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High School Students' Knowledge and Risk Perceptions of Climate Change: The Role of an Elective Environmental Science Course

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Abstract: This study investigated a sample of Saudi Arabian high school students' understanding of science concepts underlying climate change and their risk perceptions associated with the adverse impacts of climate change before and after participating in an elective environmental science course. A previously validated climate change content knowledge assessment and two Likert-scale items measuring climate change risk perception were administered to 51 eleventh- and twelfth-grade students. The results showed that students had a limited understanding of some key climate change concepts before the course, particularly regarding the greenhouse effect. However, their understanding significantly improved after completing the course, highlighting the positive impact of formal instruction on climate science literacy. Additionally, students' risk perceptions of climate change were moderate before the course and increased significantly by the end, especially for long-term impacts. This may suggest that increased knowledge may contribute to heightened risk perception, although the relationship between the two was not statistically significant in this study. The findings underscore the importance of incorporating environmental science courses into secondary education to enhance students' climate literacy and promote informed decision-making regarding climate change, particularly in regions like the Middle East where climate change poses significant challenges.

Keywords: Climate Change Education; Environmental Science; Risk Perception; Secondary Students.
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Introduction

Today scientists overwhelmingly agree that the global climate is changing rapidly, which is primarily due to human activities leading to growing levels of greenhouse gases like carbon dioxide in the atmosphere (IPCC, 2022). The complex nature of the global climate system and its components as well as the uncertainties in the risks a rapidly changing climate poses make it difficult for students and adults to understand the leading causes behind increasing global temperatures and make inferences about its potential adverse impacts. This has resulted in the current situation in many countries today where there are significant differences between the public and the scientific community in terms of their views on climate change (National Science Board [NSB], 2018; Leiserowitz et al., 2022; Weber & Stern, 2011). For example, the results from a large-scale study with the American public in 2018 showed that only 55% of Americans were able to contemplate that the rise in global temperatures is caused by the greenhouse effect (NSB, 2018). This deficiency in knowledge among individuals may potentially lead to making uninformed decisions about climate change and reaching incorrect conclusions regarding its potentially catastrophic impacts (Bofferding & Kloser, 2015). In addition, previous studies indicated that a prerequisite for acknowledging the necessity of taking mitigative action includes gaining an understanding of the human factors contributing to climate change (Guy et al., 2014; Kolenatý et al., 2022; Lee et al., 2015). Therefore, exposing K-12 students to the science behind climate change in schools is important today so that future generations can have a more informed understanding of this urgent global problem and its potential consequences. Also, most college students, especially in non-STEM majors, may not take any courses related to climate change during their undergraduate studies, which can significantly decrease their chances of gaining climate literacy. Integrating climate science literacy into K-12 education can help enable the young generation to acquire a conceptual understanding of the key scientific principles underlying climate change and in turn make more informed decisions in their lives about mitigating the adverse effects of climate change.

Previous research in different countries showed that secondary students generally lacked an adequate comprehension of a number of key scientific principles (e.g., the greenhouse effect, the carbon cycle) to understand the possible reasons for anthropogenic climate change (Bodzin et al., 2014; Cartwright et al., 2021; Cirit & Aydemir, 2021; Morote & Hernández, 2024; Ratinen, 2021). For instance, secondary-level students from countries such as the U.S., Canada, Sweden, and Portugal believed that factors such as pollution, dust, acid rains, and the thinning of the stratospheric ozone layer were the leading causes of climate change (García-Vinuesa et al., 2021; Shepardson et al., 2011; Wildbichler et al., 2025). In addition, while the scientific consensus points to the fact that anthropogenic climate change is one of the biggest threats to the existence of life on our planet (IPCC, 2022), risk judgments of climate change were shown to vary significantly among students and adults in different parts of the world (Hickman et al., 2021; Lee et al., 2015; Leiserowitz et al., 2022; Steentjes et al., 2017). There has been growing research investigating the relationship between knowledge, risk perception and taking pro-environmental action in the context of human-induced climate change and the findings in the literature indicated that this relationship is multi-faceted and complex (Kolenatý et al., 2022; Qin et al., 2024; Tamar et al., 2021). Studies have shown a correlation between higher levels of knowledge related to climate science concepts and higher levels of concern or perceived risk about climate change among students (Aksit et al., 2018; Zobeidi et al., 2020) and adults (Guy et al., 2014; Libarkin et al., 2018; Shi et al., 2016; Stoutenborough & Vedlitz, 2014). In addition, past research has found that individuals' knowledge of climate change and their risk perceptions are crucial drivers of their pro-climatic actions and willingness to engage in mitigation efforts (Kolenatý et al., 2022; Xie et al., 2019; Yu et al., 2020). For instance, in their study with secondary Czech students, Kolenatý et al. (2022) found that that greater climate knowledge positively influenced concern and self-efficacy, which in turn increased willingness to engage in pro-environmental actions.

Secondary Students' Understanding of Climate Change

The interdisciplinary and multidimensional nature of the global climate system makes climate change a highly challenging topic for secondary students and even adults with a good background in science. Understanding climate change requires systems thinking skills and a multidisciplinary approach by holistically employing a variety of scientific concepts from different disciplines such as Earth science, physics, chemistry, meteorology, and so on (McNeal et al., 2014; Ballew et al., 2019). Many studies have been conducted in various countries to investigate secondary students' ideas and understanding of climate change science concepts as well as the difficulties and alternative conceptions they might have about climate change (Akaygun & Adadan, 2020; Bodzin et al., 2014; Cartwright et al., 2021; Jarrett & Takacs, 2020; Punter et al., 2011; Ratinen, 2021). The findings of these studies generally indicated that secondary students in most countries tended to lack a conceptual understanding of the core scientific principles underlying climate change and also held various non-scientific ideas that can potentially inhibit their learning and reasoning about climate change.

One of the most widespread and persistent alternative conceptions among secondary students in the context of climate change is the conflation of climate change and the depletion of the ozone layer (Bhattacharya et al., 2021; Cirit & Aydemir, 2021; Shepardson et al., 2009; Varela et al., 2020; Wildbichler et al., 2025). According to previous studies, students often thought that depletion of the ozone layer leads to rises in global temperatures as 'the ozone hole' causes more radiation from the Sun to pass through the atmosphere and contribute to global warming (Cirit & Aydemir, 2021; Shepardson et al., 2009). Students also believed that the greenhouse gases are responsible for the depletion of ozone layer (Cartwright et al., 2021; Chang & Pascua, 2016; Jarrett & Takacs, 2020) and that the main driving factor for the greenhouse effect is the ozone gas in the atmosphere (Dawson & Carson, 2013). In their study with secondary students in Singapore, Chang and Pascua (2016) reported that the participants were not able to distinguish between the natural and enhanced greenhouse effect, while findings from other studies showed that students failed to demonstrate a conceptual understanding of the importance of the natural greenhouse effect for life on Earth (Cartwright et al., 2021; Dawson & Carson, 2013). In addition, previous studies indicated that students had a variety of alternative conceptions regarding the greenhouse effect (Bhattacharya et al., 2021; Wildbichler et al., 2025). For example, some studies have found that secondary students believed an actual greenhouse gas layer exists in the atmosphere trapping and reflecting solar radiation (Jarrett & Takacs, 2020; Varela et al., 2018). Students were shown to think that radioactive waste and using nuclear power cause and/or exacerbate the greenhouse effect (Frappart et al., 2018; Kılınç et al., 2008; Ratinen, 2021). Students also had difficulty in distinguishing the types of electromagnetic radiation (e.g., infrared waves, ultraviolet light) and understanding how different wavelengths of solar radiation interact with greenhouse gases in the atmosphere (Ratinen & Uusiautti, 2020; Shepardson et al., 2009). Additionally, past research indicated that secondary students tended to think that littering, pollutant gases, and general environmental pollution were the primary causes of the enhanced greenhouse effect (Akaygun & Adadan, 2020; Boon, 2009; Lin, 2017), and they were not able to identify and differentiate different types of greenhouse gases (e.g., methane, water vapor) in the atmosphere other than carbon dioxide (Cartwright et al., 2021; Kurup et al., 2021; Tobler et al., 2012).

Understanding the concept of scale is also crucial for developing a holistic understanding of climate change because climate change encompasses interconnected processes that operate at various temporal (e.g., years, decades, centuries) and spatial (e.g., local, regional, continental, global) dimensions (Pahl et al., 2014). Grasping these scales can enable individuals to appreciate the complexity of climate systems and the multi-layered impacts of climate change (Ervin-Blankenheim, 2023; Lombardi & Sinatra, 2012). Climate change unfolds over extended time periods, with certain processes occurring over decades to millennia (IPCC, 2022). As such, students need to develop an understanding of deep time (or geological time) to better contextualize the current climate change within the broader patterns of natural variability over millions of years and identify unprecedented shifts in today's global climate systems that have been driven mostly by human activities since the past century (Lombardi & Sinatra, 2012; Sezen-Barrie et al., 2022). For example, in a study with undergraduate students in the United States, Lombardi and Sinatra (2012) investigated whether participants' understanding of deep time was related to their ability to differentiate between weather and climate. Their findings indicated that a stronger grasp of deep time, along with enhanced perceptions of human-induced climate change, accounted for a significant portion of the variance in students' ability to conceptually distinguish between weather and climate.

Secondary Students' Perceptions of Risks Regarding Climate Change

Risk perception of climate change can be conceptualized as individuals' subjective assessments and feelings about the potential harm and adverse effects associated with anthropogenic climate change (Van der Linden, 2014). There has been growing research in the literature regarding investigating secondary students' perceptions of the risks associated with climate change (e.g., Ambusaidi et al., 2012; Boyes et al., 2014; Cosby et al., 2025; Deng et al., 2017; Hermans & Korhonen, 2017; Hickman et al., 2021; Özdem et al., 2014) while most of the related studies have primarily targeted adults and the general public in various countries (e.g., Lee et al., 2015; Leiserowitz et al., 2022; Sivonen, 2023; Spence et al., 2012; Steentjes et al., 2017; Thaker et al., 2023; Xie et al., 2019). In addition, the findings of the literature on secondary students' risk perceptions related to climate change have been inconsistent as some studies showed students attributing high levels of risk or concern to climate change (Ambusaidi et al., 2012; Boyes et al., 2014; Chhokar et al., 2012; Cosby et al., 2025; Tranter & Skrbis, 2014) while other studies reported low to average levels of perceived risk or concern among secondary students (Boyes & Stanisstreet, 2012; Hermans & Korhonen, 2017; Özdem et al., 2014). It is important to note that while some of these studies used different terminology such as 'concern' (e.g., Ambusaidi et al., 2012; Cosby et al., 2025) and 'worry' (e.g., Boyes et al., 2014; Leiserowitz et al., 2022; Sciberras & Fernando, 2022) to refer to participants' emotional responses to climate change, these constructs are closely related to, but distinct from, risk perception. Specifically, concern and worry can be seen as emotional responses that contribute to or reflect an individual's perception of the risk and threat that climate change poses (Loewenstein et al., 2001). Although not identical to risk perception, previous studies that included these constructs were considered relevant and used as proxies for understanding how secondary students evaluate the threat of climate change, given the limited research on risk perception in this age group. In a large-scale study conducted internationally with secondary students (N = 12,657) from eleven countries, Boyes et al. (2014) found that while the majority of the sample (74%) were either 'very' or 'quite' worried about the effects of climate change, students from developing countries (e.g., Brunei, India, Oman) expressed significantly more worry than those who resided in the Western and/or developed countries (e.g., U.S., Australia, Spain). In another study with a large sample of secondary students in Oman, Ambusaidi et al. (2012) found that Omani students had rather high levels of concern about climate change that the majority (84%) of the participants reported being either 'very' or 'quite' worried about it. Lastly, some studies have also shown that secondary-level female students tended to perceive climate change as a higher level of risk compared to male students (Baldwin et al., 2023; Hermans & Korhonen, 2017; Rohmawati et al., 2024; Stevenson et al., 2019). For example, in a study with a large group of middle school students (N = 426) in the U.S., Stevenson et al. (2019) found that female students were more likely than male students to exhibit higher concern regarding the impacts of climate change.

Significance of the Study

The majority of the previous studies regarding secondary students' conceptions of climate change and their associated risk perceptions were conducted mostly in Western and/or developed countries (e.g., Antronico et al., 2023; Brügger et al., 2020; Stevenson et al., 2019). However, there is a dearth of research addressing students' knowledge and beliefs about climate change, especially in developing nations including the Gulf countries considering the fact that most of these countries have long been some of the largest oil-producing nations in the world (Reiche, 2010) and are also among the most vulnerable countries in the world to the adverse impacts of climate change (Al-Maamary et al., 2017). It is important to investigate what the youth in the Gulf countries know about climate change and how they perceive the associated risks, so that appropriate climate change communication and learning strategies can be formulated for this student population. The purpose of this study was to contribute to the growing literature on this important topic by exploring a sample of Saudi Arabian high school students' understanding of the scientific concepts underlying climate change and their risk perceptions about the impacts of climate change during an elective environmental science [ES] course. The sample consisted of eleventh- and twelfth-grade students who were enrolled in a year-long, Advanced Placement [AP] ES course in a private school in Saudi Arabia. Students' understanding of the key scientific concepts underlying climate change and their risk perceptions associated with climate change before and after participating in the course were investigated to evaluate the influence of the course.

Theoretical Framework

The Knowledge Integration [KI] framework (Chiu & Linn, 2011; Linn, 2008) served as the theoretical framework of this study. The KI framework was developed by drawing upon the varied aspects of conceptual change theory (Linn, 2008). The conceptual change researchers focused on the processes and conditions under which learners successfully alter their alternative ideas with the target conceptions, and this process is commonly called conceptual change (Duit & Treagust, 2003). While some conceptual change researchers viewed alternative conceptions as cognitive obstacles to learning, the KI framework places an emphasis on the value of ideas students may bring to the classroom and argues that "...instruction designed to capitalize on the variability and the creativity of student ideas has potential for facilitating conceptual change" (Linn, 2008, p. 715). According to the KI framework, learners develop their understanding through certain mental processes that include "adding, sorting, evaluating, distinguishing, and refining ideas" (Chiu & Linn, 2011, p. 2) and it is important to note that these ideas do not only originate in the classroom but also come from personal experiences, intuition, cultural norms, social settings, and so on. Instruction that draws on the KI framework would provide learners with a variety of opportunities in the classroom to be aware of their own pre-existing ideas about the target topic and then compare and contrast their initial ideas with the ones introduced by teacher, which may lead to a more integrated and coherent understanding of these ideas (Linn, 2006).

Based on the synthesis of the relevant empirical studies, the KI framework formulated an instructional pattern that aimed to support student learning as they develop meaningful connections among the existing and new ideas. This instructional pattern included four distinct phases: (1) elicit ideas, (2) add ideas, (3) develop criteria, and (4) sort ideas (Chiu & Linn, 2011). In the first phase of eliciting ideas, learners are given chances to activate their initial ideas about the target concept and make them explicit to their peers and teacher. Different strategies such as pre-unit quizzes and think-pair-share can be used to make students think about what they already know about the topic. In the next stage of adding ideas, new ideas and concepts would be introduced to learners in a context that incorporates their existing ideas, past experiences, and patterns of thinking, which is often overlooked in traditional classroom settings (Chiu & Linn, 2011). Student-centered instruction that employs hands-on and minds-on activities, such as using interactive models and simulations, bringing relevant analogies and metaphors, can be used to introduce the target science concepts by taking into consideration the existing ideas of learners. For example, in the beginning of a lesson on the greenhouse effect, students might be asked to remember whether they had seen an actual greenhouse on farmlands or somewhere else before. If students appear to remember seeing or experiencing greenhouses, the teacher might ask students what they already knew about the greenhouses and then introduce the key concepts of the greenhouse effect through dynamic visualizations and hands-on demonstrations by drawing parallels as well as highlighting the differences between the two phenomena. In the third phase of developing criteria, students are expected to distinguish between their existing conceptions and the newly introduced ideas to see if they conflict or support each other (Chiu & Linn, 2011). For instance, continuing with the previous example, students might be asked to draw the mechanism of the greenhouse effect on paper based on their understanding. They would then compare their drawings with an interactive model or simulation provided by the teacher to see if their depiction aligns with what they observed on the simulation. By examining the model or simulation, students would be able to develop criteria to evaluate their own ideas about how the greenhouse effect works. During the last phase of sorting ideas, learners are encouraged to sort out and further refine their understanding as a result of their evaluations in the previous phase (Chiu & Linn, 2011). Teachers can support students in this stage by providing them with metacognitive opportunities to reflect upon their learning so that they can find discrepancies or gaps in their newly acquired knowledge of the target concept. Overall, this instructional pattern as suggested by the KI framework was employed in planning the individual lessons and designing the learning activities for the elective ES course.

Purpose of the Study

There were two main goals of this study. First, the study aimed to investigate what a sample of high school students in a developing Arab country in the Middle East knew about the basic science concepts underlying climate change as well as what their risk perceptions were regarding the adverse impacts of climate change before and after participating in an elective ES course. Secondly, the study examined the influence of a year-long, elective ES course on high school students' conceptual understanding and risk perception of climate change. The study also explored if any relationship exists between participants' knowledge of climate-related science concepts and their associated risk perceptions. Specifically, this study aimed to answer the following research questions:

1. What prior knowledge and risk perceptions did a sample of Saudi Arabian high school students have about climate change before participating in an elective ES course?
2. How did participation in an elective ES course influence a sample of Saudi Arabian high school students' content knowledge and risk perceptions of climate change?

3. Was there any relationship between knowledge of climate change science concepts and perceived level of risk associated with climate change among a sample of Saudi Arabian high school students before and after participating in an elective ES course?

Methods

Context

This study took place in a private school in Saudi Arabia during the 2020-2021 academic year. Ethical approval from the school was obtained before the data collection for the study. The school was serving two international programs: the International Baccalaureate [IB] and Advanced Placement [AP]. In grades 6 to 10, the IB program was offered to students who chose to study international curricula, and the AP courses were offered in grades 11 and 12. Additionally, the school was a boys' school, as most K-12 schools in Saudi Arabia are strictly gender-segregated. The sample of the study consisted of male students who were enrolled in a year-long, elective AP ES course. The class schedule consisted of four periods each week for a total of 16 weeks per semester. Each class period lasted 40 minutes. Different elective courses were offered to students as part of their coursework for the graduation requirements and the AP ES course was one of the elective courses that students were able to take during that academic year. The participating students were in two separate sections taught by the same teacher who used the same syllabus, lesson plans, learning activities, and summative assessments for both groups. Apart from the elective AP ES course there was no environmental or Earth science course available in the school as mandatory or elective during middle and high school. Therefore, the AP ES course served as the participants' first formal exposure to environmental science during their secondary school education.

The AP Environmental Science Course

The AP ES course was developed by the College Board with the aim of equipping learners with a holistic and comprehensive understanding of the complex relationships among the Earth's natural systems and the environmental challenges facing our planet (College Board, 2020). It is inherently an interdisciplinary course that integrates scientific principles from a variety of disciplines including geology, biology, chemistry, geography to explore the core concepts and applications in the field of environmental science. The AP ES curriculum was designed to align with the content covered in a typical introductory-level, one-semester college course on environmental science. Some of the course objectives included understanding the concepts, theories, principles, and methods that are required to recognize the interactions of the different systems in the environment (e.g., ecosystems, food webs), identifying the movement of matter within and between different systems (e.g., the carbon cycle), analyzing natural and human-made environmental problems, and evaluating the potential risks with these problems (College Board, 2020). The elective ES course followed the official AP ES course curriculum and syllabus provided by the College Board and used the textbook 'Environmental Science for AP' by Friedland and Relyea (2015). The last instructional unit in the AP ES curriculum, which is called 'Global Change', included the topics directly on climate change by addressing some key points such as how climate change and global warming are related, the scientific evidence for anthropogenic climate change, how scientists can investigate Earth's past climate patterns, and so on (College Board, 2020). The Global Change unit also covered the greenhouse effect and the adverse effects of climate change on oceans.

Participants

A convenience sampling technique was employed to recruit students who were enrolled in the elective AP ES course. At the beginning of the semester, all students in the course were invited to participate in the research. The sample of this study consisted of eleventh (n = 29) and twelfth grade (n = 22) male students (N = 51) who volunteered to participate. The age of the students varied from 16 to 18 with an average of 17.33 (SD = .65). Almost all participants were Saudi nationals (n = 49) except for two students who were originally from Jordan but had been living in Saudi Arabia since their childhood because of their parents' occupations. While no data was collected regarding students' socioeconomic backgrounds, the school was a private institution that offered rigorous international curricula with relatively high tuition fees and only a limited number of scholarships were available.

Data Sources

The data sources included a previously developed and validated content knowledge assessment of climate change science concepts (Libarkin et al., 2018) and two Likert-scale items on climate change risk perception, which were adapted from Kahan et al. (2012) to measure participants' risk perception of climate change. The data collection instrument was given to participants online via Google Forms in the classroom at the beginning of the first semester as a pre-test and at the end of the second semester as a post-test. Students were given one class period during both the pre- and post-test to complete the assessment.

The content knowledge assessment consisted of 21 multiple-choice questions that aim to comprehensively assess the understanding of various climate-related science concepts such as the greenhouse effect, the carbon cycle, Earth's energy balance, feedback loops, difference between weather and climate, natural factors affecting global temperatures, and so on. The validity and reliability of the climate change content knowledge assessment were addressed in a previous study with a large sample (N > 1000) of adults in the United States by using the Rasch analysis and the internal consistency of the items was found to be at an acceptable level with a Cronbach's alpha value of .73 (Libarkin et al., 2018). The same instrument was also used with a sample of undergraduate students in a subsequent study and it was found to be valid and reliable for this age group as well (Aksit et al., 2018).

The Likert-scale items, adapted from Kahan et al. (2012), asked participants to rate how serious the risk climate change poses on a scale of 0 (no risk) to 10 (extreme risk). Likewise, a number of previous studies also employed a single item measure of risk perception in various contexts (Ganzach et al., 2008; Weber et al., 2002). Literature on climate change risk perception showed that people may demonstrate temporal distance when they are asked to evaluate the risks associated with climate change (Pahl et al., 2014; Spence et al., 2012). For example, one may attribute a minimal risk to climate change today while assessing a much higher risk for future generations. So, in order to better capture participants' perceived level of climate change risk, Kahan et al.'s (2012) question was adapted into two questions to include timeframes of the 'next 20 years' (i.e., short-term) and 'next 100 years' (i.e., long-term): "How much risk do you believe climate change poses to human health, safety, or prosperity in the next 20 years on a 0 ('no risk') to 10 ('extreme risk') scale?" and "How much risk do you believe climate change poses to human health, safety, or prosperity in the next 100 years on a 0 ('no risk') to 10 ('extreme risk') scale?". The content validity of these two Likert-scale questions were addressed by consulting two experts in climate change education. Both experts confirmed that the items were appropriate and relevant for assessing climate change risk perceptions among high school students. Additionally, in order to address the face validity, a preliminary pilot testing of the items was conducted at the beginning of the semester with five students who did not enroll in the elective ES course. These students carefully read the items and commented on what they understood. Based on their comments, it was decided that the items were clear and understandable for the sample of this study. Reliability of the Likert-scale items was assessed by calculating Cronbach's alpha, which was found to be α = .79, indicating a good level of internal consistency (George & Mallery, 2019).

Data Analysis

Firstly, all responses were downloaded to a Microsoft Excel file and were carefully examined for any irregularities (e.g., choosing the same answer option for all questions). After finding no irregularities, students' responses to the content knowledge assessment were entered into the Winsteps 5.7 software (Linacre, 2024) to conduct Rasch analysis (Boone et al., 2014). The Rasch model, which is an Item Response Theory (IRT) model with one parameter, is based on a unidimensional probabilistic model in which a respondent's probability of giving a true answer to a particular item in a test or scale is determined by the difference between the student's latent trait and the difficulty level of the item (Bond & Fox, 2015). Following the data entry into the Winsteps software, an initial analysis was run to generate both person and item fit statistics (i.e., Infit MnSq/Z-Std, Outfit MnSq/Z-Std) to assess the data quality with respect to the Rasch model by checking if there were any misfitting respondents and/or misfitting items. Person and item infit-outfit MnSq values were mostly distributed between 0.7 and 1.3, which are the accepted range of values for a multiple-choice assessment (Wright & Linacre, 1994). In addition, item separation reliability value was 1.30 for the pre-test and 1.24 for the post-test, indicating an acceptable level of item separation in terms of the difficulty levels of the items on the latent variable (Linacre, 2024). Lastly, the person separation reliability index value was 0.63 for the pre-test and 0.60 for the post-test, implying relatively low person separation that suggests the instrument did not provide enough sensitivity to separate high and low performers (Linacre, 2024). In the next stage, students' logit scores were generated based on their raw scores from the climate change content knowledge assessment, and for ease of interpretation, the logit scores were rescaled to a 0-100 scale by using *uimean* and *uscale* parameters in Winsteps. Next, the logit scores were entered into the IBM SPSS software (version 27) along with the rest of the dataset for statistical data analysis. The normality of the data was examined both visually and statistically by using Q-Q plots and running the Shapiro-Wilk tests in SPSS. The results showed that the data was normally distributed with the significance values greater than .05 for the Shapiro-Wilk tests. Descriptive statistics were generated for students' scores on the content knowledge assessment and the perceived risk items. Paired-samples t-test analyses were run to compare students' pre- and post-test scores from the content knowledge assessment and the risk perception items. Lastly, Pearson correlation coefficients were calculated to evaluate the relationship, if any, between students' knowledge of climate change science concepts and their overall risk perceptions before and after participating in the elective ES course.

Results

Table 1 shows the descriptive statistics for the participants' scores of the content knowledge assessment on a logit scale (rescaled to 0-100) and the scores representing participants' perceived level of risk about climate change on a scale of 0-10 before and after participating in the course. The results overall indicated that the sample of this study demonstrated an average level of understanding of the scientific concepts underlying climate change before attending the course. Students' mean logit score for the content knowledge assessment increased by almost nine points in the post-test compared to the pre-test. In addition, at the beginning of the course, the participants appeared to have a moderate level of perceived risk for the potential impacts of climate change in the next 20 years while their risk perceptions on average were relatively higher for the long-term effects (the next 100 years) of climate change. The participants' overall risk perception of climate change, which was calculated as the average of their short- and long-term risk perceptions, was found to be at an above-moderate level at the beginning of the course. Lastly, students' overall risk perception of climate change at the end of the course was found to be at a higher level compared to the beginning of the course. It is noteworthy to mention that at the beginning of the course, some participants believed that climate change posed 'no risk' in both the short- and long-term, choosing zero on the risk scale items. However, by the end of the course, none of the students chose zero; the minimum values selected for short- and long-term risk were 3 and 5, respectively (Table 1).

Table 1

Descriptive statistics for content knowledge and risk perception of climate change

	M	*SD*	Median	Mode	Min.	Max.	Range
Content knowledge-Pre (logit)	49.34	9.07	48.94	41.10	27.46	68.54	41.08
Content knowledge-Post (logit)	58.27	9.26	61.60	64.73	37.94	72.42	34.48
Short-term risk perception-Pre	6.06	2.59	6	5	0	10	10
Long-term risk perception-Pre	7.51	2.70	8	10	0	10	10
Overall risk perception-Pre	6.78	2.41	7.50	9	0	10	10
Short-term risk perception-Post	8.00	1.64	8	9	3	10	7
Long-term risk perception-Post	8.71	1.46	9	10	5	10	5
Overall risk perception-Post	8.35	1.30	8.50	9	5	10	5

N = 51.

Table 2 includes the mean scores and standard deviations for each multiple-choice question of the content knowledge assessment of climate change for the pre- and post-test. These mean scores were calculated by dividing the total number of correct responses given to a question by the number of all responses to that question. The last column

'Gain' in Table 2 shows the percentage increase of the mean score for each question in the assessment (Gain = [M_{post} - M_{pre}] × 100). In addition, the questions were grouped together under certain categories based on the underlying scientific concept they aimed to assess. The total means and standard deviations were calculated for the questions under each category to provide an overall measure of students' understanding within each conceptual domain and to facilitate comparison of student performance across the categories in the pre- and post-test. The results in Table 2 indicate that the mean scores for all questions and all categories increased in the post-test compared to the pre-test. However, the amount of improvement varied across categories and individual questions. For instance, the item related to the feedback loops (Q-1), and the item that focused on the definition of a greenhouse gas (Q-5) showed substantial gains, whereas the questions assessing Earth's energy balance (Q-17) and the historical temperature trends (Q-11) exhibited much smaller gains. Specifically, the results suggest that before participating in the elective ES course, students had a quite limited understanding of concepts related to the greenhouse effect and greenhouse gases, with relatively low pre-test mean scores on most of the related questions (Q-5, Q-13, Q-15, Q-16, Q-21) as well as the lowest overall mean score among the categories. Additionally, less than half of the participants correctly answered the questions related to the feedback loops (Q-1), the nature of radiation emitted by the Sun and the Earth (Q-12, Q-14), and Earth's energy balance (Q-17) during the pre-test. In contrast, students demonstrated a relatively better understanding of concepts related to the carbon cycle (Q-7, Q-8), the difference between weather and climate (Q-9), and heat transfer processes around the Earth (Q-2, Q-3, Q-4) during the pre-test.

At the end of the course, some concepts remained challenging for students. For example, their understanding of Earth's energy balance (Q-17), the types of electromagnetic radiation emitted from the Sun (Q-12), and accessing historical climate data from glaciers (Q-20) was still relatively low. Additionally, several questions related to the greenhouse effect (Q-13, Q-15, Q-16, Q-21) continued to have low mean scores even after the formal instruction. On the other hand, the participants demonstrated moderate to high conceptual gains in areas such as feedback loops (Q-1), definition of greenhouse gases (Q-5), radiation reflected from Earth's surface (Q-14), and the role of non-greenhouse gases (Q-21).

Paired samples t-tests were run to examine the influence of an elective ES course on students' understanding of the science concepts related to climate change as well as their risk perceptions. Table 3 shows the results of the paired-samples t-tests, along with Cohen's *d* effect sizes, indicating that students who attended a year-long, elective AP ES course exhibited a statistically significant increase in their short- and long-term risk perceptions of climate change along with their overall risk perception. The results also showed that there was a significant increase in the level of students' understanding of the fundamental scientific concepts underlying climate change. Furthermore, Cohen's *d* effect size values pointed out the high practical significance of the results with the exception of the change in the long-term risk perception being between low to moderate practical significance (Cohen, 1992).

Table 2

Means and standard deviations for the multiple-choice questions of the climate change content knowledge assessment

Questions	Pre-test		Post-test		Gain
	M	*SD*	*M*	*SD*	
Feedback Loops & Earth System Interactions					
1. Which is the best definition of a positive feedback loop in the climate system?	.37	.48	.75	.44	38%
2. Which of the following will occur if the amount of ice floating in the ocean decreases?	.63	.48	.78	.41	15%
18. Which of the following could cause the Earth's surface temperature to change?	.45	.50	.65	.48	20%
Category Total:	.48	.49	.73	.44	25%
Heat Transfer & Earth Energy Balance					
3. Which of the following contributes to the transfer of thermal energy from place to place around the Earth?	.73	.45	.78	.41	5%
4. How does sunlight affect temperature on Earth?	.57	.50	.78	.41	21%
12. Which is the most common form of radiation given off by the Sun?	.18	.38	.33	.47	15%
14. Which is the most common form of radiation given off by Earth's surface?	.41	.49	.76	.43	35%
17. Averaged over long-time periods, how does the amount of energy arriving from space compare to the amount of energy leaving Earth?	.29	.46	.35	.48	6%
Category Total:	.44	.46	.60	.44	16%
The Greenhouse Effect & Greenhouse Gases					
5. Which of the following is the best definition of a greenhouse gas?	.29	.46	.65	.48	36%
13. How much incoming sunlight do greenhouse gases absorb?	.27	.45	.39	.49	12%
15. What do greenhouse gases do?	.43	.50	.49	.50	6%
16. Where will a photon emitted by a greenhouse gas molecule most likely go?	.29	.46	.49	.51	20%
21. Which statements about non-greenhouse gases are accurate?	.27	.45	.49	.50	22%
Category Total:	.31	.46	.50	.50	19%
The Carbon Cycle					
7. Which of the following best describes how plants take in CO_2?	.63	.48	.75	.44	12%
8. Which of the following would most likely occur if the oceans stopped absorbing CO_2?	.75	.44	.82	.38	7%
Category Total:	.69	.46	.79	.41	10%
Climate vs. Weather					
9. Which is the best description of the differences between climate and weather?	.73	.45	.82	.39	9%
Impacts of Climate Change					
19. Which of the following can be caused by climate change?	.75	.44	.90	.30	15%
Historical Climate Data & Trends					
6. How has the amount of CO_2 in the atmosphere changed since the start of the Industrial Revolution 150 years ago?	.73	.45	.84	.36	11%
10. Which of the following statements about global warming over the past 50 years is most accurate?	.75	.44	.76	.42	1%
11. Which of the following statements about air temperature change over the past million years is most accurate?	.35	.48	.49	.50	14%
20. What information do ice cores from glaciers contain about Earth?	.33	.47	.45	.50	12%
Category Total:	.54	.46	.64	.45	10%

N = 51.

Table 3

Results of the paired-samples t-tests comparing students' content knowledge and risk perception of climate change before and after participating in the elective course

	Mean Difference (Post-Pre)	95% CI for Mean Difference		t (50)	Cohen's d
		Lower	Upper		
Content knowledge (logit)	8.93	5.59	12.27	5.37^{***}	0.75
Short-term risk perception	1.94	1.47	2.41	8.32^{***}	1.17
Long-term risk perception	1.20	0.42	1.98	3.09^{**}	0.43
Overall risk perception	1.57	1.02	2.12	5.75^{***}	0.81

N = 51; *p < .05, **p < .01, ***p < .001, two-tailed.

Lastly, the results of the Pearson product-moment correlation analyses showed no correlation between students' knowledge of climate change concepts and their overall risk perception during both the pre-test (r = .051, n = 51, p = .724) and the post-test (r = -.155, n = 51, p = .279).

Discussion

Students' Knowledge of Climate Change

Given that today's youth have grown up during a time when the causes and potential impacts of climate change are well-documented and frequently covered in the media and schools, one would expect them to have a basic understanding of the core atmospheric mechanisms behind climate change and a more informed awareness of the risks associated with rapidly changing global climate patterns. However, the findings of this study align with prior research with secondary students (Düsing et al., 2019; García-Vinuesa et al., 2021; Jarrett & Takacs, 2020; Varela et al., 2020), indicating that students often lacked a robust understanding of the key scientific concepts related to climate change, despite having an increased exposure to these concepts in both formal and informal settings. The participants in this study were able to correctly answer only about half of the pre-test questions, suggesting that while their prior knowledge of climate change science concepts was not exceedingly low, it was quite limited. Comparisons with previous studies using the same instrument (Aksit et al., 2018; Libarkin et al., 2018) revealed that the participants' prior knowledge was similar to that of undergraduate students at a U.S. university and slightly higher than that of a representative sample of the American public. This suggests that exposure to rigorous international curricula may provide some foundational knowledge, but the fragmented nature of climate change education likely hinders students' ability to fully grasp and apply these concepts. Integrating climate change topics more cohesively throughout the curriculum could enhance students' comprehensive understanding and ability to reason about climate change issues.

The results also showed that most participants struggled with the questions related to the greenhouse effect, a foundational concept for understanding anthropogenic climate change. This aligns with previous studies highlighting the greenhouse effect as a quite challenging topic for secondary students (Boon, 2009; Dawson & Carson, 2013; Shepardson et al., 2011; Taylor & Jones, 2020). In contrast, the majority of students demonstrated a solid understanding of the carbon cycle, both before and after the course, potentially due to its inclusion in their grade nine science curriculum. Similarly, most participants understood the difference between weather and climate at the beginning of the course, which contrasts with the general findings of previous studies conducted with secondary students in various countries (Dawson, 2015; Fick & Songer, 2017; Gunes, 2020; Taylor & Jones, 2020). This stronger understanding among the participants in the present study may be partly attributed to more frequent exposure to these terms in the media and everyday life as part of the discourse on climate change. Despite significant conceptual gains as a result of attending the course, participants did not achieve a high level of understanding of climate-related science concepts at the end of the course, as evidenced by their post-test scores. One reason could be the demanding and content-heavy nature of the course, which covered a broad range of environmental science concepts beyond climate change. While the AP ES course provided essential knowledge about environmental science and climate change, the results suggest that secondary students may greatly benefit from repeated exposure to climate-related science concepts during their formal education for a deeper and conceptual understanding of climate change.

Students' Risk Perceptions of Climate Change

The findings of this study regarding students' risk perceptions of climate change align with previous research showing variations in perceived risk among secondary students (Ambusaidi et al., 2012; Boyes et al., 2014; Hermans & Korhonen, 2017; Özdem et al., 2014; Sciberras & Fernando, 2022). Compared directly on the same Likert scale with a sample of undergraduate students at a U.S. university who, on average, reported a relatively high-risk perception (M = 7.22, SD = 2.04) in the pre-test (Aksit et al., 2018), and with a representative sample of the American public who also exhibited a comparatively higher level of perceived risk (M = 7.4, SD = 2.4) regarding climate change (Libarkin et al., 2018), our sample in this study seemed to have had a somewhat lower level of overall perceived risk about climate change before attending the course (M = 6.78, SD = 2.41). This result might be partly attributed to the gender composition of the sample which consisted of only male students, as previous studies have indicated that female students tend to perceive climate change as a significantly higher risk than male students (Baldwin et al., 2023; Hermans & Korhonen, 2017; Stevenson et al., 2019).

The results showed that students, on average, perceived a significantly higher risk for the long-term impacts of climate change compared to its current and near-term effects, both before and after participating in the elective course. This temporal distancing, where individuals perceive climate change as a distant future threat rather than a current one, has been observed in previous studies with students and the general public (Guttry et al., 2017; Leiserowitz, 2005; Spence et al., 2012; Wang et al., 2019). This finding is particularly interesting given the fact that Saudi Arabia has already been experiencing the adverse impacts of climate change for the past two decades, such as increased extreme weather events and severe droughts (Labban et al., 2023). The observed temporal distancing among the sample could be due to a lack of direct personal experience with the current impacts of climate change or a lack of explicit connections made between these events and global climate change. It is also plausible that cultural norms and religious beliefs could influence students' risk perception to some extent, particularly in a region where these factors play a significant role in daily life. Furthermore, Saudi Arabia's global status as a major oil- and gas-producing country might have influenced students' perceptions of climate change risk to some extent. Economic dependence on fossil fuel industries may shape public discourse and societal attitudes toward climate change (Yale Program on Climate Change Communication, 2025), potentially contributing to lower perceived risk or a sense of disconnect from global climate mitigation efforts.

The temporal distancing observed in this study has important implications for climate change mitigation and adaptation efforts. When individuals perceive climate change as a distant future threat, it can lead to a sense of complacency and reduced urgency in addressing the issue (Spence et al., 2012; Xie et al., 2019). This can hinder the implementation of effective mitigation strategies and delay the development of necessary adaptation measures. Climate change education should emphasize the present and near-term impacts of climate change, making the consequences more tangible and relatable for students to counteract temporal distancing. Additionally, highlighting the potential benefits of mitigation and adaptation efforts, such as improved air quality and increased resilience to extreme weather events, could help motivate students to take action. It is important to note that this study relied on a two-item risk perception measure, which might not have fully captured the complexity of risk perception involving cognitive, affective, and behavioral components (Sjöberg, 2004; Van der Linden, 2017). Future research could employ more comprehensive measures of risk perception, including qualitative methods, to gain a more in-depth understanding of students' risk perceptions. This would allow for a more nuanced analysis of the factors influencing risk perception and the relationship between knowledge and perceived risk.

Relationship between Knowledge and Risk Perception of Climate Change

This study aimed to explore whether a relationship exists between content knowledge and perceived risk of climate change among secondary students in a Gulf country in the Middle East, a topic not previously investigated in the literature to the best of the author's knowledge. Contrary to findings in a number of previous studies in different countries (Aksit et al., 2018; Stevenson et al., 2014, 2018; Tobler et al., 2012; Yu et al., 2020; Zobeidi et al., 2020), the results showed no statistically significant correlation between students' knowledge of climate change science concepts and their perceived risk, both before and after the elective ES course. This finding warrants closer examination, particularly considering changes in students' risk perceptions over the course. Students' short-term risk perceptions, in particular, appeared quite malleable. Despite most students correctly identifying potential adverse impacts of climate change before the course (Table 2: Q-19), their perceived risk associated with these consequences, especially in the short-term, was initially relatively low. This disconnect between knowledge and risk perception might be explained by several factors. First, while Saudi Arabia has been experiencing increased extreme weather events and droughts (Labban et al., 2023), these events might not have been explicitly linked to climate change in the local media or within their social circles. Consequently, students might not have connected these events to climate change when assessing its risk. Secondly, students' sources of information about climate change could also play a role (Huang & Bu, 2025). With the prevalence of misinformation and disinformation on social media and news outlets today

(Sharma et al., 2019), students might not have encountered accurate and reliable information to inform their risk assessments on climate change.

It is also plausible that cultural norms and religious beliefs could play some role in shaping students' risk perception since these factors may influence how individuals assess and respond to potential hazards based on moral values or collective traditions (Van der Linden, 2017; Kahan et al., 2012). For example, cultural values emphasizing strong community and family ties might influence how individuals perceive the risks of a changing climate that could disrupt these social structures. The lack of correlation between knowledge and risk perception could also be attributed to the affective and experiential components of risk perception. While knowledge provides an intellectual understanding of risks, emotions and personal experiences can significantly shape how individuals perceive and respond to these risks (Slovic et al., 2004). Students might possess the knowledge about climate change but lack the emotional connection or personal experience to translate that knowledge into a sense of immediate risk. Overall, the findings point out the complex relationship between knowledge and risk perception and suggest that other factors, such as emotions, values, cultural norms, and religious beliefs might also play a role. The findings underscore the need for climate change education that not only facilitates knowledge acquisition but also fosters a deeper understanding of the associated risks and considers the sociocultural context in which students are situated. Future research could investigate how different educational approaches, such as those emphasizing the local impacts of climate change, the development of critical media literacy skills, or the integration of cultural and religious perspectives, might influence the relationship between knowledge and risk perception among secondary students in this context.

To sum up, the findings of the present study highlighted some notable differences and similarities between Saudi Arabian male adolescents attending a private school and other demographic groups studied globally. Specifically, the participants of this study demonstrated a moderate level of climate change knowledge prior to the ES course, with substantial gains following the course, which aligns with findings from similar studies conducted in Western contexts, such as the U.S. and Europe (e.g., Aksit et al., 2018; Kolenatý et al., 2022; Kurup et al., 2021). However, the overall level of knowledge remained lower than expected, particularly concerning the greenhouse effect and related concepts, which echoes findings from various countries where secondary students struggled highly with these foundational topics pertinent to climate change (Cartwright et al., 2021; Dawson & Carson, 2013; Wildbichler et al., 2025). Interestingly, the participants' risk perceptions of climate change were initially at moderate levels, with significantly higher concern for long-term impacts compared to short-term risks. This pattern of temporal distancing has been observed in both Western and non-Western contexts (Guttry et al., 2017; Wang et al., 2019), but it is particularly important to consider within the Saudi Arabian context, where unique societal and cultural factors might contribute to these perceptions. Moreover, the all-male, private school sample represents a unique demographic that may not fully reflect broader educational or societal trends in Saudi Arabia or the Middle East. Previous studies have shown that female students often exhibit higher risk perceptions related to climate change (Baldwin et al., 2023; Stevenson et al., 2019), suggesting that gender composition might influence the findings to some extent. Therefore, future comparisons to studies with more diverse samples, including public school students, female students, and participants from various socioeconomic backgrounds, may provide valuable insights into how climate literacy and risk perceptions manifest across different groups. This study contributes to the related literature by offering a region-specific perspective that has been largely neglected in the literature and showing that educational interventions can effectively enhance climate change knowledge and risk perceptions in populations that have limited prior exposure to environmental science curricula.

Conclusion and Limitations

This study aimed to contribute to the nascent literature on secondary students' knowledge and risk perceptions of climate change in a Gulf country, which has been mostly overlooked in previous research. The findings revealed that a sample of Saudi Arabian high school students demonstrated a limited understanding of climate-related science concepts, particularly the greenhouse effect, before participating in an elective ES course. However, their understanding significantly improved after the course, although some conceptual areas still required further attention. Additionally, students initially exhibited moderate levels of risk perception regarding climate change, with notably higher perceptions for long-term impacts compared to short-term effects. This suggests a degree of temporal distancing, potentially influenced by factors such as limited personal experience with the impacts of global climate change and the framing of climate change as a future threat in the media and social discourse. While the one-group pre-experimental design of this study warrants cautious interpretation, the results suggest that integrating environmental science courses into secondary education can enhance students' understanding of complex environmental issues like climate change. Given the limited exposure to such courses in non-STEM fields in higher education, incorporating climate-related science concepts into K-12 curricula appears essential for fostering climate literacy among future generations.

Several limitations of this study can be addressed in future research. Firstly, the all-male sample and the focus on private school students significantly limit the generalizability of the findings. Future studies should include more diverse samples to better understand how gender, socioeconomic background, and educational setting might influence Saudi Arabian secondary students' climate change knowledge and risk perceptions. Secondly, the study's reliance on self-reported data could be complemented by qualitative methods to gain deeper insights into students' reasoning and the factors shaping their risk perceptions. Additionally, longitudinal studies could examine the long-term retention of climate change knowledge and the stability of risk perceptions over time. Overall, this study provides valuable insights into the current state of climate change education and risk perception among high school students in Saudi Arabia. The findings highlight the need for continued efforts to improve climate change education and foster a more informed and proactive stance towards this global challenge.

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