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Exploring Secondary School Students' Attitudes Toward Socio-scientific Issues with a Focus on Climate Change Attitudes

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Abstract

This quantitative study examined Lebanese secondary school students' attitudes toward socio-scientific issues (SSIs), focusing on climate change as a representative topic due to its social, economic, and political complexities. A sample of 130 students from grades 10 to 12 in Lebanese private schools completed the Attitudes Toward Socio-scientific Issues Scale (ATSIS) and a subset of the Attitudes Toward Climate Change and Science Instrument (ACSI). Exploratory factor analysis identified four components - *Interest in SSI* (curiosity, enthusiasm, engagement), *Usefulness of SSI* (relevance), *Liking of SSI* (enjoyment), and *Anxiety Towards SSI* (apprehensions) - highlighting the multifaceted nature of students' attitudes toward SSIs. The findings reveal that while students acknowledge the importance of SSIs, their interest and enjoyment levels are moderate, and they report low anxiety, suggesting confidence in tackling these issues. Notably, female students showed greater interest and perceived usefulness in SSIs than male students, although no significant gender differences emerged in enjoyment or anxiety. Despite a high level of concern for climate change, a gap remains between awareness and climate-positive behaviors. This study underscores the need for practical, hands-on educational strategies to bridge this gap, and it recommends further exploration of gender-specific factors and longitudinal studies to track changes in attitudes over time.

Introduction

In today's rapidly evolving society, science education plays a crucial role in equipping learners with the knowledge and skills necessary for scientific and technological literacy (Howell & Brossard, 2021; Sharon & Baram-Tsabari, 2020; Valladares, 2021). Technological literacy encompasses the competencies required to effectively utilize, manage, evaluate, and comprehend technology (Hardhienata et al., 2021). It equips individuals with the capacity to interact with technological progress and to make well-informed decisions within a technologically advanced society (Mackey & Jacobson, 2014). While both forms of literacy are essential for navigating a technological and scientific world, science education primarily focuses on developing scientific literacy, enabling students to apply scientific knowledge to real-world challenges (Ke et al., 2021; Queiruga-Dios et al., 2020; Tal & Kedmi, 2006). Scientific literacy involves applying this knowledge to pressing societal issues,

such as economic stability, environmental sustainability, and health, all of which are critical to scientific advancement (Ke et al., 2021; Rubini et al., 2019; Shrivastava et al., 2020; Yenni et al., 2017).

A particularly relevant aspect of science education is its engagement with socio-scientific issues (SSIs) which are complex societal issues associated with science in conceptual, procedural, or technological ways. People encounter these challenging issues in their daily life (Zeidler & Sadler, 2023), making it important for educators to create contexts that encourage students to examine the interconnections among science, technology, and society (Driver et al., 2000; Kolstø, 2001; Zeidler et al., 2009). Among these pressing challenges is climate change, a global issue that demands both scientific inquiry and societal action. Within the SSI framework, fostering positive attitudes toward climate change prepares students to approach this issue with both scientific understanding and social responsibility (Klaver & Walma van der Molen, 2021).

Climate change has increasingly impacted daily life and various dimensions of human and environmental well-being. Extreme weather events (Ebi et al., 2021; Raymond et al., 2020), disruptions in food production (Gomez-Zavaglia et al., 2020; Molotoks et al., 2021; Muluneh, 2021), rising sea levels (Cooper et al., 2020; Griggs & Reguero, 2021; Strauss et al., 2021), and economic shifts (Batten, 2018; Khanna et al., 2022) illustrate the complex nature of this environmental challenge. Its effects extend broadly, influencing public health (Sweileh, 2020), agriculture (Chandio et al., 2020; Chen & Gong, 2021; Malhi et al., 2021), water resources (Dolan et al., 2021; Konapala et al., 2020; Schilling et al., 2020), and infrastructure (Gaaloul et al., 2020; Ioan Mogos et al., 2021; Nikolaou et al., 2020), while raising ethical questions about responsibility, justice, and equity (Ebi et al., 2024; Maja & Ayano, 2021). Addressing these challenges requires interdisciplinary approaches that incorporate natural sciences - such as meteorology, environmental science, biology, and chemistry - with social sciences, including economics, politics, and ethics (Alibašić, 2022; Barnett, 2020; Dietz et al., 2020; Wamsler & Bristow, 2022).

To enhance scientific literacy and engage students in real-world problem-solving, socio-scientific issues have increasingly been integrated into science education (Owens & Sadler, 2020; Saija et al., 2022). By encouraging students to critically analyze complex, real-world challenges, SSIs provide a framework for exploring multiple perspectives, making informed decisions, and addressing ethical dilemmas (Herman et al., 2021; Johnson et al., 2020). This approach moves students beyond theoretical knowledge enabling them to apply scientific concepts in real-world contexts, preparing them to address complex issues like climate change, genetic modification, and environmental pollution with evidence-based reasoning (Ke et al., 2021; Roehrig et al., 2021). Furthermore, by deepening students' understanding of the complex interactions between science and society, SSI instruction enhances decision-making and problem-solving skills (Lee & Witz, 2009). This dual emphasis on scientific ideas and their societal applications highlights the value of SSIs in preparing students for the multifaceted nature of contemporary scientific issues. Through SSI instruction, students develop a nuanced understanding of how science and society interact, learning to identify the strengths and limitations of their reasoning (Ratcliffe & Grace, 2003), and gaining opportunities to evaluate their learning outcomes and appreciation of scientific inquiry (Gutierez, 2015).

Recognizing the importance of SSIs in addressing societal challenges, many countries have integrated these topics

into science curricula to deepen students' understanding of real-world complexities (Hernández-Ramos et al., 2021). Common topics include biotechnology, environmental sustainability, human genetics, and climate change, all of which require students to think critically about ethical considerations and societal impacts (Sadler, 2004; Zeidler & Keefer, 2003). By engaging with these issues, students are prepared to make informed, evidence-based decisions, enhancing their ability to navigate complex societal issues with responsibility and ethical awareness. However, despite these educational advancements, relatively few studies have explored secondary students' attitudes toward SSIs. Much of the research focused on adolescent engagement with SSIs has focused on primary or tertiary education, leaving a gap in our knowledge of how secondary students approach these topics (Klaver & Walma van der Molen, 2021).

Hastürk & Ökkeşoğulları (2021) conducted a study assessing secondary school students' attitudes toward various SSIs, such as stem cells, cloning, and global warming. They found that students generally held positive attitudes toward SSIs, particularly regarding the role of scientific knowledge in addressing these issues. Interestingly, parental education levels and gender showed minimal impact on students' overall attitudes, with only slight differences in anxiety levels (Hastürk & Ökkeşoğulları, 2021). These findings highlight the importance of fostering positive attitudes toward SSIs at an early age and underscore the need for more targeted research on secondary school populations.

The available research highlights that attitudes play a crucial role in how students engage with SSIs. For instance, Lindahl and Folkesson (2016) observed that close-minded attitudes can disrupt group discussions, limiting students' ability to consider diverse perspectives, whereas open-minded attitudes, especially when paired with elaborate language, foster deeper engagement and critical thinking skills in classroom discussions. This insight underscores the potential impact of cultivating open-mindedness on students' learning experiences in SSIs. Despite these valuable findings, research on secondary school students' attitudes toward SSIs remains limited, signaling a need to further explore how these students respond to and engage with scientific issues. Aşikoğlu's (2023) study on model-based socio-scientific instruction complements these insights, showing that structured learning models can enhance students' attitudes, concern for socioscientific problems, and self-efficacy in addressing them. Together, these findings emphasize the importance of tailored pedagogical approaches that not only shape students' perceptions and engagement but also support the development of scientific literacy and active participation in societal issues.

Climate change, as a prominent SSI, presents complex scientific, social, and ethical dilemmas, requiring citizens to engage with underlying values and philosophies (Deveci & Karteri, 2022). However, students' attitudes toward climate change and other SSIs vary depending on their understanding, which is strongly influenced by classroom presentation and the pedagogical approaches used (Aşıkoğlu, 2023; Klaver et al., 2023). In Lebanon, where vulnerability to climate change is compounded by socioeconomic challenges, research on secondary school students' attitudes toward SSIs, including climate change, remains limited. Understanding these attitudes is critical for aligning educational content with students' needs, promoting critical thinking, and fostering responsible citizenship (Kurup et al., 2021; Zeidler & Keefer, 2003). Lebanese secondary school students, as future leaders, will be crucial in shaping responses to water scarcity, food insecurity, and environmental degradation (Namdar et

al., 2021). Furthermore, understanding students' attitudes allows educators to address misconceptions, build a strong knowledge foundation, and empower students as informed leaders (Liu et al., 2023; Sadler, 2004).

According to Namdar et al. (2021), Lebanon faces significant challenges related to sustainable development, particularly due to political instability and infrastructural limitations. In the MENA region, including Lebanon, the compounded impacts of climate change exacerbate socio-political and environmental issues, leading to heightened vulnerability. Climate change further strains already limited water and food resources, increasing the urgency for effective environmental policies. Given Lebanon's moderate vulnerability classification, addressing environmental sustainability policies and responsible resource management is critical. These measures are essential for mitigating long-term impacts on food and water security and for enhancing the nation’s resilience against climate-induced challenges.

Understanding public attitudes toward climate change is crucial, as these perspectives significantly shape the development and implementation of policies and actions (Dechezleprêtre et al., 2022; Hornsey & Fielding, 2020; Otto & Gugushvili, 2020). Yet, research on climate change attitudes, especially among younger generations at the secondary school level, remains limited. Despite the urgent need to raise awareness and encourage proactive behavior among the next generation, a noticeable gap exists in research addressing this demographic.

Studies have consistently shown that students generally accept the reality of climate change, regardless of regional or cultural differences. Though attitudes may vary based on factors such as gender, geography, and education level, most students acknowledge the urgency of the issue. For example, Deshiana et al. (2022) found that 98.4% of secondary school students in South Sumatra, Indonesia, were aware of climate change, and 95.7% supported mitigation efforts. However, this awareness did not consistently translate into climate-friendly actions, indicating a significant gap between recognition and practical engagement (Deshiana et al., 2022). A similar trend was observed in Ghana, where Odonkor et al. (2020) reported that while 74.5% of students understood the effects of climate change on their lives, only 50.1% actively engaged in adaptation or mitigation measures. This suggests that to bridge this gap, climate education must become more hands-on and practical, equipping students with the tools to transition from awareness to action (Odonkor et al., 2020).

Studies consistently identify a gap between recognizing climate change as an urgent issue and taking meaningful action. For example, in Ghana, a country in West Africa, students acknowledged climate change as a pressing concern but lacked the practical knowledge and resources to engage fully in mitigation efforts (Odonkor et al., 2020). In the U.S. state of New Jersey, students similarly expressed concern about climate change yet felt uncertain about how to contribute meaningfully to addressing it (Shendell et al., 2023). This trend was also observed in South Sumatra, an Indonesian province, where high levels of awareness did not translate into proactive climate-friendly behavior (Deshiana et al., 2022). Research suggests that integrating climate change education into multiple subjects can enhance students' knowledge and concern (Li & Liu, 2022; Siegner & Stapert, 2020; Tibola da Rocha et al., 2020). However, despite these efforts, students still expressed uncertainty about achieving meaningful change within their lifetimes (Shendell et al., 2023). Together, these studies suggest that climate education must expand its scope to equip students with the knowledge and tools needed to translate awareness

into action.

This study aims to explore how Lebanese secondary school students respond to SSIs, with a specific focus on their attitudes toward climate change. Given the far-reaching effects of climate change on humanity and the planet (Kemp et al., 2022), research in this area is critical for informing educational development. Understanding students' attitudes is crucial for developing effective strategies to engage young people in addressing socio-scientific challenges. Although students often demonstrate an understanding of the broader issues related to climate change, their grasp of the concepts may be unclear or incomplete. Targeted educational interventions can provide them with a clearer understanding of the issue and guide them toward meaningful climate action. By analyzing findings from Lebanese secondary schools, educators and policymakers worldwide can gain insights into effective strategies for teaching climate change. These insights can be adapted to fit different cultural and educational contexts, enhancing global climate education. Additionally, the research can serve as a model for other countries looking to improve their socio-scientific curricula and engage students more effectively in climate action.

By serving as a model, this study may also inspire initiatives in civic education, which is integral to the school curriculum. Civic education is integral to the school curriculum, as it fosters knowledge and attitudes about self, responsibility, and active citizenship (Haduong et al., 2024; Oliver & Adkins, 2020; Rachmadtullah et al., 2020; Schulz et al., 2023). Citizens' attitudes and actions have a profound impact on collective goals, reinforcing the need for educational frameworks that promote engagement with global issues like climate change (Casmana et al., 2023; Somerwill & Wehn, 2022; Torres & Bosio, 2020). Addressing climate change through civic education and socio-scientific issues promotes knowledge acquisition and adaptive solutions for a meaningful and fulfilled life (Awan et al., 2021; Cordero et al., 2020; Kopnina, 2020). This quantitative study focuses on Lebanese secondary school students' attitudes toward SSIs and climate change, aiming to raise awareness of global challenges. By situating the study within Lebanon's unique sociocultural context, it seeks to help students navigate uncertainty and understand their social responsibilities in a globalized world.

To address these knowledge gaps, this study poses the following research questions:

1. What insights can be derived from employing factor analysis to explore the underlying structure of the ATSIS Instrument in assessing secondary school students' attitudes toward SSIs? Additionally, how reliable is the ATSIS Instrument, and what implications does this reliability have on the validity of the study's findings?
2. What are secondary school students' general attitudes toward SSIs?
3. Are there significant differences in secondary school students' attitudes toward SSIs based on grade level?
4. Are there significant differences in secondary school students' attitudes toward SSIs based on gender?
5. What are the distribution patterns of secondary school students' attitudes toward the urgency of climate change?
6. Is there a positive or negative correlation between attitudes toward SSIs and attitudes toward climate change urgency?

Method

Participants

Nine private secondary schools in Beirut and Matn agreed to participate in this study. Using convenience sampling to recruit a total of 130 students (54 males and 76 females) from grades 10, 11, and 12 were recruited. In Lebanon, students in these grades are typically between 16 and 18 years old. The students in this study were either enrolled in the Lebanese Baccalaureate or an American high school program. Including students from various grades allowed for an exploration of whether attitudes toward socio-scientific issues and climate change varied across the secondary school experience.

The participants were categorized by grade, gender, and academic program as shown in Table 1. Although the groups were not evenly distributed for practical reasons, this imbalance has been accounted for in the analysis and discussion sections.

Table 1. Distribution of Participants by Grade Level and Gender

Grade level	Number of Students	Gender		Percentage (%)
		Male	Female	
Grade 10	95	41	54	73.1
Grade 11	18	5	13	13.8
Grade 12	17	8	9	13.1
Total	130	54	76	100.0

Curriculum Context

The study is congruent with the science education curriculum implemented in Lebanese secondary schools, which aims to enhance students' scientific literacy. This curriculum emphasizes several key areas:

- Understanding core scientific concepts and principles, such as climate systems and environmental sustainability.
- Developing critical thinking and problem-solving skills to address socio-scientific issues (SSIs) like climate change and its societal impacts.
- Cultivating pro-environmental attitudes and behaviors, encouraging students to engage with global challenges such as climate change.

Students will gain an understanding of socio-scientific issues through this curriculum, which aligns with the study's research questions assessing student attitudes toward SSIs and climate change.

Instruments Used

Attitudes Towards Socio-Scientific Issues Scale for Undergraduate Students

The data collected in this study were quantitative, obtained through two validated instruments: the Attitudes Towards Socio-Scientific Issues Scale (ATSIS) and a subset of items from the Attitudes Towards Climate Change

and Science Instrument (ACSI). Both instruments employ a Likert-scale format, providing a structured and measurable assessment of students' attitudes.

The *Attitudes Towards Socio-scientific Issues Scale* (ATSIS), developed by Topçu (2010), was used to investigate students' attitudes toward SSIs. The English version was chosen to maintain consistency with the validated instrument, as participants demonstrated sufficient English proficiency.

ATSIS assesses student attitudes across three dimensions:

- *Interest and Usefulness*: Students' recognition of the practical and academic relevance of SSI.
- *Liking*: The degree of enjoyment and enthusiasm students associate with engaging in SSI discussions.
- *Anxiety*: Students' apprehensions or concerns about discussing and addressing SSIs.

The instrument uses a validated 30-item, 5-point Likert scale, showing internal consistency with Cronbach's alpha coefficients ranging from 0.70 to 0.90. The instrument has shown internal consistency, with Cronbach's alpha coefficients ranging from 0.70 to 0.90. Topçu demonstrated ATSIS's ability to distinguish between majors and non-majors, highlighting a trend of more positive SSI attitudes among majors. Further research has recommended exploring attitudes toward SSIs to build on these findings.

ATSIS has been applied in diverse educational settings, establishing its reliability across contexts (Klaver & Walma van der Molen, 2021; Ozgur Kapici & Osman Ilhan, 2016; Sibiç & Topçu, 2020). For this study, the items were divided into four dimensions: *Liking of SSI*, *Anxiety towards SSI*, *Interest in SSI*, and *Usefulness of SSI*.With the instrument's developer's permission (personal communication, July 14, 2022), a copy of ATSIS was provided for use in this study, allowing the inclusion of selected items as part of the assessment.

Four primary factors relevant to attitudes toward SSIs have been identified in prior research: *Interest in SSI*, *Usefulness of SSI*, *Liking of SSI*, and *Anxiety towards SSI*. Initially, exploratory factor analysis suggested combining *Interest in* and *Usefulness of SSI* into a single dimension, later referred to as *Interest and Usefulness of SSI* (Topçu, 2010). Additionally, research by Suparman et al. (2022) in chemistry education identified five related factors - anxiety, interest, likes, benefits, and self-confidence - through Confirmatory and Exploratory Factor Analysis. In line with these approaches, this study will conduct a similar factor analysis to identify underlying factors in our data, aiming to enhance understanding of students' attitudes toward socio-scientific issues.

Attitudes towards Climate Change and Science Instrument

The Attitudes towards Climate Change and Science Instrument (ACSI), developed by Dijkstra and Goedhart (2012), is an open-access tool designed to measure students' knowledge of climate change, attitudes toward science, and pro-environmental behavior. For this study, we used a subset of questions specifically targeting attitudes toward the urgency of climate change.

Dijkstra and Goedhart (2012) reported that principal component analysis indicated unidimensionality across all scales, confirming both the validity and reliability of the instrument. With Cronbach's alpha values ranging from 0.71 to 0.87, the ACSI demonstrated high internal reliability. They concluded that the ACSI effectively captures students' perceptions of science, scientists, climate change, and the environment, offering valuable insights for science and environmental education. The instrument is noted for its validity, reliability, and versatility, making it suitable for various educational settings.

In this study, we selected a subset of items from the ACSI instrument specifically aligned with our research focus. Six items measuring attitudes toward the urgency of climate change, rated on a Likert scale from *strongly disagree* to *strongly agree*, were used to assess students' level of concern about this global issue.

Attitudes towards the Urgency of Climate Change

The six items, adapted from Dijkstra and Goedhart (2012), measured attitudes toward the urgency of climate change. Rated on a 5-point Likert scale from *strongly disagree* (1) to *strongly agree* (5), these items assessed students' level of concern about this global issue:

- Item 1: People should care more about climate change.
- Item 2: Climate change should be given top priority.
- Item 3: It is annoying to see people do nothing about the climate change problems.
- Item 4: People worry too much about climate change.
- Item 5: The seriousness of climate change has been exaggerated.
- Item 6: Climate change is a threat to the world.

This study was conducted in December 2022 in several schools across the Beirut and Matn regions, which were selected for convenience. As some schools restrict student involvement in research, only those that consented to participate were included. Participating schools were informed of the study's objectives and methodology, and principals notified secondary school parents to obtain consent for student participation.

Due to the COVID-19 pandemic, all communication with school principals was conducted via email, where they received detailed information about the study. Once parental consent was obtained, classroom advisors introduced the study to students, reading a prepared overview of the research and methodology (previously shared with principals). Advisors then distributed a Google Forms survey link to students, allowing them to complete the 45-minute survey online, regardless of their class schedules. Advisors supervised the session to ensure data collection integrity.

To begin the survey, students first read a paragraph explaining their rights, including voluntary participation, the option to withdraw at any time, and a summary of the research. After confirming their consent by clicking an approval button, students proceeded with the survey. To maintain data integrity, students were instructed not to use calculators, tablets, smartphones, or external information sources (e.g., books, websites) while completing the questionnaire. Each question required them to select one answer from the available options.

Reliability and Validity

A pilot study was conducted with 10 undergraduate students to assess the clarity and navigability of the instruments. The study confirmed that the instruments were straightforward and easy to understand, with no major issues identified, ensuring a smooth data collection process.To ensure content validity and internal consistency, we conducted a reliability analysis using Cronbach's alpha on the ACSI subset and each ATSIS subscale (Liking, Anxiety, Interest, and Usefulness). This analysis validated the internal consistency of each subscale, confirming the reliability of the instruments for assessing student attitudes toward SSIs. Data from the pilot study was excluded from the main analysis to ensure the results were representative of the primary participant sample.

This section outlines the statistical procedures employed to analyze the data in this study, with all analyses conducted in Jamovi statistical software (version 2.4.8.0) unless otherwise noted.

To address Research Question 1, which examines the factor structure and internal consistency of the Attitudes Towards Socio-scientific Issues Scale (ATSIS), we conducted an exploratory factor analysis (EFA) and assessed reliability using Cronbach's α coefficient.

For Research Question 2, which explores secondary school students' attitudes toward socio-scientific issues, descriptive statistics were calculated, including measures of central tendency (mean, median) and dispersion (standard deviation) for relevant items from the ATSIS.

Research Question 3 investigates differences in attitudes toward SSIs across grade levels. To identify statistically significant differences between grades 10, 11, and 12, we used the Kruskal-Wallis non-parametric test. The rationale for selecting this test is elaborated in the results section.

For Research Question 4, which examines gender differences in attitudes toward SSIs, we applied the Mann-Whitney U test for group comparisons.

Research Question 5 focuses on students' attitudes toward the urgency of climate change. Here, percentage response analysis was conducted, along with Cronbach's alpha to assess reliability. These analyses, including Figure 2, were completed using Excel.

Research Question 6 investigates the relationship between attitudes toward SSIs and the urgency of climate change. We generated a correlation matrix for this purpose using Jamovi.

Results

Exploring the Factor Structure, and Reliability Analysis of the ATSIS Instrument

To identify the underlying factor structure of the ATSIS instrument, an Exploratory Factor Analysis (EFA) was conducted. The adequacy of the sample was confirmed by a Kaiser-Meyer-Olkin (KMO) value of 0.872, well above the minimum threshold of 0.50, and Bartlett's Test of Sphericity, which yielded a significant chi-square value ($\chi^2 = 2106$, $p < 0.001$). Based on these findings, it is apparent that the data are suitable for factor analysis, which allows for a meaningful examination of its structure (Tabachnick & Fidell, 2007).

The EFA identified four distinct components reflecting students' attitudes toward socio-scientific issues (SSI): *Interest in SSI, Usefulness of SSI, Liking of SSI,* and *Anxiety Towards SSI*. While most items loaded strongly onto

their respective factors, some items did not meet the 0.2 cutoff. Table 2 displays the factor loadings for the retained items, highlighting the multidimensional nature of the ATSIS instrument.

An overview of the components identified through factor analysis is provided in Table 2.

Table 2. Exploratory Factor Analysis Results

Socio-Scientific Issue Items	Loading Factor
Component 1: Interest in SSI	
Item 1 I would like to learn socioscientific innovations.	0.739
Item 4 Debates on SSI attract my attention.	0.694
Item 14 I would like to know more about SSI.	0.676
Item 15 Since SSI is related to daily life, I would like to learn more details about SSI.	0.759
Item 20 I am curious about learning interesting knowledge about SSI.	0.785
Item 21 I like trying to understand the actions around my environment with SSI knowledge.	0.638
Item 26 I get bored when I try to understand SSI.	-0.338
Item 28 I am not interested in SSI.	-0.405
Item 30 I am interested in the effects of SSI on society.	0.559
Component 2: Usefulness of SSI	
Item 2 SSI provide me with an opportunity to understand science well.	0.569
Item 9 SSI take an important place in daily life.	0.382
Item 11 I think that it is important to know more about SSI.	0.530
Item 18 In media, more emphasis should be given to SSI.	
Item 22 I would like to learn more knowledge about the effects of SSI on society.	*
Item 23 SSI provides us with an opportunity to rethink technological developments.	0.431
Item 27 In science lessons, more emphasis should be given to SSI.	*
Component 3: Liking of SSI	
Item 6 I like SSI much better than scientific issues.	0.440
Item 7 I learn science well by discussing SSI.	0.463
Item 8 SSI are issues that I like much.	*
Item 10 I would like to pursue socioscientific innovations by media.	*
Item 13 I like conducting research on SSI	*
Item 17 Attending debates on SSI does not appeal to me.	*
Item 24 I read supplementary resources related to SSI.	*
Component 4: Anxiety Towards SSI	
Item 3 Socioscientific developments (SSI) cause social degeneration.	0.662
Item 5 I worry about socioscientific developments in terms of moral and ethical perspectives.	*
Item 12 I am not approving implementations of SSI in terms of religion.	*

Socio-Scientific Issue Items	Loading Factor
Item 16 I think implementations of SSI are abused by the people having harmful targets.	*
Item 19 Socioscientific developments are harmful to society rather than its benefits.	0.686
Item 29 I think that social values suffer from the implementation of SSI.	0.603

* This table does not display some factor loadings due to the cutoff point of 0.2. Factor loadings above this threshold are reported. As these items are conceptually related to the constructs they are aiming to measure, they are retained within these dimensions based on their conceptual importance in assessing participants' attitudes toward Socio-Scientific Issues (SSI).

An internal consistency analysis was conducted before the main study to determine the reliability of the components. With a Cronbach's Alpha of 0.914, the *Interest in SSI* component showed excellent reliability. Both the *Usefulness of SSI* and *Liking of SSI* components, which each contain seven items, showed acceptable reliability, with Cronbach's Alpha values of 0.723 and 0.701, respectively. The *Anxiety Towards SSI* component yielded a Cronbach's Alpha of 0.562, which suggests room for refinement in this subscale. Having a slightly lower value may suggest that students' apprehensions or concerns about addressing socio-scientific issues are nuanced and varied.

Based on Topçu's (2010) original framework, the 30 items were initially categorized into three dimensions: *Interest in and Usefulness of SSI*, *Liking of SSI*, and *Anxiety Towards SSI*. However, the EFA results indicated a more refined factor structure, prompting the division of *Interest and Usefulness of SSI* into two distinct components: *Interest in SSI* and *Usefulness of SSI*. This reclassification aligns more closely with the dimensions revealed in the analysis, as presented in Table 3.

Table 3. Comparison of Topçu (2010) and Revised Grouping of ATSIS Items Based on Factor Analysis

Dimensions	Dimension Description	Original grouping of Items	Revised grouping of Items
Interest and Usefulness of SSI (Topçu, 2010)	The extent to which students are interested in SSI and how useful the application of SSI is.	1, 2, 4, 9, 11, 14, 15, 18, 20, 21, 22, 23, 25, 26, 27, 28, 30	-
Interest in SSI (revised)	The extent to which students are interested in SSI	-	1, 4, 14, 15, 21, 25, 26, 27, 28, 30
Usefulness of SSI (revised)	How useful the application of SSI is.	-	2, 9, 11, 18, 22, 23, 27
Liking of SSI	The extent to which students have feelings of enjoying or liking SSI.	6, 7, 8, 10, 13, 17, 24	6, 7, 8, 10, 13, 17, 24
Anxiety Towards SSI	The extent to which students have concerns and worry about SSI.	3, 5, 12, 16, 19, 29	3, 5, 12, 16, 19, 29

Table 3 displays the transition from the original classification to the revised one, showing the difference between *Interest in SSI* and *Usefulness of SSI*. Refining these dimensions reveals a deeper understanding of students' attitude toward socio-scientific issues. Through this reclassification, it is possible to gain deeper insights into how students perceive and engage with socio-scientific issues in educational contexts. Data interpretation and analysis will be enhanced by the revised structure.

Investigating Secondary School Students' Attitudes Toward Socio-Scientific Issues

As part of this study's exploration of students' attitudes toward SSIs, we analyzed various components, including *Interest in*, *Usefulness of*, *Anxiety towards*, and *Liking* of SSIs. Figure 1 presents the mean scores across these components, offering insight into how students engage with SSIs in different dimensions.

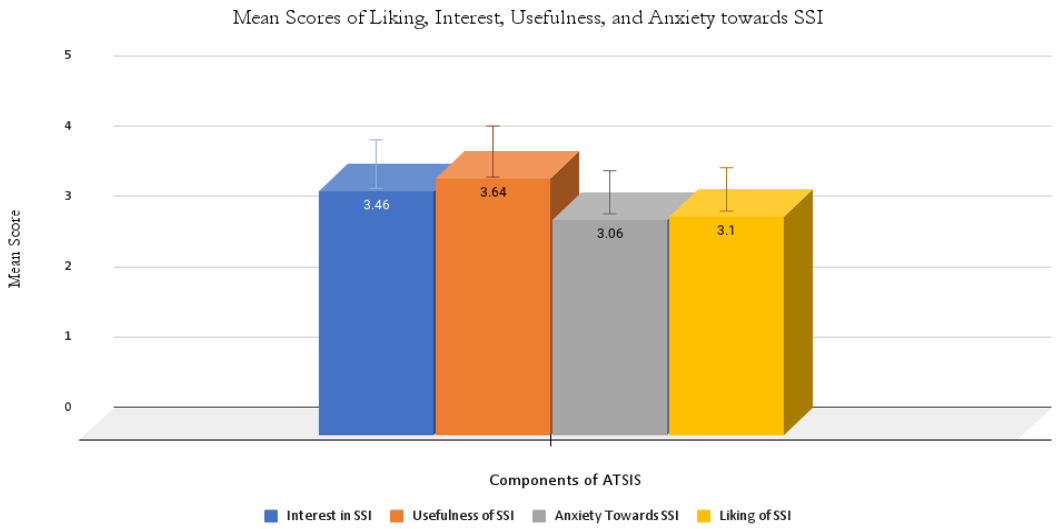

Figure 1. Mean Scores of Liking, Interest, Usefulness, and Anxiety towards SSI

The bar graph in Figure 1 illustrates the mean scores across the four components of the Attitudes Towards Socio-scientific Issues (ATSIS) scale: *Interest in SSI*, *Usefulness of SSI*, *Anxiety towards SSI*, and *Liking of SSI*. The *Usefulness of SSI* component received the highest mean score (3.64), indicating that participants generally consider SSIs beneficial and applicable. *Interest in SSI* was rated at 3.46 by participants, indicating a moderate level of curiosity, enthusiasm, and engagement with SSIs. *Liking of SSI*, with a mean score of 3.10, indicates a neutral to somewhat favorable attitude toward enjoying it. In addition, participants' ratings in the *Anxiety towards SSI* component were the lowest (3.06), indicating relatively low levels of concern about SSIs. Error bars represent standard deviations for each component, with slight variations observed across dimensions.

A descriptive analysis of secondary school students' attitudes toward SSIs is conducted focusing on the mean, standard deviation, mode, and percentile distribution of their attitudes. To inform curriculum development, pedagogical approaches, and further research in science education, we used a quantitative approach to reveal

general trends and variability in students' attitudes. An overview of the descriptive statistics can be found in Table 4.

Table 4. Descriptive Analysis of Attitudes Towards SSI among Secondary School Students (N=130) using the ATSIS

Descriptives	Mean Score Interest items	Mean Score Usefulness in SSI	Mean Score Liking of SSI	Mean Score Anxiety Towards SSI
N	130	130	130	130
Mean	3.46	3.64	3.10	3.06
Median	3.60	3.71	3.14	3.17
Mode	3.60*	4.00	3.71	3.17
Standard Deviation	0.699	0.567	0. 645	0.489
Skewness	-0.410	-0.263	-0.161	-0.358
Kurtosis	0.173	0.293	-0.0368	2.39
Shapiro-Wilk W	0.973	0.981	0.980	0.957
Shapiro-Wilk p	0.011	0.067	0.049	< .001
25^{th} percentile	3.02	3.29	2.71	2.83
50^{th} percentile	3.60	3.71	3.14	3.71
75^{th} percentile	3.57	4.00	3.57	4.00

Table 4 presents the descriptive statistics for the four components of the ATSIS scale: *Interest in SSI*, *Usefulness of SSI*, *Liking of SSI*, and *Anxiety towards SSI*. *Usefulness of SSI* scored highest, with a mean value of 3.64 (SD = 0.567), indicating that students consider SSIs relevant and applicable. There was a moderate level of interest in socio-scientific issues among participants as indicated by a mean score of 3.46 (SD = 0.699).

According to the *Liking of SSI* component, the mean score was 3.10 (SD = 0.645), indicating a neutral to slightly positive attitude towards socio-scientific issues. Lastly, the Anxiety toward SSI component had the lowest mean score of 3.06 (SD = 0.489), suggesting that students experience relatively low levels of apprehension regarding socio-scientific issues.These findings are further confirmed by the median and mode scores for each component. For instance, *Usefulness of SSI* had a median score of 3.71 and a mode of 4.00, while *Interest in SSI* had a median score of 3.60 and a mode of 3.60. *Liking of SSI* and *Anxiety towards SSI* both had medians of 3.14 and 3.17, respectively, with modes of 3.71 and 3.17.A Shapiro-Wilk test for normality revealed that *Liking of SSI* (p = 0.049) and *Anxiety towards SSI* (p = 0.001) components deviated slightly from normality, while *Interest in and Usefulness of SSI* components were closer to normality. Moreover, all components exhibited a relatively normal distribution in terms of skewness and kurtosis, with *Interest in SSI*, *Usefulness of SSI*, and *Liking of SSI* exhibiting a slight negative skewness, and Anxiety (2.39), indicating a peaked distribution. Additionally, the percentiles (25th, 50th, and 75th) for each component provide insight into how responses are distributed. For each component, the 50th percentile (median) is close to the overall mean.

Exploring Grade-Based Differences in SSI Attitudes Through ATSIS Components

The suitability of non-parametric methods was evaluated using descriptive statistics and normality tests. The Shapiro-Wilk test for normality indicated that several components of the dataset, including *Interest in* and *Anxiety toward SSI*, significantly deviated from a normal distribution. Additionally, the data showed left-skewness in the *Interest in* and *Usefulness of* SSI components, along with kurtosis variations. Consequently, the Kruskal-Wallis H test was chosen as an alternative to the parametric ANOVA due to the non-normal distribution of the data. This test does not assume normality and allows for comparisons of medians across multiple groups. The Kruskal-Wallis H test is also robust to variance inequality.

Kruskal-Wallis H tests were performed to determine whether significant differences existed among the different grades regarding *Liking of*, *Interest in*, *Usefulness of*, and *Anxiety towards* SSIs. For *Interest in SSI*, the chi-square value was 2.463 with a p-value of 0.292, indicating there was no significant difference between the different grades. According to the *Usefulness of SSI* analysis, students' perceptions of SSI's practical relevance did not vary significantly between grades, with a chi-square value of 1.766 and a p-value of 0.413. The *Liking of SSI* component chi-square test resulted in a p-value of 0.693 and a chi-square value of 0.733, indicating no statistically significant difference between grades. The results suggest that students felt similarly about SSIs across grades in terms of enjoyment or preference. Finally, the *Anxiety towards SSI* component showed a chi-square value of 0.820 and a p-value of 0.664, meaning there were no significant differences between grades in levels of concern or worry about SSIs.

Based on Kruskal-Wallis H test results, with all p-values exceeding 0.05, there were no statistically significant differences between different grades in *Liking of*, *Interest in*, *Usefulness of*, and *Anxiety towards* SSI. Students' perceptions of SSIs did not differ significantly based on their grades across these dimensions.

Identifying Significant Differences in Secondary School Students' Attitudes Toward SSI Based on Gender

An analysis of the Mann-Whitney U test was conducted for each component of the ATSIS scale in order to explore the possibility of gender differences in student attitudes towards socio-scientific issues. This non-parametric test was chosen due to its suitability for comparing differences between two independent groups, in this case, male and female students.

Table 5. Mann-Whitney U Test Results and Gender-Based Mean Scores for Components of ATSIS

Component	Male Mean Score	Female Mean Score	Mann-Whitney U	p-value
Interest in SSI	3.32	3.57	1657	0.061
Usefulness of SSI	3.46	3.77	1774	0.188
Liking of SSI	3.01	3.16	1406	0.02
Anxiety towards SSI	2.98	3.11	1845	0.323

The results of the Mann-Whitney U test are shown in Table 5, which examines potential gender differences across four components of the ATSIS scale: *Interest in*, *Usefulness of*, *Liking of*, and *Anxiety towards* SSI. The following is a breakdown of the results for each component.For the *Interest in SSI* component, the Mann-Whitney U value was 1657, with a p-value of 0.061. The mean score for the male students was 3.32, while for female students it was 3.57. Even though this result approaches significance, it suggests that the difference in interest in SSIs between male and female students is not statistically significant.In terms of *Usefulness of SSI*, the Mann-Whitney U value was 1774, with a p-value of 0.188. Male students had a mean score of 3.46 compared to 3.77 for female students. This indicates that both genders perceive the usefulness of SSIs similarly, with no significant difference.For the *Liking of SSI* component, the Mann-Whitney U test yielded a value of 1406 and a p-value of 0.02, indicating a statistically significant difference between genders. Male students had a mean score of 3.01, while female students scored slightly higher at 3.16, suggesting that female students find SSIs more enjoyable than their male counterparts.Finally, for the Anxiety toward SSI component, the Mann-Whitney U value was 1845, with a p-value of 0.323. Male students had a mean score of 2.98, while female students scored 3.11. This result suggests that both genders experience similar levels of anxiety about SSIs.

Investigating Secondary School Students' Attitudes Toward the Urgency of Climate Change

A reliability analysis was conducted to assess the consistency of the instrument measuring attitudes toward climate change urgency, which included six Likert-scale items. Based on Cronbach's Alpha, the overall level of internal consistency for the scale was 0.742, which is considered acceptable for research.

Figure 2 depicts the distribution of student responses regarding the urgency of climate change, expressed as percentages.

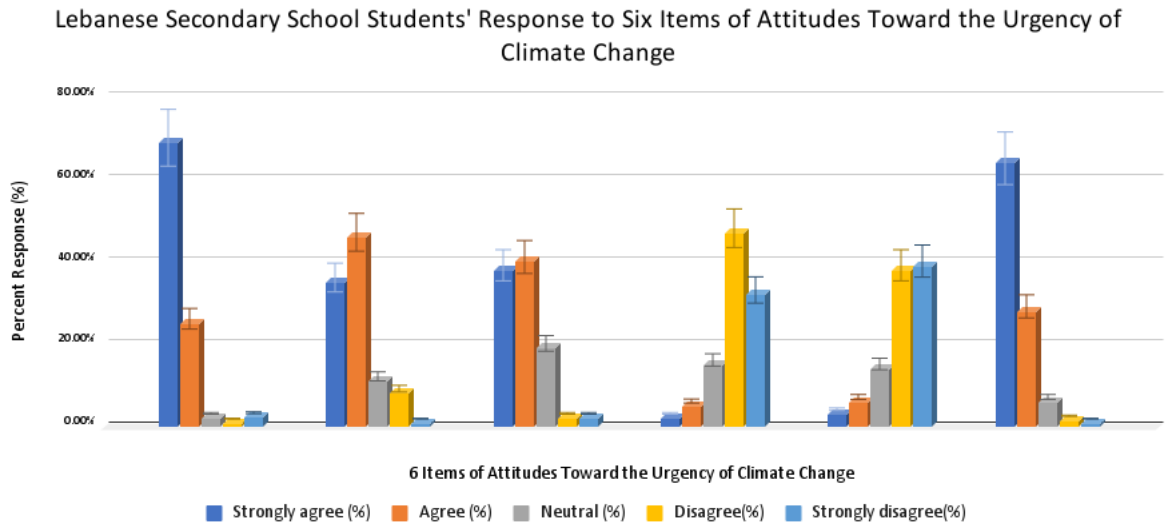

Figure 2. Student Responses to Attitudes Toward the Urgency of Climate Change: A Breakdown by Percentage

The bar graph illustrates participants' attitudes toward climate change based on six items related to socio-scientific concerns. The distribution of responses highlights key trends in students' perspectives on the urgency and

seriousness of climate change.

Item 1: *"People should care more about climate change."*

69% of participants agreed with this statement strongly, while 25% said they agreed. It appears that students are aware and concerned about climate change issues to the point of 94% agreement.

Item 2: *"Climate change should be given top priority."*

35% of students strongly emphasized the urgency of addressing climate change, with 46% selecting "Strongly Agree" and 35% selecting "Agree". Students, as evidenced by this combined agreement of 81%, perceive climate change as a primary concern.

Item 3: *"It is annoying to see people do nothing about climate change problems."*

The frustration with inaction on climate issues is evident in the fact that 78% of participants agreed with this statement (38% "Strongly Agree," 40% "Agree"). Students are not only aware of climate change, but are also invested in seeing proactive measures taken to address it.

Item 4: *"People worry too much about climate change."*

Compared to the previous items, 47% of respondents chose "Disagree" and 32% chose "Strongly Disagree" on this statement." Considering that 79% of participants reject the notion that climate change is overblown, it is evident that the issue warrants significant attention.

Item 5: *"The seriousness of climate change has been exaggerated."*

Similar results were observed for this item, where 39% of participants selected "Strongly Disagree" and 38% chose "Disagree." This 77% disagreement shows students do not view climate change as an exaggerated issue, but rather as a legitimate one.

Item 6: *"Climate change is a threat to the world."*

92% of respondents chose "Agree," with 64% choosing "Strongly Agree," and 28% choosing "Agree." The high level of agreement shows that many students are aware of climate change as a global threat.

Examining the Relationships Between ATSIS Components and Climate Change Urgency: A Correlation Matrix Analysis

Pearson's correlation coefficients were computed to evaluate the associations among the ATSIS components. This

analysis sheds light on the instrument's internal structure by revealing the strength of correlations between its components. Table 6 below presents the correlation matrix.

Table 6. Correlation Matrix of ATSIS components, and Urgency of Climate Change

Mean Scores		Attitude Towards the Urgency of CC	Anxiety Towards SSI	Usefulness of SSI	Interest in SSI	Liking of SSI
Attitudes Towards the Urgency of CC	Pearson's r	-				
	p-value	-				
Anxiety Towards SSI	Pearson's r	0.029	-			
	p-value	0.747	-			
Usefulness of SSI	Pearson's r	0.409	0.099	-		
	p-value	< .001	0.261	-		
Interest in SSI	Pearson's r	0.383	0.146	0.755	-	
	p-value	< .001	< .001	< .001	-	
Liking of SSI	Pearson's r	0.342	0.193	0.634	0.795	-
	p-value	< .001	0.028	< .001	< .001	-

The correlation between *Attitude Towards the Urgency of Climate Change* and *Anxiety towards SSI* is weak ($r = 0.029$, $p = 0.747$), indicating no statistically significant relationship. This suggests that students' perceptions of the urgency of climate change do not significantly influence their anxiety levels regarding the issue.

In contrast, a moderate positive correlation is observed between *Attitude Towards the Urgency of Climate Change* and *Usefulness of SSI* ($r = 0.409$, $p < 0.001$), showing a statistically significant connection. Students who perceive climate change as more urgent also tend to view SSIs as more useful. Similarly, there is a moderate positive correlation between *Attitude Towards the Urgency of Climate Change* and *Interest in SSI* ($r = 0.383$, $p < 0.001$). This significant relationship implies that students who view climate change as urgent are more likely to express interest in SSIs.

The correlation between *Attitude Towards the Urgency of Climate Change* and *Liking of SSI* ($r = 0.342$, $p < 0.001$) is also moderate and statistically significant, indicating that students who feel a sense of urgency about climate change tend to have a higher appreciation for SSIs. Furthermore, a strong correlation exists between *Usefulness of SSI* and *Interest in SSI* ($r = 0.755$, $p < 0.001$), suggesting that students who find SSIs useful are also highly interested in them. A similarly strong relationship is found between *Interest in SSI* and *Liking of SSI* ($r = 0.795$, $p < 0.001$), highlighting that students who are more interested in SSIs also tend to like them more.The relationship

between *Usefulness of SSI* and *Liking of SSI* is also strong ($r = 0.634$, $p < 0.001$), reinforcing the close connection between these factors. On the other hand, *Anxiety towards SSI* shows weak correlations with the other variables (*Usefulness of SSI, Interest in SSI, and Liking of SSI)*, suggesting that anxiety is largely unrelated to students' views on the usefulness, interest, or liking of SSI.

Discussion

Assessing the Reliability and Validity of the ATSIS instrument for Measuring SSI Attitudes in Secondary School Students

The exploratory factor analysis (EFA) conducted on the *Attitudes Towards Socio-scientific Issues* (ATSIS) instrument revealed four distinct components: *Interest in SSI*, *Usefulness of SSI*, *Liking of SSI*, and *Anxiety Towards SSI*. While the data in this study supports a slightly refined structure, the original dimensions proposed by Topçu (2010) are aligned with the data in this study. The Kaiser-Meyer-Olkin (KMO) value of 0.872 and Bartlett's Test of Sphericity of 2106 (p 0.001) confirmed that this sample was adequate for factor analysis. It is apparent from this study that students' A*ttitudes toward SSI* are multidimensional, with the majority of items loading strongly on their respective components. As such, students' attitudes are influenced by cognitive (*Interest in* and *Usefulness of SSI*) as well as affective (*Liking of* and *Anxiety towards SSI*) elements. In their study, Eş and Öztürk (2021) also highlight the multidimensional structure of SSI, emphasizing how ethical, moral, social, and economic factors influence students' reasoning and decisions.

Nonetheless, some items did not meet the factor loading cutoff of 0.2, suggesting that students have difficulty understanding certain aspects of SSI, particularly anxiety. The *Anxiety towards SSI* component, for instance, exhibited a lower Cronbach's Alpha value (0.562), suggesting that students' responses were less consistent and more variable. Considering this result, it may serve as a reminder that students' emotional responses to socio-scientific issues are nuanced and context-dependent. This finding aligns with Topçu's (2010) recommendation, which also highlights the importance of further exploring the factors influencing anxiety toward SSIs, as these factors may affect students' willingness to engage with complex socio-scientific topics.

Based on the reliability analysis conducted for the ATSIS components, varying levels of internal consistency were observed across the four dimensions: *Interest in SSI*, *Usefulness of SSI*, *Liking of SSI*, and *Anxiety towards SSI*. The *Interest in SSI* component has a Cronbach's Alpha of 0.914, indicating excellent reliability. SSI interests are reliably measured by items within this dimension, based on their high level of internal consistency. In an article published by Amirrudin et al. (2020), it is highlighted that data variability, particularly variance and standard deviation, has a significant impact on Cronbach's Alpha values, highlighting how data variability must be considered when assessing internal consistency.

In both the *Usefulness of SSI* and *Liking of SSI* components, each with seven items, Cronbach's Alpha values were 0.775 and 0.773. In these findings, the items in these components are sufficiently cohesive and consistently measure the constructs of *Usefulness of SSI* and *Liking of SSI*, making them reliable scales for capturing participants' perceptions. As opposed to this, the *Anxiety towards SSI* component exhibited a Cronbach's Alpha

value of 0.562, indicating poor reliability. The items were retained in the analysis despite being below the commonly accepted threshold for internal consistency. As such, this decision is in line with the theoretical structure of the original instrument. However, the generalizability of the findings related to *Anxiety towards SSI* should be interpreted with caution across different populations of secondary school students, as this dimension showed moderate internal consistency.

Interpreting Secondary School Students' Attitudes Towards Socio-Scientific Issues: Key Findings and Implications

As shown in Figure 1, the mean score analysis shows some important trends regarding students' attitudes toward SSIs. The *Usefulness of SSI* has the highest mean score, suggesting students find SSIs as highly relevant and applicable to real-life situations, potentially increasing engagement. This is in accordance with the findings of Şaşmazören et al. (2023), SSI are viewed as closely related to everyday life and are thought to enhance students' understanding of real-world problems. In addition, the *Interest in SSI* component also received a relatively high score, indicating students are not only aware of SSI but also intrigued by it, which may support its integration into education. It is in line with Choi & Lee (2021) findings that SSI research-based programs are linked to increased engagement with real-life issues and increased motivation to act in response.

Compared to *Anxiety towards SSI*, which has a relatively lower mean score, students acknowledge the importance of SSIs, but they do not express significant concern or worry about them. The finding is in line with Verlie et al. (2020) finding that providing emotional support can reduce anxiety among students facing complex ecological problems. Although students acknowledge the urgent or complex nature of these issues, they feel confident or neutral about addressing them, similar to Sakamoto et al. (2021), who found structured activities can promote decision-making confidence. Similarly, the *Liking of SSI* component shows moderate levels of enjoyment, suggesting that students do not actively dislike engaging in SSIs but do not find it extremely enjoyable. As Kristensen & Knain (2024) have also demonstrated, students' attitudes and reasoning practices determine their level of engagement and enjoyment in SSI discussions. In general, these results suggest that students maintain interest in SSIs while experiencing relatively low anxiety and moderate liking for them.

The descriptive statistics presented in Table 4 are valuable in understanding student attitudes toward SSIs. Students rated SSIs as valuable and relevant in the *Usefulness of SSI* component ($M = 3.64$, $SD = 0.567$). This component had high median and mode scores, indicating that a large number of students shared this opinion. Similarly, Klaver et al. (2023) found that students engaged with SSI knowledge perceived it as valuable and practical.

According to the *Interest in SSI* component, the mean score was moderate ($M = 3.46$, $SD = 0.699$), suggesting that while students are interested in SSI, their interest falls short of their perceptions of its value. It is consistent with Cian's (2020) findings that students' interest in SSIs changes depending on their personal context. As well, Ke et al. (2021) suggest using multiple models to promote deeper engagement and understanding, which could help bridge the gap between student interest and their perception of SSI's value.

The *Liking of SSI* component had a lower mean score (M = 3.10, SD = 0.645), indicating a more neutral attitude toward enjoying SSIs. The results suggest that students recognize SSI's importance, but don't necessarily enjoy engaging with these issues. It is consistent with Herman et al. (2021) findings on SSIs, who observed that students' engagement with SSIs is shaped more by their sense of responsibility and ethical considerations than by their enjoyment. Students' *Anxiety towards SSI* component was lowest (M = 3.06, SD = 0.489), indicating that they are relatively confident in their ability to understand or deal with SSIs. As well as increasing students' confidence, Anwar and Ali (2020) found that structured discussions could foster a sense of competence when addressing SSIs by improving their argumentation skills and critical thinking skills.

According to the skewness and kurtosis values of all four components, the data are relatively normally distributed, with slight negative skewness in all but Anxiety, which shows a slightly higher kurtosis (2.39), indicating that most students scored around the mean, but that a few scored much higher or much lower. Furthermore, Shapiro-Wilk test results indicate slight deviations from normality in Liking and *Anxiety towards SSI* (p = 0.049 and p 0.001, respectively). Despite this, the percentiles (25th, 50th, and 75th) indicate a reasonably stable distribution of scores across dimensions, with median scores reflecting their central tendency.

Exploring Grade-Level Differences in Secondary Students' Attitudes Toward Socio-Scientific Issues: Interpretations and Implications

Based on Kruskal-Wallis H test results, no significant differences were found between the mean scores for *Interest in SSI*, *Usefulness of SSI*, *Liking of SSI*, and *Anxiety towards SSI*. Based on this, we can conclude that students, regardless of their grade, hold similar *Attitudes towards SSI*. It is possible that the lack of statistically significant differences reflects a consistent perception of the value, interest, and emotional reaction to socio-scientific issues across the grade levels. A similar observation was derived by Eş and Öztürk (2021), who observed stable perceptions of socio-scientific issues across different groups of students.

While the *Interest in SSI* component had the highest chi-square value (X^2 = 2.463), the results remained non-significant, suggesting that students share a relatively uniform *Interest in SSI* topics. The *Usefulness of SSI* component, which had the highest mean score in the descriptive analysis, also showed no significant group differences, suggesting that students view SSIs consistently. It has been suggested that this uniformity in interest and perception may be correlated with students' shared involvement in critical thinking and active learning, as Jack et al. (2024) found that SSI learning contexts can increase students' interest and consistency by encouraging critical thinking and group participation. Furthermore, the low chi-square values for liking and anxiety reinforce the notion that students engage with socio-scientific issues with similar levels of enjoyment and anxiety. In line with Muis et al. (2021) they found that emotions such as curiosity and anxiety contribute to students' ability to process SSIs, so managing them well can lead to consistent critical engagement.

SSI perceptions were uniform among students, indicating that SSI may not be a clear dividing factor, in this case grade level, that has a significant impact on students' perceptions of socio-scientific issues in terms of interest, usefulness, liking, and anxiety. According to Ke et al. (2020), this uniformity may be related to students'

engagement with science education through SSI-based learning. It has been found that students are more engaged and interested when SSI-based learning combines scientific concepts with societal issues. In future studies, additional factors and larger sample sizes may be explored to see if subtle differences exist between groups that were not detected in the current study.

Examining Gender Differences in Secondary Students' Attitudes Toward SSI: Discussion and Implications

The Mann-Whitney U test was conducted to explore potential variations in student *Attitudes towards SSI* between male and female students. The analysis revealed some important findings regarding the interest, liking, usefulness, and anxiety that students perceive about SSI.

For the *Interest in SSI* component, a p-value of 0.061 indicates that although no statistically significant difference was found between genders, the result is close to the conventional threshold. This suggests a potential trend in which *Interest in SSI* may vary between male and female students, though further analysis with a larger sample size may be required to confirm this. These near-significant results could be explained by gender-specific factors, such as differing levels of exposure to or engagement with socio-scientific topics. It is possible that male and female students' levels of engagement with SSIs are influenced differently by factors like group participation and self-efficacy, as identified by Jack et al. (2024).

In terms of *Liking of SSI*, the p-value of 0.188 indicates that no significant differences exist between male and female students. The results suggest that both genders generally enjoy or engage with socio-scientific issues in similar ways. This consistency in liking suggests that students, regardless of gender, maintain a neutral to positive attitude toward SSIs throughout secondary school, demonstrating that both male and female students engage with these topics with similar levels of enjoyment. As reported by Klaver and Walma van der Molen (2021), students' engagement with SSIs is influenced by a variety of sources of information, including media and school, suggesting that both genders enjoy these topics in similar ways.

A statistically significant difference was found in the *Usefulness of SSI* component, with a p-value of 0.002. This finding indicates that male and female students perceive the relevance and applicability of SSIs differently. It is possible that this variation is due to differing perceptions of how these issues relate to daily life or future career paths. As students mature, they may develop different perspectives on how SSIs apply to real-world situations, with one gender possibly seeing greater value in SSI than the other. Cultural and social factors were found to influence students' decision-making and reasoning regarding SSIs by Ghazal et al. (2024). This suggests that these factors may also contribute to the disagreements between genders in the present study.

For the *Anxiety Towards SSI* component, the p-value of 0.323 shows no significant difference in anxiety levels between genders. This suggests that male and female students experience similar levels of concern or apprehension about socio-scientific issues. Despite the recognition of SSI's importance, the consistency in anxiety levels across genders indicates that these issues do not evoke significantly different emotional responses in male and female students. The results of Suparman et al. (2022) agree with our findings, indicating that anxiety is a

major influencing factor on students' participation in SSIs. However, their study did not find significant gender-specific differences.

Interpreting Secondary School Students' Attitudes Toward the Urgency of Climate Change: Insights and Implications

It is evident from the findings of this study that secondary school students are overwhelmingly aware of the urgency of climate change, with most participants strongly agreeing that this global problem needs to be addressed. Nevertheless, the variability of responses to climate urgency statements raises important questions, particularly among those who disagree with them. Despite the fact that students are aware of climate change, translating this awareness into action may be difficult due to a variety of factors, such as feelings of helplessness, lack of personal connection to the issue, or inadequate educational support. This aligns with the findings of Kolenatý et al. (2022), who discovered that despite students' increased knowledge of climate change through educational programs, action required self-efficacy and the belief that their actions mattered.

The results of this study are consistent with prior research, which shows that although young people are aware of climate change, proactive behaviors are often lacking (Calculli et al., 2021; Pickering et al., 2020). To bridge this gap, future educational interventions should not only raise awareness, but also equip students with practical, actionable steps they can take to mitigate climate change. To foster greater climate action, further research is needed to explore the specific barriers that prevent students from making climate change their top priority.

Analyzing the Relationship Between Attitudes Toward Socio-Scientific Issues and Climate Change Urgency: Insights and Implications

The correlation matrix provides valuable insight into the relationship between the components of the *Attitudes Towards Socio-scientific Issues* (ATSIS) instrument and students' attitudes towards climate change (CCA). The findings highlight the link between students' engagement with socio-scientific issues and their perception of climate change urgency.

In this study, there was a weak correlation between students' perception of climate change urgency and their *Anxiety about SSI* ($r = 0.029$, $p = 0.747$), suggesting that student concerns about SSIs do not significantly influence climate change perception. Despite experiencing anxiety about socio-scientific developments, students do not demonstrate a greater sense of urgency regarding climate change based on this study. This aligns with findings by Kolenatý et al. (2022), reported that while climate education programs helped students become more aware of climate change and concerned about it, translating that knowledge into urgent personal action required more than just awareness - a belief that individual actions could make a difference and self-efficacy were both required. Understanding how anxieties about scientific issues affect broader environmental concerns may be clarified by further investigation.

In contrast, there were moderately positive correlations between students' Attitudes toward the Urgency of Climate

Change and their *Usefulness of SSI* (r = 0.409, p 0.001) and *Interest in SSI* (r = 0.383, p 0.001). Based on these results, students who view SSIs as more useful and relevant are more likely to view climate change as an urgent issue as well. In the same way, students who exhibit a higher interest in SSIs are more likely to recognize the need to address climate change. Relationships like these demonstrate the importance of fostering strong links between socio-scientific issues and real-world problems. Emphasizing the practical applications and relevance of these topics may help reinforce students' understanding of environmental issues' urgency. A similar conclusion was reached by Sanchez et al. (2024), who found that SSI-based approaches to education significantly improved students' knowledge and attitudes toward environmental issues, emphasizing their relevance and practical applications. By implementing such strategies, students may be able to comprehend the urgency of acting on environmental concerns such as climate change.

A similar moderate correlation was found between Attitudes towards the Urgency of Climate Change and *Liking of SSI* ($r = 0.342$, $p < 0.001$), suggesting that students who enjoy social science issues are more likely to see climate change as important. As a result, this relationship illustrates the potential to integrate socio-scientific issues into educational content in ways that engage and motivate students, ultimately enhancing their awareness and motivation to address global challenges. In a similar vein, Rousell and Cutter-Mackenzie-Knowles (2020) noted that engaging students in climate change education requires participatory and interdisciplinary approaches. In addition, Widiyawati (2020) has highlighted how integrating socio-scientific issues, such as climate change, into science education increases students' scientific literacy and problem-solving abilities, thereby motivating them to advocate for environmental issues.

Moreover, strong correlations between the ATSIS components themselves - particularly between *Usefulness of* and *Interest in SSI* ($r = 0.755$, $p < 0.001$), *Interest in* and *Liking of* ($r = 0.795$, $p < 0.001$), and *Usefulness of* and *Liking of SSI* ($r = 0.634$, $p < 0.001$) reinforce the close connection between these factors. A student who finds SSIs interesting also perceives them as useful and enjoys engaging with them. Considering these strong internal relationships, educational interventions aimed at increasing student interest in SSIs can simultaneously improve students' perceptions of their usefulness and enjoyment, thereby fostering positive attitudes toward science and environmental issues. It is consistent with the findings of Sanchez et al. (2022), who demonstrated substantial improvements in students' engagement, environmental attitudes, and understanding of global issues through SSI-based educational approaches. A similar approach was advocated by Widiyawati (2020) in order to enhance students' scientific literacy and foster a stronger connection between their interest, enjoyment, and perceptions of science as relevant to their lives.

Conversely, *Anxiety toward SSI* shows weak correlations with the other ATSIS components, indicating that students' perspectives on the usefulness, interest, and enjoyment of these topics are largely unrelated to their anxiety about SSIs. This finding suggests that anxiety may be a result of broader social or cultural concerns rather than students' direct engagement with socio-scientific issues. For students to overcome these emotional barriers, it may be necessary to develop tailored educational approaches that facilitate a more constructive relationship with complex socio-scientific challenges.

Conclusion

This study provides valuable insights into Lebanese secondary school students' attitudes toward SSIs and climate change. It examines variation across gender, grade levels, and perceived urgency of climate issues. Despite their generally favorable views of SSIs, students' interest levels and enjoyment are more neutral, indicating the need for more engaging and dynamic teaching methods. By implementing project-based learning approaches and interactive approaches, students may be motivated to engage in SSIs and develop a deeper connection to them.

The study found gender differences, with female students showing a higher level of interest and perceived usefulness toward SSIs. The findings are consistent with literature indicating that females are often more engaged with social and environmental issues. In order to overcome this gap, educators might consider incorporating technology and engineering applications into SSIs to make them more relevant to male students and potentially increase engagement.

In regards to climate change, there was a strong consensus among students that it was urgent. There is, however, an "action gap" in which climate-positive behavior does not always coincide with heightened awareness. It is therefore critical to develop educational strategies that emphasize actionable steps, such as climate initiatives and community initiatives, that will help students convert awareness into action. It is through practical, hands-on experiences that educators can facilitate students' transition from knowledge to proactive environmental stewardship.

In the future, SSI education should be explored using project-based and interdisciplinary approaches, focusing on gender-specific engagement patterns. Longitudinal studies examining SSI-based learning's impact on students' attitudes, understanding, and behavior could provide deeper insights. It is clear that integrating SSIs like climate change into education will foster critical thinking, scientific literacy, and active citizenship. Students can be equipped with the skills and mindset to address global challenges effectively through such approaches, laying the foundation for informed and responsible leadership in the future.

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