secondary Physics has not yet been available. This study fills that gap by adapting and validating a shortened five-factor model and presenting factor means, relationships, and group comparisons specific to Greece. The research questions are as follows:

1. What is the factor structure and reliability of the Greek adaptation of the TOSRA questionnaire, based on exploratory and confirmatory factor analyses?
2. What are the levels of acceptance across the five retained factors of the TOSRA questionnaire, and how are these factors interrelated in terms of students' attitudes toward science?
3. To what extent do students' demographic characteristics—such as gender, school location (urban vs. rural), and grade level (10th vs. 11th)—influence their attitudes toward science across the dimensions of the TOSRA questionnaire?

2. Materials and Methods

2.1. Sample and Questionnaire Administration Process

The questionnaire was administered to a sample of 707 first- and second-year high school students from public schools in two geographic regions of Greece (Athens/urban and Larisa/rural) during the 2022–2023 academic year. The participating students had prior experimental experience, and the teachers who administered the questionnaire to their classes reported that both they and past teachers had conducted experiments in the physics laboratory.

The administration process of the questionnaire aligned with Fraser's (1981) description. Students were informed about the study's purpose and invited to participate voluntarily, without monetary compensation, and assured of their anonymity and their right to withdraw. Additionally, brief instructions were provided on how to use the five-point Likert scale: Not at all true (1), Slightly true (2), Moderately true (3), Quite true (4), and Very true (5). Students were advised not to answer items they did not understand. Moreover, they were encouraged to ask questions to prevent potential misunderstandings and to further reduce the likelihood of unanswered items. There was no time limit for completing the questionnaire. The average completion time was about 20 min, with the maximum observed time being 30 min, which corresponds with the time limits reported by Fraser (1981).

2.2. Process of Adapting the Questionnaire into Greek

The adaptation of TOSRA into Greek aimed to make it suitable for Greek students while maintaining a close relationship with the original as possible. Cultural modifications were kept to a minimum to ensure comparability and high reliability. Two educators collaborated to translate the questionnaire into Greek: a Physics teacher (who is also the

co-author of this study) and an English Literature teacher. The translation was tailored to ensure that students aged 16–17 could comprehend it. Five of the seven factors in the original questionnaire were selected, excluding the “Social Implications of Science (S)” and “Normality of Scientists (N)” factors. This choice is based on our study, which focuses on classroom-related outcomes of experimental and inquiry-based physics. The S and N scales assess broader socio-cultural concepts (views about science’s societal impact and images of scientists), which were not primary goals and would have expanded the scope of the construct domain, making it harder to interpret the effects within our educational framework. Additionally, the full 70-item TOSRA can be a burden for respondents; shortening the instrument improved feasibility for in-class administration and reduced the risk of missing data without compromising our goals. Finally, the N scale is sensitive to culture-specific stereotypes and, without a related intervention on scientist identity, could risk becoming irrelevant in the current Greek context. For these reasons, we retained the five scales (I, A, E, L, C) that most directly relate to the teaching practices and outcomes we are examining.

After translation, a Greek Language and Literature teacher reviewed the questionnaire for spelling and grammar. It was then piloted on a small sample of students ($n = 5$) for semantic validation during two 45-min sessions with five first-year high school students. During these sessions, each question was read aloud, and students were asked to express in their own words what they understood from each question. This process led to minor rewording of certain items for better clarity. The revised items were subsequently resubmitted to the language teacher for a final spelling and grammar check.

3. Results

3.1. Questionnaire Evaluation Process

Figure 1 presents the sample selection process for administering the questionnaire. Initially, questionnaires were collected from 707 students; however, 45 were excluded from the analysis. Specifically, 5 students were removed due to a lack of prior experimental experience in science, and 40 questionnaires were excluded because they were incomplete. As a result, the final sample comprised 662 students, including 438 first-year students (66.2%) and 224 second-year students (33.8%) from high schools. The gender distribution was balanced, with 332 boys (50.2%) and 330 girls (49.8%). In terms of geographic representation, 428 students (64.7%) came from general rural high schools (Larisa Prefecture), while 234 students (35.3%) were from two urban schools (Attica). The sample of 662 students was then randomly divided into two equal groups, Group A ($n = 331$) and Group B ($n = 331$), ensuring balanced representation regarding gender, grade level, and geographic area. Exploratory Factor Analysis (EFA) was applied to the responses from Group A, while Confirmatory Factor Analysis (CFA) was carried out on the responses from Group B.

Exploratory Factor Analysis (EFA) identifies the number and structure of latent variables that underlie responses to observed variables (Watson, 2017). It groups interrelated items into factors that explain shared variance with minimal terms. In this study, EFA was essential because the questionnaire was modified and applied to a different sample than originally intended (Field, 2013).

EFA aims to explain shared variance using the fewest factors by eliminating items that do not significantly contribute to the factor structure (Field, 2013). Güvendir and Özkan (2022) outline three primary strategies for item removal:

1. Remove items with high loadings across multiple factors when the difference in loading is less than 0.10, starting with the smallest difference until each item loads on only one factor.
2. Immediately eliminate all items with cross-loadings below 0.10, then repeat the process until all items clearly load on a single factor.

3. Remove items that show significant loadings on more than two factors (difference < 0.10), then continue using the first strategy.

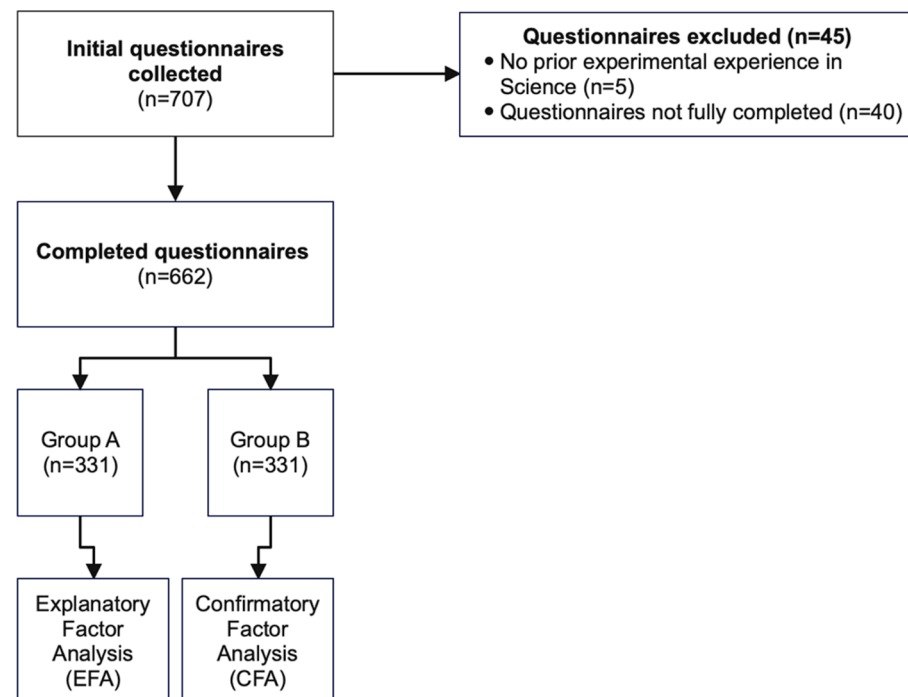


Figure 1. Flow of the questionnaire sample selection process.

This study followed the third strategy, showing slightly higher reliability indices than the other two (Güvendir & Özkan, 2022).

Several methods are employed to estimate the number of factors, such as the Eigenvalue criterion (Larsen & Warne, 2010), Scree Plot (Cattell, 1966), Bartlett's χ^2 test (Bartlett, 1950), and Parallel Analysis (Horn, 1965). These methods often produce different results due to their inherent limitations, ultimately leaving the final decision to the researcher. This variability arises because each technique possesses distinct characteristics and limitations. For instance, determining factors using the Eigenvalue criterion may lead to overestimating factors and is affected by sample size and data structure (Bobko & Schemmer, 1984; Hayton et al., 2004). The Scree Plot requires subjective judgment (Ledesma et al., 2015), while Bartlett's test is sensitive to small sample sizes (Ma et al., 2015).

This study utilized both the Scree Plot and Parallel Analysis to determine the number of factors. The Scree Plot is deemed reliable for samples exceeding 200 (Yong & Pearce, 2013), while Parallel Analysis provides more accurate estimates by comparing actual data eigenvalues with those derived from random data (Ledesma & Valero-Mora, 2007). Factor loadings below 0.35 were excluded. Extraction was conducted using Principal Axis Factoring, and Direct Oblimin rotation was applied to facilitate correlations among factors (Asparouhov & Muthén, 2009; Field, 2013).

Confirmatory Factor Analysis (CFA) assesses whether observed data align with a pre-determined theoretical model by analyzing the relationships between latent and observed variables (Smelser & Baltes, 2001). Unlike Exploratory Factor Analysis (EFA), CFA limits items to specific factors, enabling researchers to confirm or refute the proposed structure (Yialamas et al., 2024).

CFA evaluated the model fit from EFA, calculating several indices. The CMIN/DF index should be less than 5.0 (Hu & Bentler, 1999). The Comparative Fit Index (CFI) measures how well the model fits compared to an independent null model, with values

above 0.95 suggesting a good fit (Padgett & Morgan, 2019). The Tucker–Lewis Index (TLI) reflects how well the theoretical model fits observed data, with values near 1 indicating a good fit and above 0.90 considered acceptable (Cai et al., 2023). The Goodness of Fit Index (GFI) measures discrepancies between sample and estimated covariances, with a cutoff around 0.93 for $n > 100$ indicating a better fit (Cho et al., 2020). The Root Mean Square Error of Approximation (RMSEA) shows how well observed data match the model, with a cutoff near 0.06 indicating a good fit (Hu & Bentler, 1999).

In the CFA, the cutoff factor loading (λ_{ik}) was set to 0.35. After extracting factors, internal reliability was evaluated using Cronbach's α , both overall and per factor, to assess the relatedness of questionnaire item responses. Discriminant validity was then measured with the Mean Inter-Item Correlation index to gauge each factor's mean correlation with others. Finally, independent samples t -tests examined the impacts of gender, region, and grade level on student attitudes. Questionnaire analysis utilized IBM SPSS (ver. 28.0) and JASP (ver. 0.16.4).

3.2. Exploring the Factor Structure and Reliability of the Greek Adaptation of the TOSRA Questionnaire

3.2.1. Results of EFA (Group A, $n = 331$)

It was determined that only the question Q17 of the questionnaire, "Finding out about new things is unimportant", had skewness (-2.09) and kurtosis (4.07) values that fell outside the normality range of $[-2, 2]$ (George & Mallery, 2019). Also, question Q12, "I am curious about the world in which we live", demonstrated skewness (-1.59) and kurtosis (2.01) values within the normality limits. The generation of boxplots for each question did not show any outliers, and the analysis of Q-Q plots indicated that the items fell within the normality limits. Bartlett's test of sphericity yielded results ($\chi^2 = 6785.255$, $df = 1176$, $p < 0.001$), demonstrating that the questionnaire items are interrelated and appropriate for identifying underlying structure.

Figure 2 presents the Scree Plot and the results of the Parallel Analysis conducted to determine the optimal number of factors to extract from the data. As clearly shown in the figure, a distinct break point is observed at the seventh factor, suggesting that the optimal number of factors to retain is six. This finding is further supported by the results of the Parallel Analysis, where the eigenvalues of the first six factors derived from the actual data clearly exceed those obtained from randomly simulated data. From the seventh factor onward, the eigenvalues converge with those from the randomly simulated datasets, indicating that additional factors do not significantly enhance the explained variance. Based on these findings, we conclude that a six-factor solution is the most suitable for analyzing these data, as it provides a clear and reliable interpretation of the underlying structure of the questionnaire.

Table 1 presents the factor loadings for the 50 items from exploratory factor analysis, categorized by the six extracted factors, with positive or negative directions specified. Loadings above 0.35 are viewed as significant and indicate each item's relation to its factor. The structure captures distinct dimensions of students' attitudes toward science, with each item aligning with their corresponding factor. Factor 6 consists of two items.

Figure 3 illustrates the step-by-step procedure for eliminating items used in this study, based on the aforementioned methodological criteria. The figure reveals that from the initial pool of 50 items, one item was excluded at the preliminary stage due to Skewness and Kurtosis values that exceeded the acceptable limits for normal distribution $[-2, +2]$. Next, a five-stage iterative process adopting the third cross-loading elimination strategy. Items were eliminated if they had factor loadings below 0.35 or loaded on more than one factor. This approach led to the exclusion of an additional 10 items. After this screening, an initial six-factor model with 34 items emerged. However, the sixth factor was identified as

unstable since it consisted of only two items (Q24, Q43), which made the factor unsuitable for further analysis as it can be found in the literature (Costello & Osborne, 2005). As a result, these two items were removed from the model. Finally, the process resulted in a final model of 32 items across five defined factors.

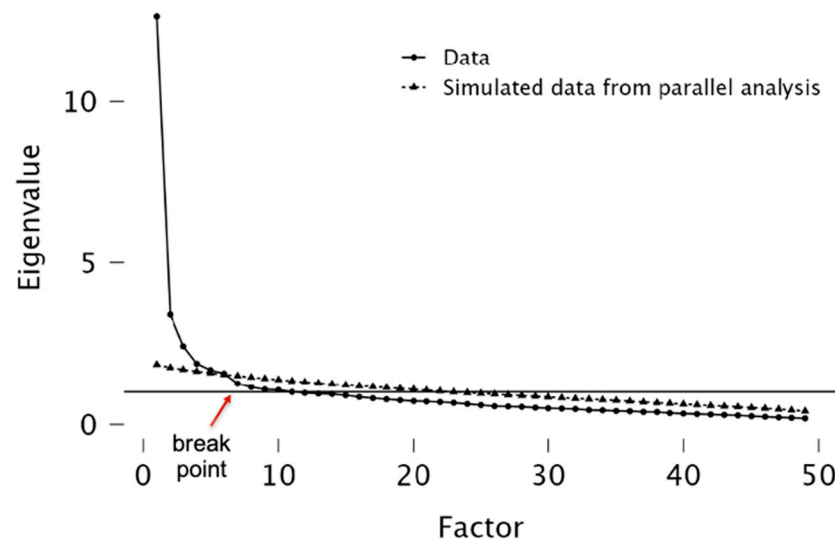


Figure 2. Scree plot and confirmation via parallel analysis for determining the number of factors.

Table 1. Pattern Matrix of EFA with Loading Coefficients for Each Item (n = 331) (Qxx refers to item numbers; Fx denotes the factor number; “+” or “−” indicates the direction of each item’s phrasing).

	F1	F2	F3	F4	F5	F6	Comments
Factor 1. Attitude to Scientific Inquiry (I)							
Q36. It is better to ask the teacher the answer than to find it out by doing experiments (−)	0.593	−0.047	0.238	−0.004	0.022	−0.048	
Q26. I would rather find out about things by asking an expert than by doing an experiment (−)	0.592	0.025	0.113	−0.192	−0.189	−0.103	
Q46. It is better to be told scientific facts than to find them out from experiments (−)	0.539	0.082	0.019	0.101	0.068	−0.046	
Q21. I would prefer to do my own experiments than to find out information from a teacher (+)	0.481	0.086	−0.290	0.006	−0.135	0.202	
Q31. I would rather solve a problem by doing an experiment than be told the answer (+)	0.433	−0.040	−0.038	0.228	0.181	0.131	
Q41. I would prefer to do an experiment on a topic than to read about it in science magazines (+)	0.407	0.001	−0.217	0.099	0.083	0.308	
Q16. I would rather agree with other people than do an experiment to find out for myself (−)	0.385	−0.003	0.088	0.095	0.231	−0.075	
Q1. I would prefer to find out why something happens by doing an experiment than by being told (+)	0.295	0.143	−0.122	0.106	0.201	0.046	Loading < 0.35

Table 1. Cont.

	F1	F2	F3	F4	F5	F6	Comments
Q6. I would rather find out about things by asking an expert than by doing an experiment (–)	0.340	0.154	–0.084	0.082	–0.013	–0.164	Loading < 0.35
Q11. I enjoy reading about things which disagree with my previous ideas (+)	0.311	0.257	–0.270	–0.049	–0.064	0.206	Loading < 0.35
Factor 2. Adoption of Scientific Attitudes (A)							
Q22. I like to listen to people whose opinions are different from mine (+)	–0.172	0.579	0.067	–0.072	–0.017	0.072	
Q47. I dislike listening to other people's opinions (–)	–0.085	0.521	–0.006	–0.058	0.149	–0.061	
Q27. I find it boring to hear about new ideas (–)	0.032	0.457	0.108	0.123	0.216	–0.218	
Q37. I am unwilling to change my ideas when evidence shows that the ideas are poor (–)	0.119	0.424	0.013	–0.025	–0.060	–0.071	
Q2. I enjoy reading about things which disagree with my previous ideas (+)	–0.036	0.356	0.164	–0.115	–0.071	0.193	
Q12. I dislike repeating experiments to check that I get the same results (–)	0.144	0.316	–0.216	0.060	0.087	0.078	Loading < 0.35
Q17. In science experiments, I like to use new methods which I have not used before (+)							Skewness, Kurtosis
Q7. I would rather solve a problem by doing an experiment than be told the answer (+)	0.079	0.173	0.140	0.110	0.177	–0.058	Loading < 0.35
Q32. I get bored when watching science programs on TV at home (–)	0.021	0.157	0.039	0.292	0.146	0.256	Loading < 0.35
Q42. When I leave school, I would like to work with people who make discoveries in science (+).	0.280	0.299	0.084	0.173	–0.096	0.153	Loading < 0.35
Factor 3. Enjoyment of Science Lessons (E)							
Q38. The material covered in science lessons is uninteresting (–)	0.126	0.118	0.623	–0.015	–0.031	0.001	
Q8. I dislike science lessons (–)	–0.078	0.127	0.609	0.032	0.058	0.001	
Q48. I would enjoy school more if there were no science lessons (–)	0.017	–0.012	0.469	0.080	0.144	0.011	
Q18. Science lessons bore me (–)	–0.007	0.090	0.468	0.128	0.148	0.098	
Q23. Science is one of the most interesting school subjects (+)	0.044	0.078	0.457	0.126	0.043	0.297	
Q13. School should have more science lessons each week (+)	0.138	–0.284	0.450	0.001	0.237	0.157	
Q3. I would prefer to do experiments than to read about them (+)	0.024	–0.067	0.326	0.125	0.254	0.128	Loading < 0.35

Table 1. Cont.

	F1	F2	F3	F4	F5	F6	Comments
Q43. I would dislike a job in a science laboratory after I leave school (–)	0.168	0.105	0.313	0.189	0.011	0.381	Unstable factor
Q28. The material covered in science lessons is uninteresting (–)	0.123	0.457	–0.003	0.023	0.302	–0.068	Loading in more factors
Q33. I would like to be given a science book or a piece of scientific equipment as a present (+)	0.054	0.582	0.088	0.046	0.045	0.255	Loading in more factors
Factor 4. Leisure Interest in Science (L)							
Q19. I dislike reading books about science during my holidays (–)	0.140	0.098	0.018	0.598	–0.040	0.058	
Q29. Talking to friends about science after school would be boring (–)	0.057	0.168	0.055	0.592	0.032	–0.017	
Q39. Listening to talk about science on the radio would be boring (–)	0.036	0.046	0.054	0.572	0.106	0.131	
Q9. I get bored when watching science programs on TV at home (–)	0.108	–0.064	0.050	0.530	0.084	0.224	
Q49. I dislike reading newspaper articles about science (–)	0.212	0.182	0.035	0.413	0.164	–0.149	
Q4. I would rather agree with other people than do an experiment to find out for myself (–)	0.341	–0.109	0.062	0.253	0.086	0.233	Loading < 0.35
Q14. Finding out about new things is unimportant (–)	0.247	–0.086	0.349	0.037	0.106	0.389	Loading in more factors
Q24. Science lessons bore me (–)	0.058	0.186	–0.014	0.236	0.031	0.597	Unstable factor
Q34. I dislike reading books about science during my holidays (–)	0.423	–0.023	0.258	–0.010	–0.066	0.352	Loading in more factors
Q44. Working in a science laboratory would be an interesting way to earn a living (+)	0.120	0.097	0.040	0.344	0.060	0.322	Loading < 0.35
Factor 5. Career Interest in Science (C)							
Q50. I would like to be a scientist when I leave school (+)	–0.003	–0.077	0.022	0.040	0.820		
Q30. I would like to teach science when I leave school (+)	–0.016	–0.098	0.037	–0.026	0.705		
Q10. When I leave school, I would like to work with people who make discoveries in science (+)	–0.036	0.014	–0.011	0.084	0.691		
Q40. A job as scientist would be interesting (+)	0.102	0.093	–0.019	–0.085	0.682		
Q15. I would dislike a job in a science laboratory after I leave school (–)	–0.130	0.269	0.164	–0.043	0.505		
Q45. I would dislike becoming a scientist because it needs too much education (–)	0.030	0.143	0.116	0.056	0.492		
Q5. I would dislike being a scientist after I leave school (–)	–0.117	0.110	0.097	0.007	0.462		

Table 1. Cont.

	F1	F2	F3	F4	F5	F6	Comments
Q20. Working in a science laboratory would be an interesting way to earn a living (+)	−0.049	0.164	−0.114	−0.064	0.449		
Q35. A job as a scientist would be boring (−)	0.019	0.253	0.265	0.011	0.418		
Q25. Science is one of the most interesting school subjects (+)	0.390	0.351	0.246	−0.005	0.018	−0.085	Loading in more factors

Note: Values less 0.35 were suppressed and not used for factor interpretation.

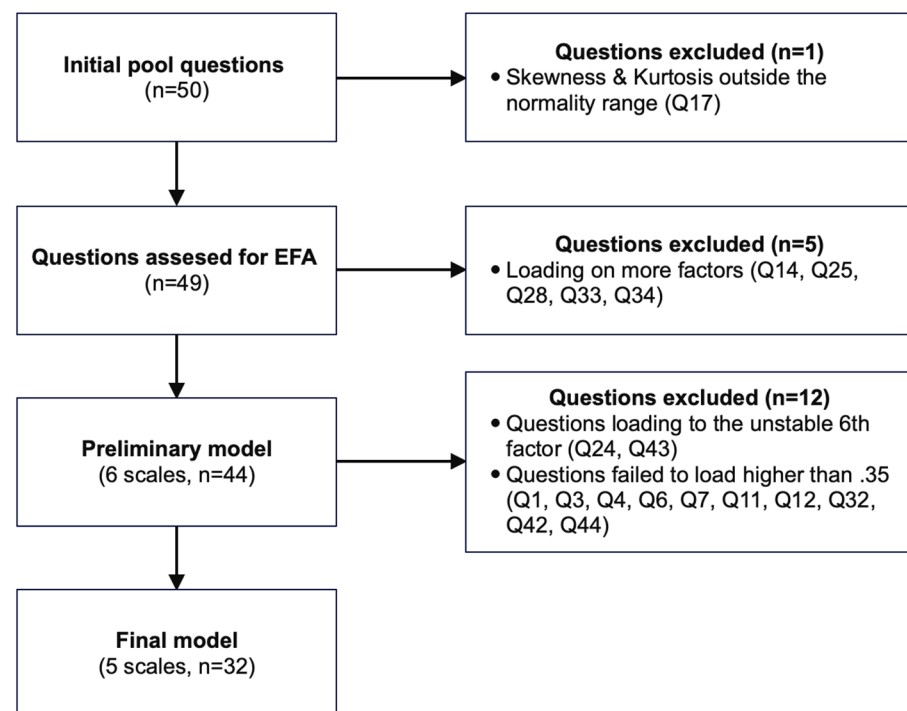


Figure 3. Iterative item removal process.

3.2.2. Results of CFA (Group B, n = 331) and Factor Reliability

Figure 4 illustrates the results of the CFA conducted on Sample B (n = 331) to assess the quality of the model derived from the EFA on Sample A (n = 331). The CFA confirmed the five-factor structure, as no item was removed based on the cutoff criterion of $\lambda_{ik} = 0.35$, thereby reinforcing the stability and reliability of the initial model from the EFA. The model fit indices indicate a good to very good fit with the data: CMIN/DF = 2.04, CFI = 0.969, TLI = 0.966, GFI = 0.966, and RMSEA = 0.064, all within the recommended thresholds found in the relevant literature. These results suggest that the factor structure proposed by the EFA sufficiently fits the validation sample.

Furthermore, Figure 4 displays the structural model of the questionnaire, including the standardized loadings of each item on its corresponding factor (Qxx) and the covariances between the factors (I, A, E, L, C). Notably, slightly elevated correlations are observed among the factors $I \leftrightarrow E$, $E \leftrightarrow L$, and $L \leftrightarrow C$. This finding is expected to some extent given the conceptual proximity of these factors, which reflects interrelated dimensions of the student experience. Overall, the CFA strengthens the validity and theoretical coherence of the model, confirming that the 32-item questionnaire is organized into five stable and distinct factors.

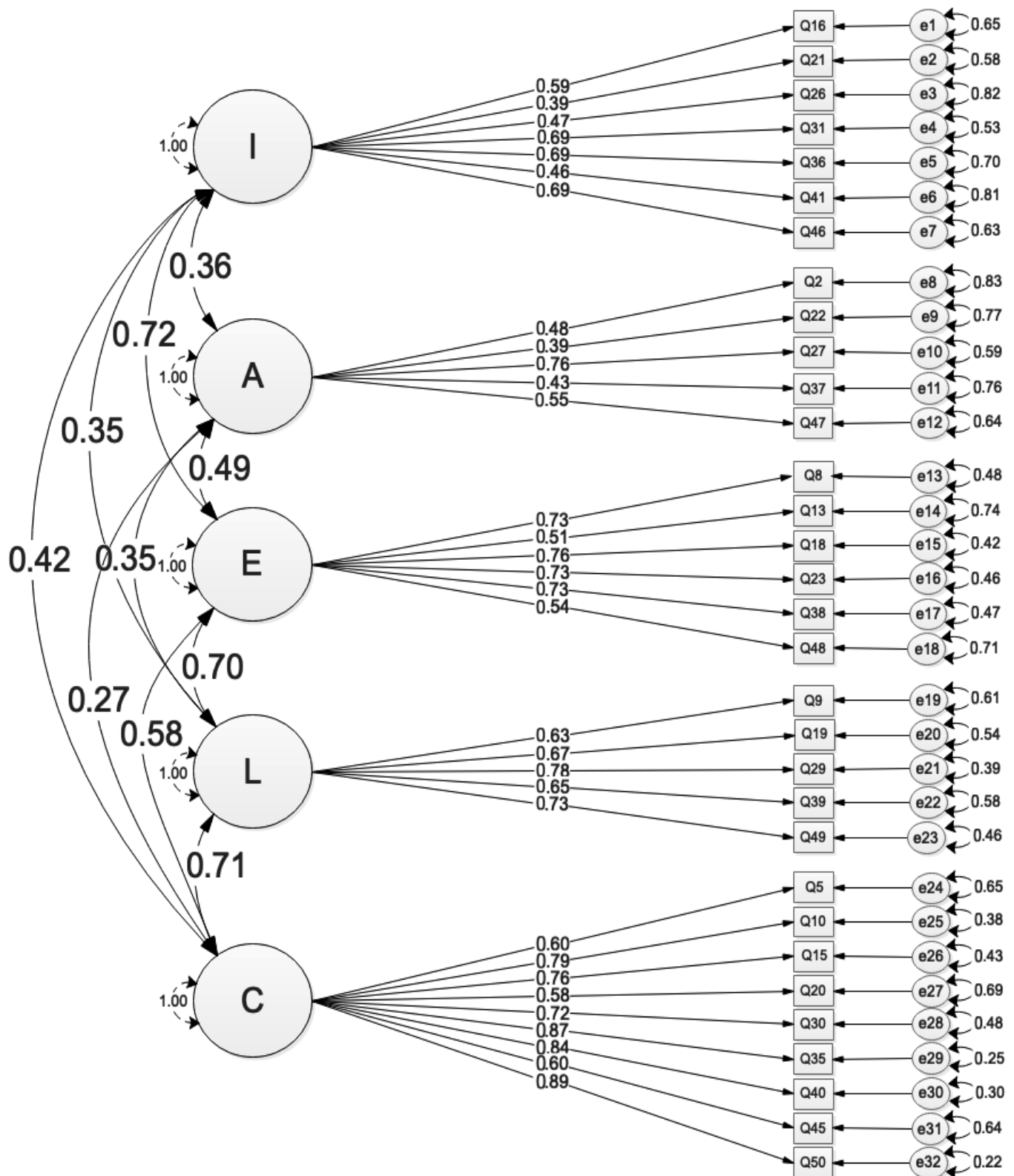


Figure 4. Structural model with standardized estimates. “Qxx” refers to question numbers, and “exx” indicates error terms for each observed variable.

3.2.3. Reliability of the Greek Version of the TOSRA Questionnaire

Table 2 presents the Cronbach’s alpha reliability coefficients for the five factors of the Greek version of the TOSRA questionnaire, in comparison with Fraser’s original version. The overall in-ternal consistency for the Greek adaptation, which included 32 items, was

$\alpha = 0.89$ which is considered good. More specifically, the Career Interest in Science factor demonstrated the highest re-liability at $\alpha = 0.87$, indicating a good reliability. Leisure Interest in Science ($\alpha = 0.79$), Enjoyment of Science Lessons ($\alpha = 0.78$), and Attitude to Scientific Inquiry ($\alpha = 0.73$) factors displayed acceptable reliability. However, Adoption of Scientific Attitudes factor had the lowest alpha coefficient ($\alpha = 0.58$), indicating poor reliability. This suggests that items in this factor may need refinement or further cultural adaptation in the Greek context.

Table 2. Cronbach’s α reliability coefficients for each factor compared to Fraser’s (1981) questionnaire findings.

Factor (Items)	Factor Name	Greek TOSRA Years 10–11 n = 662	Original TOSRA Year 10 (Fraser, 1981) n = 324
F1 (16, 21, 26, 31, 36, 41, 46)	Attitude to scientific inquiry (I)	0.73	0.86
F2 (2, 22, 27, 37, 47)	Adoption of scientific attitudes (A)	0.58	0.67
F3 (8, 13, 18, 23, 28, 48)	Enjoyment of science lessons (E)	0.78	0.93
F4 (9, 19, 29, 39, 49)	Leisure interest in science (L)	0.79	0.89
F5 (5, 10, 15, 20, 30, 35, 40, 45, 50)	Career interest in science (C)	0.87	0.91
Total		0.89 (in 5 factors)	0.84 (in 7 factors)

The second factor consistently demonstrated the lowest reliability across studies. Although it yielded slightly lower values than Fraser’s (1981) original study, reliability remains in the “acceptable” to “very good” range according to established standards (DeVellis, 2012). It is important to recognize that this factor’s reliability seems affected by the educational environment in which it is used, especially how much scientific attitudes are fostered through inquiry-based teaching.

Studies in countries with traditional teaching practices report lower reliability values for Factor 2. More specifically, Anwer et al. (2012) found a reliability coefficient of 0.66 in a sample of 3526 Pakistani students, while Naiker et al. (2020) reported a lower value of 0.58 among 641 grade 11 Fiji students. Also Khatoon found a value of 0.60, which improved to 0.80 in a larger sample (n = 1097), indicating the influence of sample characteristics (Khatoon, 2021). Other studies focusing on similar age group reported comparable reliability values (Ali et al., 2013), while some studies indicate even higher values (Navarro et al., 2016; Sharma et al., 2021).

The mean correlations between each factor and the others ranged from 0.24 to 0.45, indicating acceptable discriminant validity. Mean inter-item correlations were generally consistent with Fraser’s (1981) original TOSRA, except for first factor (Attitude toward Scientific Inquiry), which demonstrated a higher correlation with other factors (0.30 compared to 0.13 in Fraser’s study). The other factors had values between 0.24 and 0.45, aligning with Fraser’s findings. These small observed variations may be attributed to the fact that in Greece, laboratory instruction tends to be limited and primarily theoretical and teacher-centered because of a heavy curriculum focused on university entrance exams. In contrast, other countries with more hands-on science activities and experimentation may demonstrate more reliable student attitude measurements.

3.2.4. Levels of Acceptance and Intercorrelations Among the Five TOSRA Factors Related to Students’ Attitudes Toward Science

Figure 5 illustrates the mean values of students’ attitudes across the five measured factors of the questionnaire (n = 662), examining how students perceive and engage with

science both in and outside the classroom. As shown in the figure, the highest mean values were observed in the following three factors: Enjoyment of Science Lessons (E), Adoption of Scientific Attitudes (A), and Attitude to Scientific Inquiry (I). Specifically, the highest score was recorded in the “E” factor ($M = 4.06$), followed by the “A” factor ($M = 3.77$) and the “I” factor ($M = 3.50$). These results suggest a strong positive orientation among students toward the process of doing science and participating in experimental activities within a given educational context. They also reflect students’ appreciation of the scientific process, their openness to scientific thinking, and their enjoyment of learning experiences.

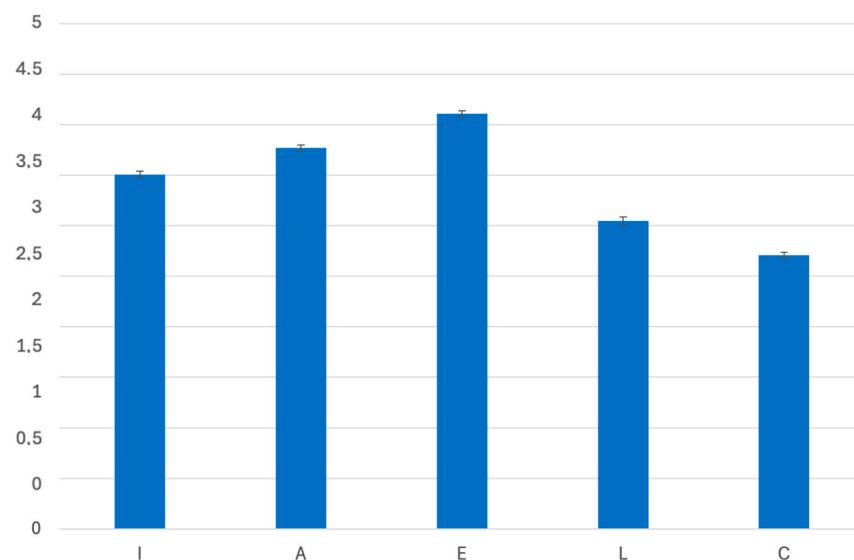


Figure 5. Mean values of attitudes per factor ($n = 662$). I = Attitude to Scientific Inquiry, A = Adoption of Scientific Attitudes, E = Enjoyment of Science Lessons, L = Leisure Interest in Science, C = Career Interest in Science.

In contrast, lower mean values were found in the Leisure Interest in Science (L) and Career Interest in Science (C) factors, with means of 2.97 and 2.68, respectively. These findings indicate that, although students enjoy engaging in science within the school context, they exhibit less interest in exploring science-related topics during their free time or in pursuing science as a future career. This pattern highlights a possible gap between academic enthusiasm and long-term involvement with science beyond the classroom.

Moreover, the skewness and kurtosis values for each factor were within acceptable normality ranges. Based on these findings, we can conclude that there is a positive emotional response to school-based scientific practices. However, the study also identifies areas where further support or enrichment could enhance deeper, more lasting connections between students and science in their daily lives or future goals. Table 3 (also illustrated in Figure 5) demonstrates the mean values of attitudes for each factor.

A Spearman’s rho non-parametric correlation analysis was conducted since the questionnaire responses were on an ordinal scale (Stamovlasis, 2016). The analysis demonstrated statistically significant positive correlations among the factors with at the $p = 0.01$ level with values ranging between 0.169 and 0.569, indicating associations between the factors. Dancy and Reidy (2007) note that correlation coefficients between 0.01 and 0.19 suggest negligible relationships, 0.20 to 0.29 are weak, 0.30 to 0.39 moderate, 0.40 to 0.69 strong, and 0.70 to 1.0 very strong. The observed correlations predominantly fall within the moderate to strong range, suggesting consistent patterns in students’ attitudes toward science across the TOSRA factors.

Table 3. Mean values of attitudes for each factor.

Factor Name	Mean (Standard Deviation)	Skewness (Standard Error)	Kurtosis (Standard Error)
Attitude to scientific inquiry (I)	3.50 (0.75)	−0.23 (0.09)	−0.01 (0.19)
Adoption of scientific attitudes (A)	3.77 (0.72)	−0.42 (0.09)	−0.30 (0.19)
Enjoyment of science lessons (E)	4.06 (0.78)	−0.92 (0.09)	0.38 (0.19)
Leisure interest in science (L)	2.97 (1.03)	−0.02 (0.09)	−0.81 (0.19)
Career interest in science (C)	2.68 (0.87)	0.09 (0.09)	−0.66 (0.19)

Strong positive correlations (Table 4) were identified between Attitude to Scientific Inquiry (I) and Enjoyment of Science Lessons (E), as well as between Enjoyment of Science Lessons (E) and Leisure Interest in Science (L), between Enjoyment of Science Lessons (E) and Career Interest in Science (C), and between Leisure Interest in Science (L) and Career Interest in Science (C). These findings suggest that students who enjoy science experiments are more likely to participate in extracurricular science activities and develop an interest in science-related careers. Additionally, moderate correlations were found between Attitude to Scientific Inquiry (I) and Career Interest in Science (C), along with Adoption of Scientific Attitudes (A) and Enjoyment of Science Lessons (E), further reinforcing the link between students' positive attitudes toward science and their involvement in related activities.

Table 4. Correlation Analysis (Spearman's rho) Among the Five Factors of the Questionnaire.

Factor	I	A	E	L
I				
A	0.169 *			
E	0.483 *	0.349 *		
L	0.242 *	0.268 *	0.477 *	
C	0.315 *	0.191 *	0.473 *	0.569 *

Note: I = Attitude to scientific inquiry, A = Adoption of scientific attitudes, E = Enjoyment of science lessons, L = Leisure interest in science, C = Career interest in science, * $p < 0.01$. Values less 0.35 were suppressed and not used for factor interpretation.

The weak and negligible correlations observed imply that certain factors measure different aspects of students' scientific attitudes. For instance, the weak correlation between Adoption of Scientific Attitudes (A) and the other factors suggests that students' openness to new scientific ideas is not closely related to their enjoyment of science activities or career aspirations. Likewise, the negligible correlation between Attitude to Scientific Inquiry (I) and Adoption of Scientific Attitudes (A) indicates that while both pertain to scientific thinking, they emphasize different dimensions—one on inquiry and experimentation, and the other on beliefs about scientific knowledge. These insights can aid in refining educational strategies to better integrate scientific attitudes with hands-on engagement and career motivation in science.

3.2.5. The Influence of Demographic Variables (Gender, Grade Level, and School Location) on Students' Attitudes Toward Science Across the TOSRA Dimensions

The Effect of Gender on Students' Attitudes

Figure 6 illustrates the comparison of students' attitudes towards science by gender. The mean scores of boys and girls were examined across five attitude factors to identify any significant differences in their perceptions and interests in science. As illustrated, boys consistently reported slightly higher mean scores than girls across all five factors. However, these differences were not statistically significant in most cases, with one exception: a statistically significant difference was found in the Leisure Interest in Science (L) factor, where boys scored higher ($M = 3.05$, $SD = 0.99$) compared to girls ($M = 2.89$, $SD = 1.07$), $t(660) = 2.029$, $p = 0.043$, with 95% confidence level between 0.01 and 0.32. This indicates that boys are more willing to participate in science-related activities or content during their leisure time than girls.

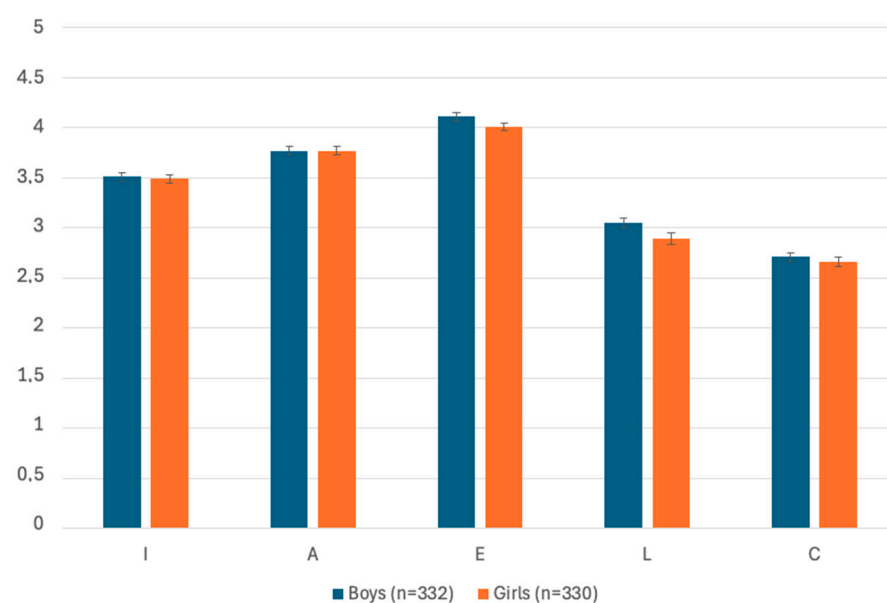


Figure 6. The effect of gender on attitudes (with standard errors). I = Attitude to Scientific Inquiry, A = Adoption of Scientific Attitudes, E = Enjoyment of Science Lessons, L = Leisure Interest in Science, C = Career Interest in Science.

While most differences are small and statistically insignificant, the trend favoring boys contrasts with findings from various international studies, which often indicate more favorable science attitudes among girls. Other studies report mixed results regarding the impact of gender. However, most of them indicate a more positive attitude towards girls in certain variables (Navarro et al., 2016) or generally across most variables (Anwer et al., 2012; Naiker et al., 2020; Sharma et al., 2021). Any differences between the comparison of literature findings and Greece may reflect to the varying socio-cultural realities of each country and the roles assigned to genders within them. In Greece, social expectations and traditional roles might influence boys' perceptions of science and further encourage their interest in it. Additionally, girls in Greece may face more clearly defined societal roles that distance them from the field of science, impacting their attitudes. These differences between countries underscore the importance of examining each nation's cultural and social contexts to fully understand the variations in attitudes toward science between genders.

Effect of Grade Level on Students' Attitudes

Figure 7 illustrates the comparison of students' attitudes toward science based on their grade levels. This analysis aims to determine whether being in the 10th grade (A' Lyceum)

or 11th grade (B' Lyceum) influences students' perspectives and engagement with science-related topics. As shown in the figure, 11th-grade students consistently reported higher mean values across all five attitude factors compared to 10th-grade students.

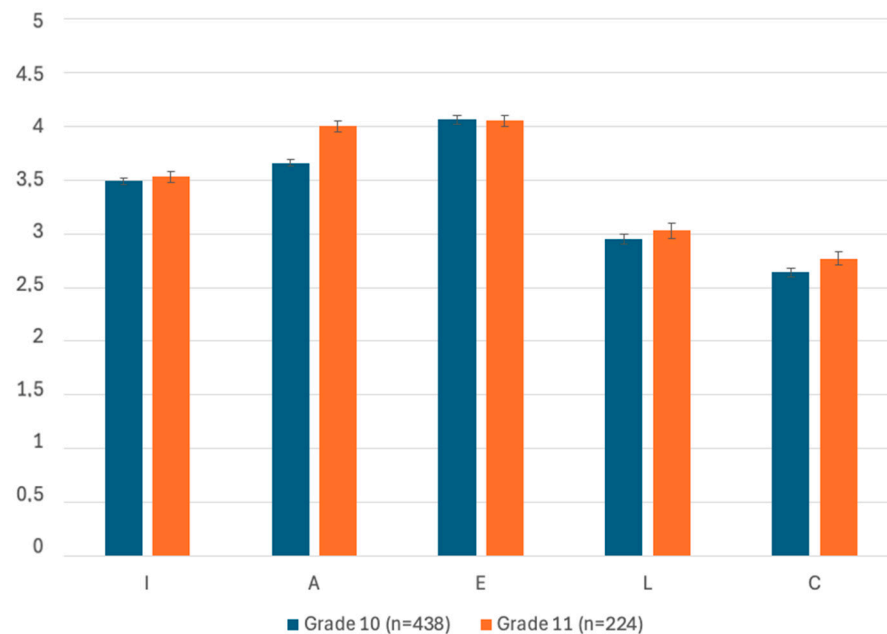


Figure 7. Effect of grade level on attitudes (with standard errors). I = Attitude to Scientific Inquiry, A = Adoption of Scientific Attitudes, E = Enjoyment of Science Lessons, L = Leisure Interest in Science, C = Career Interest in Science.

While most differences were not statistically significant, a notable exception was found in the factor “Adoption of Scientific Attitudes (A)” where the difference was significant. Notably, 11th-grade students scored higher ($M = 4.00$, $SD = 0.71$) compared to 10th-grade students ($M = 3.66$, $SD = 0.70$), $t(660) = 5.86$, $p < 0.001$, with 95% confidence level of 0.22 to 0.45. This indicates that older students, possibly due to their greater exposure to scientific content or higher cognitive development, tend to adopt scientific attitudes.

Although the other differences did not reach statistical significance, the overall trend suggests a slightly more positive attitude among 11th-grade students. It is worth noting that in the literature, there are mixed findings regarding the role of grade level. Some studies (Naiker et al., 2020) suggest that students in higher grades demonstrate more positive attitudes due to increased academic exposure, while others (Sharma et al., 2021) argue the opposite, pointing to possible fatigue or disconnection from science over time. In the Greek context, the results may reflect curriculum design, teaching practices, or even exam-oriented instruction in science at higher grades. Nonetheless, the notable rise in scientific attitudes among older students highlights the possible influence of extended educational involvement on their conceptual and affective connection to science.

Effect of the School Location of Attendance on Students' Attitudes

Figure 8 illustrates the comparison of students' attitudes toward science based on their location of school attendance (effect of the City Attendance—School Location), distinguishing between students from urban areas and those from rural areas. The analysis aimed to determine whether the geographical context affects how students perceive science and its relevance in their lives.

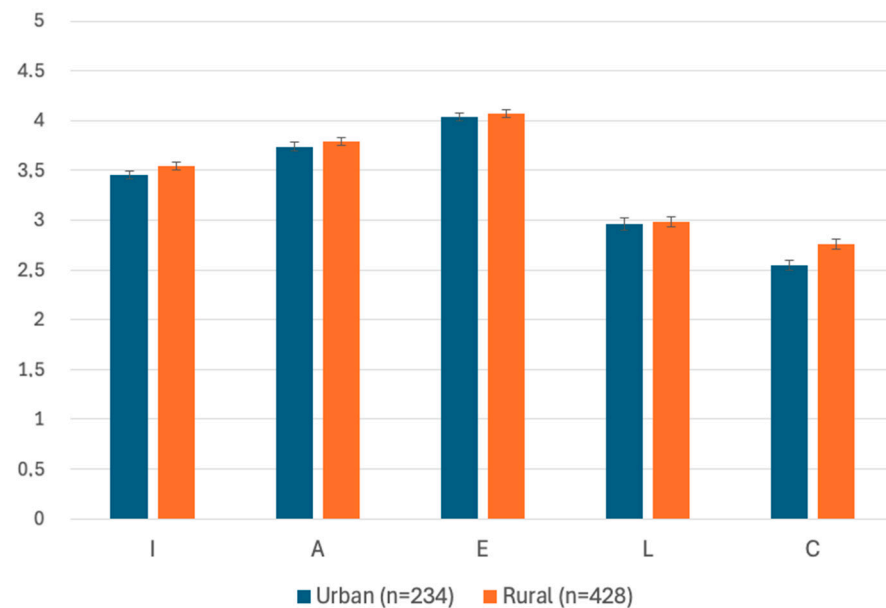


Figure 8. Effect of city on attitudes (School Location) (with standard errors). I = Attitude to Scientific Inquiry, A = Adoption of Scientific Attitudes, E = Enjoyment of Science Lessons, L = Leisure Interest in Science, C = Career Interest in Science.

As can be seen in the figure, students from rural areas demonstrated higher mean values than students from urban in all five attitude factors. However, most of these differences were not statistically significant, except in the “Career Interest in Science (C)” factor, in which rural students scored significantly higher attitudes ($M = 2.76$, $SD = 0.88$) than urban students ($M = 2.55$, $SD = 0.84$), $t(660) = 2.895$, $p = 0.004$, with 95% confidence level ranging from 0.07 to 0.34. This indicates that students in rural schools express a stronger desire or motivation to pursue a career in science.

While the numerical differences are small, the consistent trend suggests a slightly more favorable orientation toward science among rural students. These findings align with previous international studies, [Anwer et al. \(2012\)](#) and [Sharma et al. \(2021\)](#), which also reported more positive attitudes toward science in rural areas.

One possible interpretation of this finding is that, even though rural areas have fewer facilities and lower socioeconomic status compared to urban areas, students in these regions may see science as a pathway to better career prospects and improved socioeconomic standing. As a result, despite having more limited options, rural students might be more committed to their scientific studies. In contrast, urban students may face a broader range of choices and increased societal and parental pressures, which can lead them to concentrate less solely on science as a means of achieving their professional goals and social mobility. These data suggest that the geographical context can influence students’ career motivations in science, underscoring the importance of tailoring educational policies and interventions to account for the socioeconomic and cultural dynamics of different regions.

4. Discussion

This section presents the findings related to the three research questions. It starts with the psychometric structure and reliability of the adapted instrument, then explores the acceptance patterns across the five retained factors and their relationships, and finishes with an analysis of demographic differences, highlighting the educational implications throughout.

4.1. Factor Structure and Reliability of the Greek TOSRA

To address the first research question—whether the adapted instrument demonstrates a factor structure with adequate reliability—the structure of the Greek TOSRA was examined. Of the seven original TOSRA scales, five were retained as they most closely align with inquiry- and experiment-focused teaching—Attitude to Scientific Inquiry (I), Adoption of Scientific Attitudes (A), Enjoyment of Science Lessons (E), Leisure Interest in Science (L), and Career Interest in Science (C). Exploratory factor analysis supported a straightforward model, and after screening items, resulted in a 32-item, five-factor solution that maintained the conceptual boundaries of the original constructs while adapting the wording to the Greek upper-secondary Physics context (see Figure 4).

A confirmatory factor analysis validated the EFA solution, showing a good fit for the five-factor, 32-item structure (CFI = 0.969, TLI = 0.966, RMSEA = 0.064; see Figure 4). Internal consistency was high overall ($\alpha = 0.89$; Table 2). At the scale level, reliability coefficients ranged from acceptable to good for four factors (Attitude to scientific inquiry 0.73; Enjoyment of science lessons 0.78; Leisure interest in science 0.79; Career interest in science 0.87), while Adoption of Scientific Attitudes was lower at 0.58—a pattern observed in several international studies. Inter-factor correlations were modest (0.13 to 0.40), suggesting related but distinct dimensions. Crucially, item reduction did not weaken conceptual coverage: the Greek version is a shorter, structurally comparable form optimized for the local context.

A substantial body of research has documented cross-language adaptations of TOSRA. In Spanish, Chinese, and Korean editions (e.g., Navarro et al., 2016; Sivan & Chan, 2013; Fraser & Lee, 2015), forward/back translation with expert review was used, and the original seven-factor, 70-item structure was mostly maintained. Subsequent factor analyses confirmed the seven dimensions, and internal consistency remained high (typically $\alpha = 0.83$ to 0.96), indicating that closely preserving the instrument maintains strong psychometric properties across languages.

In contrast, adaptations that address local curricular and linguistic needs—such as the Urdu and Indonesian versions (Ali et al., 2013; Adolphe, 2002)—made significant reductions and reconfigurations of items (e.g., about 25 items across four factors in Urdu; about 20–30 items for younger groups in Indonesia), while still maintaining acceptable reliability ($\alpha \approx 0.80$ –0.84). Overall, these patterns place the current Greek adaptation as a shortened yet theoretically grounded solution: reducing items can improve practicality without losing construct coverage, as long as the retained factors closely align with the targeted educational practices.

The findings closely match international evidence. In the four-factor adaptation by Ali et al. (2013), internal consistency ranged from $\alpha = 0.67$ to 0.88, and mean inter-factor correlations ranged from 0.19 to 0.34 (values similar to those found in the current study). Studies that maintained the full seven-factor structure (Navarro et al., 2016; Sharma et al., 2021) also reported high reliability ($\alpha = 0.63$ to 0.90 and 0.81 to 0.86, respectively), consistent with the overall reliability observed here. In Ali et al. (2013), some dimensions were combined (e.g., Enjoyment with Leisure Interest), highlighting their conceptual link; a similar pattern is evident in the positive inter-factor correlations observed in the Greek data (see Table 2). Conversely, Anwer et al. (2012) reported lower coefficients ($\alpha = 0.47$ to 0.78), especially for Attitudes toward Scientific Inquiry, emphasizing that inquiry-related constructs can be psychometrically difficult across different contexts and may need careful item refinement.

4.2. Levels and Interrelations of Students' Attitudes Toward Science

Acceptance levels were summarized as factor means (see Table 3; Figure 5). Higher scores appeared in the inquiry-related dimensions—Attitude to Scientific Inquiry ($M = 3.50$, $SD = 0.75$), Adoption of Scientific Attitudes ($M = 3.77$, $SD = 0.72$), and Enjoyment of Science Lessons ($M = 4.06$, $SD = 0.78$)—demonstrating a classroom-focused profile marked by openness to investigation, willingness to revise ideas based on evidence, and satisfaction with science lessons. Conversely, lower acceptance was found for Leisure Interest in Science ($M = 2.97$, $SD = 1.03$) and Career Interest in Science ($M = 2.68$, $SD = 0.87$), indicating limited engagement with science outside of school and weaker interest in pursuing science-related careers. This pattern aligns with international applications of TOSRA. Studies such as those by Ali et al. (2013), Navarro et al. (2016), Sharma et al. (2021), and Anwer et al. (2012) also show that a higher acceptance of classroom-based science and inquiry correlates with lower leisure and career orientations. This cross-context pattern suggests that positive experiences in lessons and labs do not necessarily extend to extracurricular activities or long-term career goals.

The analysis of inter-factor correlations offered further insights into how different aspects of scientific attitudes relate to students' interests (see Table 4). Moderate, positive links were found between the inquiry-related factors (Enjoyment, Adoption, and Inquiry) and Leisure/Career Interest, suggesting that students who enjoy classroom inquiry and report enthusiasm also tend to show slightly more engagement outside of school and a greater interest in careers. These connections are indicative rather than definitive and maintain distinct validity among the constructs. This pattern supports evidence that early, hands-on experiences foster more positive attitudes and intentions toward science (European Commission, 2007; VanMeter-Adams et al., 2014). Therefore, emphasizing experiential learning opportunities—like structured lab activities, inquiry projects, science clubs and camps, and mentorship programs—can transform classroom enjoyment into sustained extracurricular participation and encourage future interest in science studies and careers.

Analysis of inter-factor relationships revealed that the Adoption of Scientific Attitudes scale had the weakest connections with other factors, with some correlations being non-significant (see Table 4). This suggests that being willing to revise ideas based on evidence is not strongly linked to enjoyment of lessons, enthusiasm for experiments, or intentions to pursue science careers. This aligns with the unique epistemic nature of the Adoption construct and its relatively lower internal consistency; therefore, the weaker connections are better understood as evidence of discriminant validity rather than limitations of the measure itself. Overall, students' interest in science is shaped by a complex network of factors rather than a single influence (European Commission, 2007; Osborne et al., 2003), and attitudes are closely related to teaching methods (European Commission, 2007). These insights support comprehensive instructional strategies that actively develop epistemic skills—such as evidence-based argumentation, reflection on the nature of science, and metacognitive prompts—alongside practical inquiry, to enhance the Adoption trait while preserving its conceptual independence.

Additionally, family influences and cultural capital significantly shape students' attitudes toward science. According to DeWitt and Archer (2015), parents' positive attitudes toward science, coupled with a supportive home environment that fosters students' engagement with science (e.g., museum visits, science discussions at home, and access to scientific materials), enhance the likelihood that students will cultivate an interest in science. However, even when parents express positive views of science, this does not always lead to scientific career aspirations for their children. This discrepancy is due to the level of

“scientific capital” within the family, which affects how effectively students can transform their interest into sustained engagement with science.

Similarly, students’ attitudes toward science are influenced by their perceptions of who can become a scientist. Research has shown that students often do not view science as a career option for themselves, even if they enjoy science subjects. This is linked to socio-cultural factors, such as media representations and messages from the school environment, which can reinforce stereotypes about who is considered “suitable” for science (DeWitt & Archer, 2015).

Therefore, scientists agree that no single factor determines students’ attitudes toward science. Instead, the interplay of cognitive, pedagogical, and socio-cultural factors influences how receptive students are to new scientific concepts. Schools, families, and society together create a broad network of influences that affect how students develop their aspirations and interests in science.

4.3. Influence of Demographic Variables on Science Attitudes

To address the third research question, independent-samples *t*-tests were used to examine differences in science attitudes by gender, grade, and school location. Significant group effects were observed, although the magnitudes were small boys reported higher scores only on Leisure Interest in Science; 11th-grade students showed higher Adoption of Scientific Attitudes than 10th-grade students; and rural students expressed higher Career Interest in Science than their urban peers. These patterns indicate domain-specific variation rather than overall group advantages.

The results align with international evidence but should be interpreted cautiously. Meta-analyses and large-scale assessments often find more positive self-reported attitudes among boys and lower expressed interest by girls in physics-related areas (Osborne et al., 2003; OECD, 2016). However, such differences are widely understood to be influenced by socialization, opportunity structures, and identity cues rather than innate differences. Therefore, the present between-group differences should be viewed as context-dependent and potentially modifiable through targeted support (e.g., inclusive co-curricular opportunities, mentoring and role-model exposure, and career guidance), rather than fixed traits of the groups.

More specifically, the social context of each country shapes gender expectations and roles, influencing how young people perceive and value science (European Commission, 2007). These social influences—such as the lack of female role models in STEM, different socialization patterns for boys and girls, and stereotypes reinforced by the surrounding environment—affect girls’ interest in science (Brickhouse et al., 2000). However, studies suggest that inquiry-based science education can help reduce these disparities, fostering a more inclusive learning environment for girls and enhancing their participation and interest in scientific activities (European Commission, 2007; OECD, 2016). Therefore, recognizing the impact of social expectations, educational practices can be adjusted to encourage both genders equally, providing positive role models and equal opportunities without discrimination (Osborne et al., 2003).

Finally, findings that show students in rural areas have more positive attitudes toward science than those in urban areas highlight the complex relationship between environment and educational influence. According to international literature, students in rural schools often have fewer opportunities to access educational resources and scientific experiences (Avery, 2013). However, they often demonstrate greater enthusiasm and motivation to engage in scientific activities compared to their urban peers. One possible explanation is that, despite limited resources and stimuli in rural areas, science serves as a vital tool for

their development and future prospects, a point also emphasized in the literature (Avery & Kassam, 2011).

These findings underscore the importance of targeted educational policies and initiatives in enhancing rural students' access to resources and science programs (Barley & Beesley, 2007). Educational policies should consider the specific needs and circumstances of each region to promote genuine equity and fairness in education (Showalter et al., 2019). Research indicates that inquiry-based learning programs tailored to local contexts can enhance rural students' interest and involvement in science, thereby helping to narrow the educational gap often observed between rural and urban students (Avery, 2013; Barley & Beesley, 2007).

5. Conclusions

This study involved adapting the TOSRA (Test of Science-Related Attitudes) questionnaire to Greek, validating it, and administering it to a large group of high school students. The main goals were to evaluate (a) the factor structure and reliability of the Greek TOSRA version, (b) students' attitudes toward science and their interrelations, and (c) how demographic variables influence science attitudes.

Adapting TOSRA into Greek required careful selection and translation of items, along with administering the questionnaire to a diverse group of students from urban and rural regions. Through exploratory and confirmatory factor analyses, a five-factor structure was identified, comprising 32 items that closely aligned with the original instrument's concept. The Greek version demonstrated high reliability and validity, proving to be an effective assessment for evaluating students' attitudes toward science within the Greek educational setting.

Specifically, in response to the first research question, this study revealed that the Greek version of the TOSRA questionnaire preserved a solid factor structure and demonstrated high internal consistency, with Cronbach's alpha values ranging between 0.74 and 0.90. The five identified factors closely aligned those in Fraser's original questionnaire, and the moderate inter-factor correlations upheld the structural soundness and reliability of the Greek adaptation.

Regarding the second research question, the findings demonstrated that students generally held positive views toward scientific inquiry, adopted scientific attitudes, and enjoyed science lessons. However, their leisure interest in science and science-related careers was comparatively lower. This pattern aligns with results from international versions of TOSRA, implying that positive experiences in science classes do not necessarily lead to sustained or broader engagement with science activities and career paths.

Concerning the third research question, notable differences in science attitudes were observed based on gender, grade level, and location. Boys expressed a greater interest in science as a leisure activity than girls, 11th graders demonstrated a stronger adoption of scientific attitudes, and students from rural areas exhibited a greater career interest in science compared to those in urban areas. These results emphasize the complex influence of social, cultural, and contextual factors on students' attitudes toward science.

In conclusion, this study offers valuable insights into the attitudes of Greek high school students toward science and provides a validated instrument for future educational research. The findings underscore the importance of fostering positive classroom experiences, addressing demographic differences, and considering the multifaceted factors that influence students' engagement with science.

6. Limitations

This study is accompanied by certain limitations that should be acknowledged. First, a significant limitation is that the sample consisted of students in the 10th and 11th grades (A and B Lyceum) from two geographical areas (Larisa—a rural area—and Attica—an urban area). Consequently, the findings may not be entirely generalizable to the entire Greek student population, particularly in areas with different socio-economic and cultural characteristics.

Another limitation involves the translation and adaptation process, which included only five of the seven factors from the original TOSRA questionnaire. Although this decision was intentional, reflecting broader research objectives and the necessity to shorten the questionnaire, it resulted in the omission of measurements concerning aspects such as the social impact of science and the normality of scientists. Future studies might consider including these factors to present a more comprehensive view of students' attitudes toward science.

Furthermore, the results of the Confirmatory Factor Analysis (CFA) indicated relatively high correlations among some factors, suggesting a lack of clear distinction between certain dimensions. Future research could concentrate on a more detailed examination of these factors, possibly by adding new items that would better differentiate the dimensions.

7. Suggestions for Future Research

Concerning potential future research directions related to the Greek adaptation of the GR-TOSRA-PHY questionnaire, a significant area of study is the effect of specific teaching interventions, such as inquiry-based learning or experimental activities, on students' attitudes toward physics or science in general.

Additionally, it would be interesting to investigate the evolution of students' attitudes over time, tracking possible changes from middle school to the end of high school.

Finally, future research could further explore the effects of students' socio-economic background and other factors, such as prior academic performance in science and parental attitudes toward science.

Author Contributions: Conceptualization, V.G.; methodology, V.G., E.P. and E.H.; writing—original draft preparation, V.G.; visualization, writing—review and editing, E.P. and E.H.; project administration, E.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Research Committee of the Aristotle University of Thessaloniki (Eidikos Logariasmos Kondilion Erevnas—ELKE).

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics and Deontology Committee (REDC) of the Aristotle University of Thessaloniki (protocol code 98642/2023 approval date: 5 April 2023) for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original data presented in the study are openly available in Zenodo.org at <https://zenodo.org/records/15424373> (accessed on 1 September 2025).

Conflicts of Interest: The authors declare no conflicts of interest.

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