

Investigating the level of physics teachers' implementation of the STS and STEM models in Saudi secondary schools in relation to professional licensing standards

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Abstract

Science education is currently witnessing a rapid and radical change. In fact, schools are not only expected to teach scientific facts but also to help learners understand how science relates to technology and society and how scientific knowledge is used to solve real-life problems. Two main models are being used, namely, the science-technology-society (STS) model and the science, technology, engineering, and mathematics (STEM) approach. In this study, a descriptive survey was completed by 424 physics teachers, using two scales – the STS and STEM – each of which consists of 15 items. The findings indicated that teachers reported relatively high levels of implementing both STS and STEM practices. The results also demonstrated a strong significant, positive correlation between STS and STEM implementation among secondary school physics teachers in Saudi Arabia, suggesting that these approaches are complementary and commonly used together in classrooms. Additionally, the findings reflected a strong alignment between teachers' instructional practices and the competencies outlined in Saudi Arabia's professional licensing standards, though some gaps still remain, particularly in engineering-focused instruction. The study stresses the importance of targeted professional development programs that enhance the integration of engineering design and applied mathematics into physics education. It also emphasizes the need to align teacher preparation and ongoing training with modern instructional models to improve the quality of science education in Saudi secondary schools.

Keywords: STS, STEM, physics teachers, professional license standards, instructional models

INTRODUCTION

Today, science education is undergoing rapid and significant changes. Schools are now expected not only to teach scientific facts but also to help students understand the connections among science, technology, and society and how scientific knowledge is applied to solve real-world issues (Dillon & Wong, 2025). To promote this, various teaching models have been created to encourage teachers to move beyond traditional lectures and integrate approaches that relate science to everyday life. Two prominent models include the science-technology-society (STS) model and the science, technology, engineering, and mathematics (STEM) approach.

Both approaches had been investigated with regard to science education. Research synthesis, systematic review, and meta-analysis have provided essential practical evidence related to the implementation and effectiveness of these models (Bennett et al., 2007; Martín-Páez et al., 2019; Pedretti & Nazir, 2011). Both approaches link scientific knowledge to everyday life and promote interdisciplinary learning, problem solving, and higher-order thinking skills that strengthen modern physics education (Kelley & Knowles, 2016; Zeidler et al., 2005).

The STS model aims to help learners connect scientific knowledge to technology and social issues. Learning science involves discussing real-world problems such as energy resources, technological advances, and environmental challenges. According to

Contribution to the literature

- This study provides survey-based evidence collected from 424 physics teachers regarding their level of implementation of both STS and STEM approaches in Saudi secondary schools, exploring an area that receives limited research attention.
- The study explores a positive relationship between STS and STEM implementation, suggesting that physics teachers employ both approaches in a complementary manner rather than treating them as two separate approaches.
- By examining teachers practice in relation to the Saudi professional licensing standard, the study identifies the gap in teaching engineering-focused practice, which supports in guiding professional development programs.

Yager (1996), the STS strategy helps students realize that science is integrated with society, as science both influences and is shaped by social needs and technological innovations. Yager (1996) states, "The STS approach emphasizes learning science in ways that relate directly to human experiences" (p. 23). Consequently, teaching based on the STS model can make science more engaging and meaningful for students.

Similarly, STEM instruction has gained much attention worldwide as it prepares students for modern careers and innovation (Bybee, 2010). STEM integrates science, technology, engineering, and mathematics into a unified experience that encourages interdisciplinary learning and problem-solving rather a separate approach to each subject. According to Bybee (2013), "STEM learning emphasizes problem-solving, design, and real-world applications" (p. 9).

These two approaches are particularly important in physics education. Physics concepts can seem abstract to students, and physics at secondary school level is considered to be the most difficult subject, which can lead to low interest in learning it (Oon & Subramaniam, 2011). Ideas such as force, energy, and electricity are easier to grasp when they are connected to real-world situations through the STS approach (Haglund & Hultén, 2017; Ortiz-Revilla et al., 2025). Additionally, students can engage with physics topics as they learn about renewable energy systems, simple machines, climate change, and everyday technological devices (Aikenhead, 2006; Zeidler et al., 2005). Likewise, mathematics is regarded as a fundamental element in physics thinking rather than simply a tool for performing calculations (Uhden et al., 2012). Moreover, engineering design relies on authentic physics principles instead of being only an external context (Kelley & Knowles, 2016). Both STS and STEM teaching methods can help teachers establish these scientific concept links, thereby boosting students' motivation and comprehension.

Reforms in the Saudi educational system are emphasizing improvements in science teaching (Ministry of Education, 2021). As part of Vision 2030, Saudi Arabia introduced professional licensing

standards for teachers through the education and training evaluation commission (ETEC). These standards define the knowledge, teaching skills, and professional practices that teachers are expected to demonstrate. They also aim to ensure that teachers use effective instructional strategies and support students' critical thinking and problem-solving abilities (National Center for Assessment, 2025). However, the availability of such standards and policies does not necessarily mean that they are fully implemented in classrooms. For example, teachers may face challenges such as limited training, lack of resources, or unfamiliarity with new instructional models. Because of this, it is important to examine how teaching approaches are actually used in schools. Understanding the current level of implementation can help identify strengths and areas that need improvement.

The Rationale Behind This Study

Physics plays a crucial role in fostering scientific thinking and technological understanding (Docktor & Mestre, 2014; Huang et al., 2025). However, many teachers still depend heavily on traditional teaching methods. This has created a need for this current study focused on physics teachers in Saudi secondary schools and how they incorporate STS and STEM models into their classrooms. Although these two models originate from slightly different educational backgrounds, both prioritize real-world applications and problem-solving. Another key aspect of this study is the assessment of how well these models align with Saudi professional licensing standards. Measuring the extent of how physics teachers apply these models with their students can be a true measurement of their performance (ETEC, 2020).

Both the STS and STEM approaches have been chosen for examination in this research, as they are explicitly named as being among the contemporary trends in science education (Bybee, 2013; Kelley & Knowles, 2016; Pedretti & Nazir, 2011). Therefore, if STS and STEM models improve student competencies that are required by national standards, promoting their use in classrooms would help teachers meet professional expectations and enhance student learning.

Consequently, this study aims to determine how extensively physics teachers implement STS and STEM instructional models in Saudi secondary schools. It also investigates the relationship between the two approaches and their conformity with Saudi Arabia's professional licensing standards for teachers.

LITERATURE REVIEW

The Changing Goals of Science Education

Science education has experienced a major shift away from traditional methods that focus on memorizing facts and formulas (Yager, 2000). In the past, students were asked to learn definitions, solve textbook problems, and study for exams. However, in recent decades, this approach has been questioned because it does not fully prepare students for the modern world, as science education today is expected to extend beyond simply delivering information. In reality, students need to understand how science, technology, society, and everyday life are interconnected (Bhardaj et al., 2025; Osborne & Dillon, 2008). Critical thinking, problem-solving, and collaboration have become essential 21st century skills, because modern challenges – such as climate change, energy consumption, and technological innovation – are complex and require interdisciplinary thinking. This is why researchers and educators promote the STS and STEM models that link scientific knowledge to real-world issues.

The STS Approach: Theoretical Foundations and Key Features

The STS approach was created as an alternative to traditional science education and is based on the core idea that science instruction should be linked to technological advances and social issues. According to Yager (1996), the STS model helps teachers present science in real-world contexts, meaning that lessons should help students understand how scientific knowledge affects society and how social needs can influence scientific research. In STS classrooms, teachers often address issues that are directly relevant to their students' communities. These include air pollution in their city, renewable energy sources, and the impacts of new technologies. These conversations help students see science as relevant, meaningful, and engaging.

STS instruction has several key features that set it apart from traditional science teaching. For example, the lesson often begins by posing a real-world problem or social issue instead of immediately introducing a scientific concept. Teachers guide students in generating ideas to explain the issue through discussions and inquiry-based tasks. Students are encouraged to ask questions, share opinions, and consider different viewpoints. This process helps develop their critical thinking skills. The STS approach also emphasizes the

role of technology in society. Students learn how scientific discoveries lead to technological innovations and how those technologies affect daily life. This helps students become scientifically literate citizens (Aikenhead, 2006). The same author stated that "scientific literacy involves understanding science in ways that allow people to participate in societal decision-making" (p. 18).

STS in Physics Education: Evidence and Challenges

Researchers such as Aikenhead (1994) and Yager (1996) suggested that integrating the STS approach into science classrooms can positively influence how students perceive science. When science lessons are connected to real-life situations, students are more likely to see science as relevant and engaging rather than abstract or difficult. In this respect, Solomon (1993) explained

that integrating topics such as environmental protection or sustainable energy allows teachers to introduce physics concepts in a meaningful context. She added that, instead of teaching theories in isolation, teachers can help students explore how energy transformations occur through real-world applications such as solar panels and wind turbines in their communities. As a result, students are better able to understand and retain scientific ideas. Furthermore, Zeidler et al. (2005) asserted that the STS model helps develop important skills such as critical thinking and decision-making. They argued that when students are guided to analyze scientific information, reflect on social implications, and consider possible solutions to complex problems, they develop these abilities. This is an especially important requirement today, as everyday life decisions often require a certain level of scientific or technological understanding.

Despite the benefits of the STS approach, implementing it in science classrooms can be challenging. Solomon (1993) and Yager (1996) expressed concerns about teachers' lack of preparation to use the approach, as many have not been trained in designing STS lessons. Time is also another obstacle. Teachers need to cover large amounts of content for exams, making it difficult to create opportunities for discussions or projects (Aikenhead, 1994). Zeidler et al. (2005) argued that resources are another issue. Effective STS teaching sometimes requires access to real-world data, community examples, or project-based activities. Without these resources, teachers may struggle to fully apply the approach. Due to these challenges, Aikenhead (2006) argued that the level of STS integration in the classroom may vary across schools and teachers. Studies that focus on how this approach is used in physics teaching are mostly missing, even though the STS teaching model is clearly included in the national professional standards for physics teachers (ETEC, 2020). This lack of research is one reason for this study.

STEM Education in Science Teaching

Concept, development, and theoretical foundations of STEM education

The founding principle of STEM education is that science, technology, engineering, and mathematics are interrelated in people's lives, so they should be linked in the classroom as well. According to Bybee (2013), STEM education encourages students to use knowledge from different subjects to solve complex problems. He noted that "STEM learning integrates the four disciplines to address real-world challenges and develop innovative solutions" (p. 10). The focus on this educational model started in the early 21st century, as many educational organizations aimed to prepare learners for future careers in science and technology by emphasizing and promoting this approach in science classrooms.

STEM teaching is based on several core principles, one of which is integration. The STEM approach combines engineering, scientific inquiry, technological literacy, and mathematical thinking design into one discipline rather than having students learn these skills separately (Kelley & Knowles, 2016). Problem-based learning is another key principle (Durnali & Gökbulut, 2025; Giang et al., 2024), and students are often given open-ended challenges that require investigation and creativity. For example, they might be asked to design a bridge, build a simple electrical system, or develop a water filtration device. Students learn how to plan solutions, test their ideas, and improve their designs through experimentation. This process helps students develop both practical skills and theoretical knowledge (Mohr Schroeder et al., 2014).

STEM in physics education

Physics is a key subject in STEM education because it explains many of the principles underlying engineering and technology. While many STEM activities draw on physical principles, what distinguishes physics within STEM is not the frequency of such connections but their structural nature: Mathematics functions as a constitutive element of physical reasoning rather than a supporting calculation tool (Uhden et al., 2012), and the major engineering disciplines are built directly upon physical principles (Kelley & Knowles, 2016). Therefore, physics provides a setting in which the four STEM components can be integrated within a single instructional sequence rather than juxtaposed artificially.

Serway and Jewett (2018) argued that concepts such as force, motion, energy, and electricity are crucial for understanding many technological systems. They also noted that when these concepts are taught through STEM activities, students can easily see how physics applies in real-life situations. For example, physics teachers might ask students to design a small vehicle

powered by elastic energy. While working on this project, students practice physics concepts related to motion and energy. At the same time, they use mathematics to calculate distances and use engineering design principles to improve their solutions. Such integrated STEM activities provide authentic learning experiences that enhance students' engagement and promote meaningful connections between physics concepts and real-world applications (Kelley & Knowles, 2016).

In the Saudi context, STEM education has been pursued by the Ministry of Education since 2011 as a policy for improving student performance in STEM (Alsalamat, 2024). Evidence of its introduction in classrooms, however, remains limited. Recent studies have shown that STEM implementation relies on teachers' readiness, self-efficacy, and ongoing professional development. Although teachers may acknowledge the significance of STEM and comprehend its implementation requirements, knowledge and positive perceptions alone do not ensure effective classroom application (Aldahmash et al., 2019; Alsalamat, 2024; El-Deghaidy et al., 2017). Research focusing specifically on physics teachers, and on the extent to which STEM practices are enacted in physics classrooms, remains scarce.

Challenges of STEM implementation

The effective implementation of STEM requires preparation and full support from educational stakeholders (National Academy of Engineering and National Research Council, 2014). Teachers' training in interdisciplinary teaching methods is crucial in this context (Ramaley, 2007). Many teachers were initially trained to teach only one subject, so integrating multiple disciplines may seem unfamiliar and could make them uncomfortable with this teaching approach. Schools also need to provide teachers with appropriate materials and technology. STEM activities often involve students building models, conducting experiments, or using digital tools. Without adequate support, teachers may find it difficult to fully implement STEM practices in their classrooms (OECD, 2019).

The relationship between STS and STEM approaches

The STS and STEM educational models share common goals even though they have different origins. Both models emphasize the connection between science and real-world contexts, and they also stress that students should apply their scientific knowledge to solve problems that affect society (National Research Council, 2012; National Science Teaching Association, 2020). However, Science Technology and Society (2018) noted slight differences in focus between the two teaching models regarding science learning. While STS often emphasizes social issues and ethical questions related to

science and technology, STEM concentrates more on integrating scientific disciplines and promoting innovation through design and engineering activities.

Despite these differences, the two approaches can be used interchangeably in science classrooms and can complement each other. For example, a teacher might combine STEM design activities with STS discussions about social impact by having students design a renewable energy system while also discussing how energy choices affect communities and the environment. Because of these similarities, teachers who implement one model also may choose to incorporate elements of the other (OECD, 2019). Therefore, investigating the relationship between STS and STEM practices can provide useful insights into teaching strategies in science classrooms.

Professional licensing standards for teachers in Saudi Arabia

The ETEC professional standards for physics teachers comprise 18 subject-specific standards covering the nature of science, scientific inquiry, laboratory safety, mathematical and statistical skills, the major content domains of physics, the relationship between physics and other sciences, contemporary trends in science education, and teaching and assessment strategies (ETEC, 2020). The present study focuses on the standard addressing contemporary trends in science education, which explicitly names STS and STEM and requires physics teachers to employ both approaches in their instruction. Accordingly, the focus of the present study is guided by the requirements of the national professional standards, which specifically identify these approaches as essential components of contemporary science education.

Improving teacher quality has become a major priority in many education systems. In Saudi Arabia, the government has introduced professional licensing standards developed by the ETEC to ensure that teachers have the necessary knowledge and teaching skills. The framework requires teachers to demonstrate competencies in areas such as subject knowledge, instructional strategies, classroom management, and professional development. The standards also promote a learner-centered approach, and teachers are expected to use teaching strategies that encourage inquiry, critical thinking, and problem-solving. These requirements align with the goals of both STS, which encourages discussion and analysis of real-world issues, and STEM, which emphasizes problem-solving and design thinking.

Connecting STS, STEM, and professional licensing standards

Researchers often talk about STS and STEM as separate methods in science education. However, a

closer look at the two models reveals that they share many ideas. Both approaches aim to shift science teaching from simply memorization to understanding, application, and problem-solving. Because of these similarities, many scholars, including Perales Palacios and Aguilera (2020), believe that STS and STEM can support the same educational goals. Since both models focus on real-world learning, they often overlap in classroom practice. For example, a STEM project might involve finding a technological solution, while an STS discussion could explore how that technology affects society. In other words, students might design a solar-powered device as a STEM activity and talk about how renewable energy can help reduce environmental problems. This indicates how the two approaches can support each other.

Regarding the professional teaching standards developed by the ETEC in Saudi Arabia, the link between the two approaches becomes even clearer. Most competencies highlighted by the ETEC closely align with the goals of STS and STEM education, which aim to promote the knowledge, skills, and practices that teachers should exhibit in their classrooms. For example, the learner-centered approach, inquiry-based learning, problem-solving, and connecting learning to real-life situations – all of which are encouraged through the professional teaching standards – are also fundamental to both STS and STEM models. When combined, these approaches can improve many of the instructional practices expected from science teachers, ultimately strengthening the learning environment.

Because of these connections, studying the relationships among STS implementation, STEM practices, and professional licensing standards can provide useful insights into current science teaching practices. It can also help identify how teachers can better integrate modern teaching approaches into their classrooms.

Conceptual Framework

Based on the Saudi professional licensing standards, the conceptual framework of the present study assumes that STS and STEM represent complementary instructional approaches that are explicitly identified within the professional standards for physics teachers. Accordingly, the study examines physics teachers' implementation of both approaches and explores the relationship between STS and STEM implementation. **Figure 1** presents the conceptual framework underpinning the study.

Research Gap

The STS and STEM educational approaches are widely explored and discussed in the literature. Research indicates that both approaches boost students' engagement and understanding of science concepts and

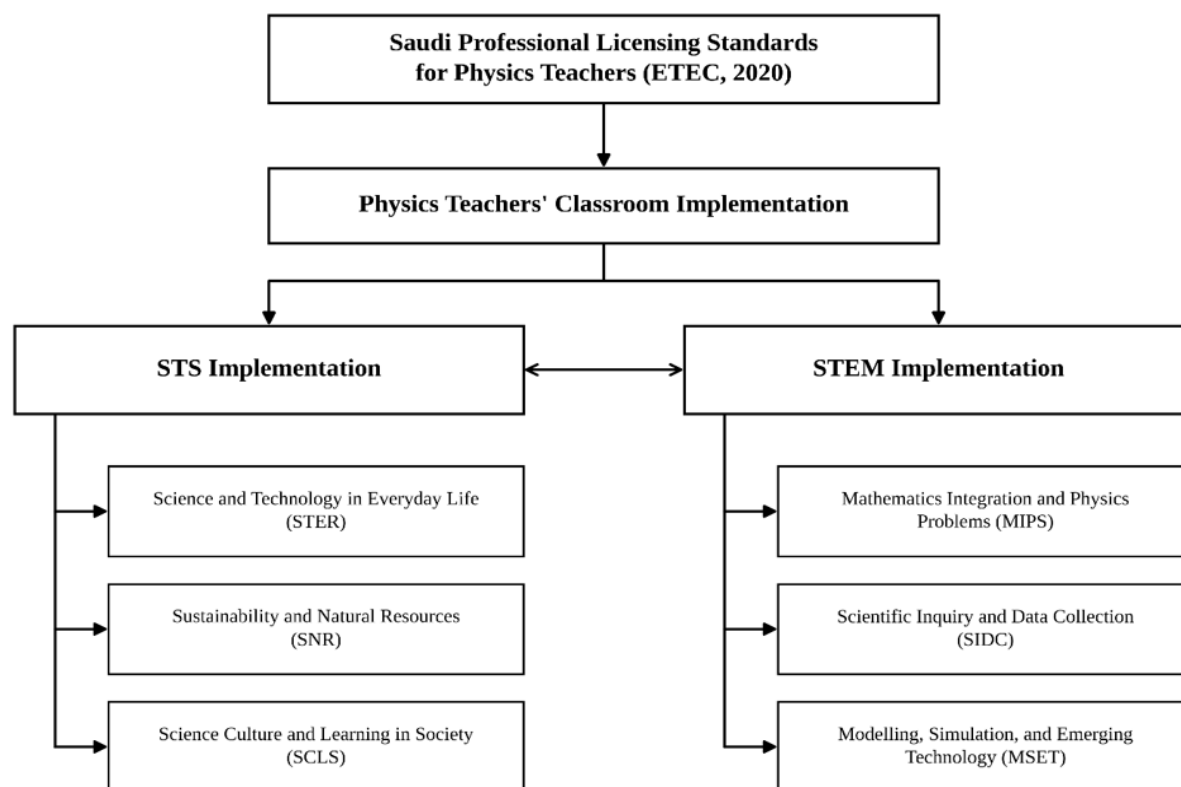


Figure 1. Conceptual framework of the study (National Center for Assessment, 2020)

encourage students to apply knowledge from multiple disciplines to solve real-world problems (Bybee, 2013; Yager, 1996). However, a closer look at the research uncovers several knowledge gaps. First, there is limited research examining both approaches together, as previous studies have examined STS and STEM separately despite their shared ideas. Therefore, studying them together could provide a clearer picture of how teachers implement modern science teaching methods.

Second, knowledge gap involves the limited research that specifically concentrates on physics teachers. Physics is often seen as one of the most challenging subjects for secondary school students. Effective teaching of physics may require instructional methods that help students connect abstract concepts with real-life applications, and STS and STEM approaches might offer useful strategies to meet this goal. However, few studies have explored how physics teachers implement these models in secondary schools. Another key gap concerns Saudi Arabia's educational context. Recently, the country has introduced several reforms aimed at improving teaching quality and fostering innovation in science education. One example is the professional licensing system established by the ETEC, which sets standards for the professional skills that teachers should demonstrate. Still, research on how modern teaching approaches align with these national standards remains limited. Third, from a theoretical perspective, the existing literature focuses mainly on students' motivation and achievements; little, if any, attention is given to teachers' classroom practices. Understanding

how teachers implement these approaches is crucial because classroom practice is the key factor that influences students' learning experiences. Accordingly, examining teachers' implementation of STS and STEM provides evidence of the extent to which these nationally mandated approaches are being translated into classroom practice. In other words, it is known that STS and STEM approaches are valuable, but researchers do not fully understand how they relate to the professional expectations for teachers in Saudi schools. Investigating this connection could help determine whether these teaching models support the competencies required by the national licensing framework.

Finally, few studies have explored the statistics regarding teachers' use of STS and/or STEM models in their classrooms. Since the two approaches share several educational principals, teachers who frequently employ one model also may use the other. Investigating this relationship could offer deeper insights into how teachers integrate modern science teaching strategies. Therefore, this study aims to address these gaps by examining the extent to which physics teachers implement both STS and STEM instructional practices in Saudi secondary schools. It also investigates the relationship between these two approaches and assesses their alignment with the professional licensing standards for teachers in Saudi Arabia. By addressing these issues, this research hopes to enhance the understanding of current science teaching practices and support future improvements in physics education.

Research Questions

This study seeks to address the following research questions:

1. What is the level of physics teachers' implementation of the STS instructional model in Saudi secondary schools?
2. What is the level of physics teachers' implementation of STEM-based instructional practices in Saudi secondary schools?
3. Is there a statistically significant relationship between physics teachers' implementation of the STS model and their implementation of STEM teaching practices?
4. To what extent are STS and STEM instructional practices aligned with the professional licensing standards for teachers in Saudi Arabia?

METHODOLOGY

Research Design

This study employed a quantitative descriptive research design to examine how secondary school physics teachers implement the STS and STEM instructional models. Quantitative survey methods are frequently used in educational research to investigate teachers' practices and to analyze relationships among instructional concepts through statistical techniques (Creswell & Creswell, 2018). In addition to assessing teachers' implementation of STS and STEM practices, the study also aimed to evaluate the psychometric properties of the measurement tools employed to assess these constructs. Ensuring the reliability and validity of measurement scales is essential in educational research, because it confirms that the collected data accurately represent the theoretical constructs under study (Hair et al., 2019).

Participants and Sampling

The target population comprised in-service physics teachers in public secondary schools across Saudi Arabia. Participants were chosen to represent teachers who are actively involved in physics teaching within the Saudi educational system. Educational reforms in Saudi Arabia are increasingly focusing on enhancing teaching quality through professional development and licensing standards for teachers. These reforms aim to ensure that teachers have the professional skills needed to adopt innovative teaching methods and improve student learning outcomes (Maashi et al., 2022).

This study utilized a convenience sample when selecting participants. This technique depends on accessibility of participants on practical constraints regarding the geographical distribution of the targeted population and time limitation (Etikan et al., 2016). The questionnaire was administered electronically using

Table 1. Demographic characteristics of the sample

Characteristic		n	P (%)
Gender	Male	134	31.6
	Female	290	68.4
Teaching experience	Fewer than 5 years	40	9.4
	5-10 years	48	11.3
	10-15 years	94	22.2
	More than 15 years	242	57.1

Note. n: Frequency; P: Percentage (%); N = 424; & All participants were in-service physics teachers at public secondary schools

Google Forms and distributed through a professional community of secondary school physics teachers in 2025. Participation was voluntary, and only in-service teachers currently teaching physics at the secondary level were eligible to participate. A total of 424 valid responses were received and included in the analysis. The sample comprised 134 male (31.6%) and 290 female (68.4%) teachers. In terms of teaching experience, 242 participants (57.1%) had more than 15 years of experience, 94 (22.2%) had 10-15 years, 48 (11.3%) had 5-10 years, and 40 (9.4%) had fewer than 5 years of experience, indicating a predominantly experienced sample (see Table 1).

Official statistics disaggregating secondary school teachers by subject specialization are not publicly available in Saudi Arabia; therefore, the representativeness of the sample relative to the national population of physics teachers could not be directly assessed. The achieved sample size of 424 exceeded conventional recommendations for factor analysis, satisfying both the criterion of at least 10 respondents per item and the recommendation of a minimum of 300 participants for stable factor solutions (Hair et al., 2019).

Participation in the study was voluntary. Before completing the questionnaire, participants were provided with information about the purpose of the study and completion of the questionnaire implied informed consent, responses were collected anonymously, and confidentiality was maintained throughout the study. Data collection was conducted after permission was obtained from the relevant educational authority.

Instruments

Data were gathered using two structured scales designed to measure teachers' instructional practices related to the STS and STEM educational frameworks. The instrument was developed based on the Saudi professional standards for physics teachers issued by the ETEC (2020) and an extensive review of the literature on STS and STEM education. The items were designed to reflect the competencies specified in the professional standards and the conceptual characteristics of the two instructional approaches. The preliminary version of the instrument was reviewed by a panel of experts in science education in general and physics education specifically

Table 2. Descriptive statistics, reliability, convergent validity (AVE), and discriminant validity (Fornell-Larcker criterion) for the STS and STEM constructs

Latent construct	Observed construct	M ± SD	CA	CR	AVE	√AVE	1	2	3
STS	1. STER	4.54±0.53	0.91	0.90	0.63	0.79	0.79		
	2. SNR_SA	4.46±0.53	0.89	0.89	0.63	0.79	0.77	0.79	
	3. SCLS	4.00±0.86	0.79	0.80	0.65	0.81	0.67	0.75	0.81
STEM	1. MIPS	4.41±0.62	0.88	0.90	0.59	0.77	0.77		
	2. SIDC	4.43±0.53	0.92	0.91	0.60	0.77	0.73	0.77	
	3. MSET	3.80±0.91	0.78	0.80	0.61	0.78	0.67	0.60	0.78

to evaluate the relevance, clarity, and appropriateness of the items. Their comments were incorporated before the final version of the instrument was administered.

The final instrument consisted of 30 items measured on a 5-point Likert scale ranging from 1 (never) to 5 (always). The instrument comprised two constructs: STS (15 items) and STEM (15 items). Each construct consisted of three dimensions, with five items representing each dimension.

STS scale

The STS scale evaluated teachers' ability to integrate scientific knowledge with technological and societal contexts. The scale included three constructs, and the STS construct comprised three dimensions. The first dimension, *science and technology in everyday life and solving real-world problems (STER)* (5 items), assessed teachers' practices in relating physics concepts to everyday life and encouraging students to solve authentic real-world problems. The second dimension, *sustainability and natural resources in Saudi Arabia (SNR)* (5 items), assessed the integration of sustainability issues and responsible use of natural resources within physics instruction. The third dimension, *science culture and learning in society outside the classroom (SCLS)* (5 items), assessed teachers' practices in promoting scientific culture through extracurricular activities, scientific exhibitions, field visits, and engagement with contemporary scientific developments.

The STS framework emphasizes the link between scientific knowledge and real-world social challenges. According to Yager (1996), STS-based instruction encourages students to explore "the interactions among science, technology, and society and their implications for everyday life" (p. 23).

STEM scale

The STEM scale measured teachers' interdisciplinary instructional practices integrating science, technology, engineering, and mathematics. The STEM construct consisted of three dimensions. The first dimension, *mathematics integration and physics problem-solving (MIPS)*, with 5 items, assessed teachers' practices in integrating mathematics into physics instruction and engaging students in problem-solving and project-based learning to promote interdisciplinary understanding.

The second dimension, *scientific inquiry and data collection (SIDC)*, with 5 items, assessed the extent to which teachers implemented scientific inquiry, experimental investigation, data collection, and evidence-based reasoning as essential components of STEM instruction. The third dimension, *modelling, simulation, and emerging technologies (MSET)*, with 5 items, assessed teachers' use of scientific models, simulations, digital technologies, and emerging technological tools to support students' conceptual understanding of physics.

STEM education encourages integrated learning experiences and practical problem-solving. As Bybee (2014) has highlighted, STEM education seeks to engage students in genuine scientific and engineering practices that reflect real-world challenges. All items were assessed using a Likert scale, enabling respondents to indicate to what extent they apply each practice in their classroom teaching. Collectively, the STS and STEM constructs provide a comprehensive framework for assessing physics teachers' implementation of both learning approaches in physics instruction.

Data Analysis

Data were analyzed using IBM SPSS and IBM SPSS Amos. Several statistical procedures were performed to evaluate the psychometric properties of the scales and to explore the relationships between the constructs. First, descriptive statistics (means [Ms] and standard deviations [SDs]) were calculated to summarize teachers' responses and determine the overall level of implementation of STS and STEM practice (see Table 2). Second, reliability analysis was conducted using Cronbach's alpha (CA) and composite reliability (CR) to assess the internal consistency of the scales. Reliability coefficients greater than 0.70 are generally considered acceptable (Hair et al., 2019). Third, convergent validity was evaluated using the average variance extracted (AVE). AVE values exceeding 0.50 indicate that the construct explains more than half of the variance of its indicators. Finally, discriminant validity was assessed using the Fornell-Larcker criterion, which compares the square root of the AVE with the correlations among constructs. Discriminant validity is supported when the square root of AVE exceeds the inter-construct correlations (Fornell & Larcker, 1981). Pearson correlation analysis was conducted to examine the

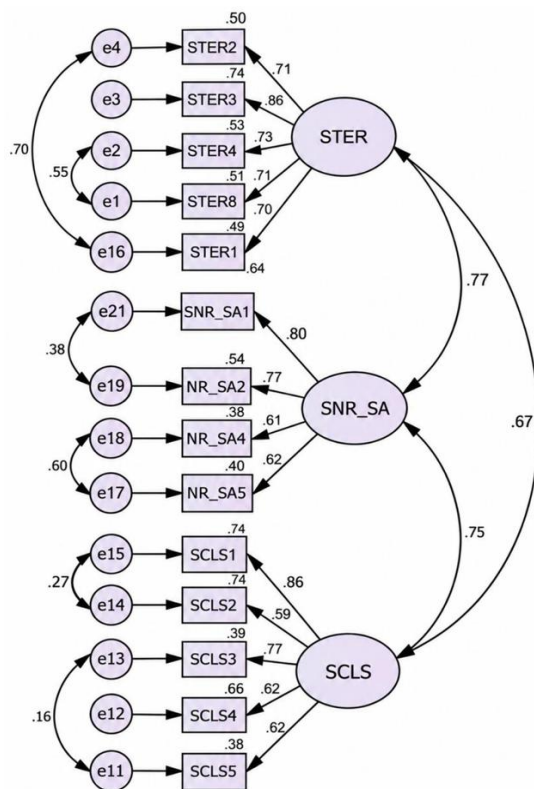


Figure 2. CFA of STS scale (Amos output)

relationships among the study constructs. Statistical significance was evaluated at the 0.01 level ($p < .01$)

RESULTS

The descriptive statistics, as presented in **Table 1**, indicated relatively high levels of implementation of both STS and STEM instructional practices among physics teachers.

Within the STS dimension, as mentioned in the **Figure 2**, the construct science-technology educational relevance (STER) recorded the highest mean score ($M = 4.54$, $SD = 0.53$), indicating that teachers often emphasize the importance of scientific knowledge to technological applications. The construct science and societal needs in Saudi Arabia (SNR_SA) also exhibited a high mean score ($M = 4.46$, $SD = 0.53$), suggesting that teachers frequently link scientific topics to societal issues. The construct scientific concepts in life situations (SCLS) reported a slightly lower mean ($M = 4.00$, $SD = 0.86$), but it still reflects a relatively strong level of implementation.

Within the STEM dimension (see **Figure 3**), the construct scientific inquiry and design competencies (SIDC) recorded a mean of 4.43 ($SD = 0.53$), while modern interdisciplinary problem-solving (MIPS) exhibited a mean of 4.41 ($SD = 0.62$). These results suggest that teachers frequently use inquiry-based and interdisciplinary instructional strategies. In contrast, mathematics and science engineering thinking (MSET) reported a lower mean ($M = 3.80$, $SD = 0.91$), indicating

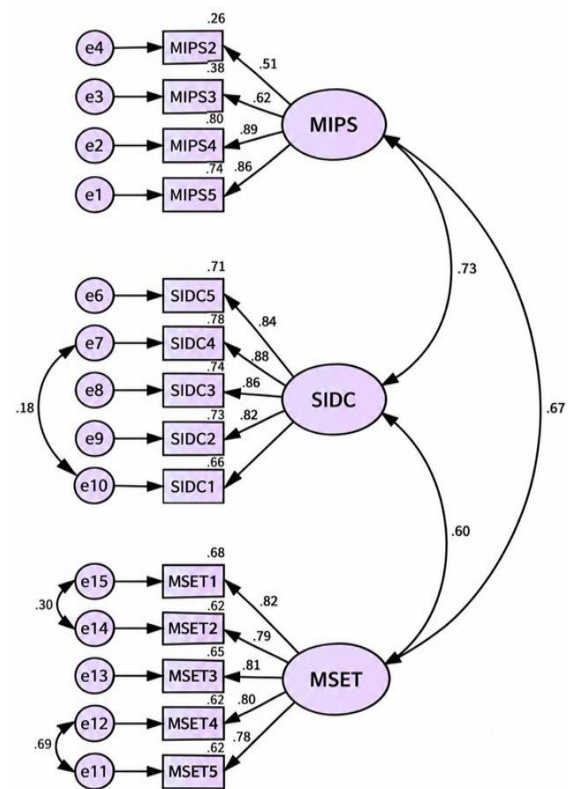


Figure 3. CFA of STEM scale (Amos output)

that engineering-oriented thinking may be less consistently applied.

Reliability and Validity

The reliability analysis revealed that all constructs had high internal consistency. CA values ranged from 0.78 to 0.92, surpassing the commonly recommended cutoff of 0.70 (Hair et al., 2019). Likewise, CR values ranged from 0.80 to 0.91, further supporting the reliability of the measurement scales. Regarding convergent validity, all AVE values ranged from 0.59 to 0.65, surpassing the recommended minimum of 0.50. These findings suggest that the observed indicators adequately represent their respective latent constructs. Furthermore, discriminant validity was demonstrated. The square root of AVE for each construct was higher than its correlations with other constructs, satisfying the Fornell-Larcker criterion (Fornell & Larcker, 1981). Overall, these results confirm that the measurement model exhibits satisfactory reliability and construct validity.

Additionally, the Pearson correlation analysis revealed a strong positive relationship between the overall STS and STEM constructs ($r = 0.81$, $p < 0.01$) (**Figure 4**). The scatter plot illustrates a positive linear relationship between STS and STEM. As STEM values increase, STS values tend to increase as well. The regression line indicates a positive association between the two variables, suggesting that higher levels of STEM are associated with higher levels of STS.

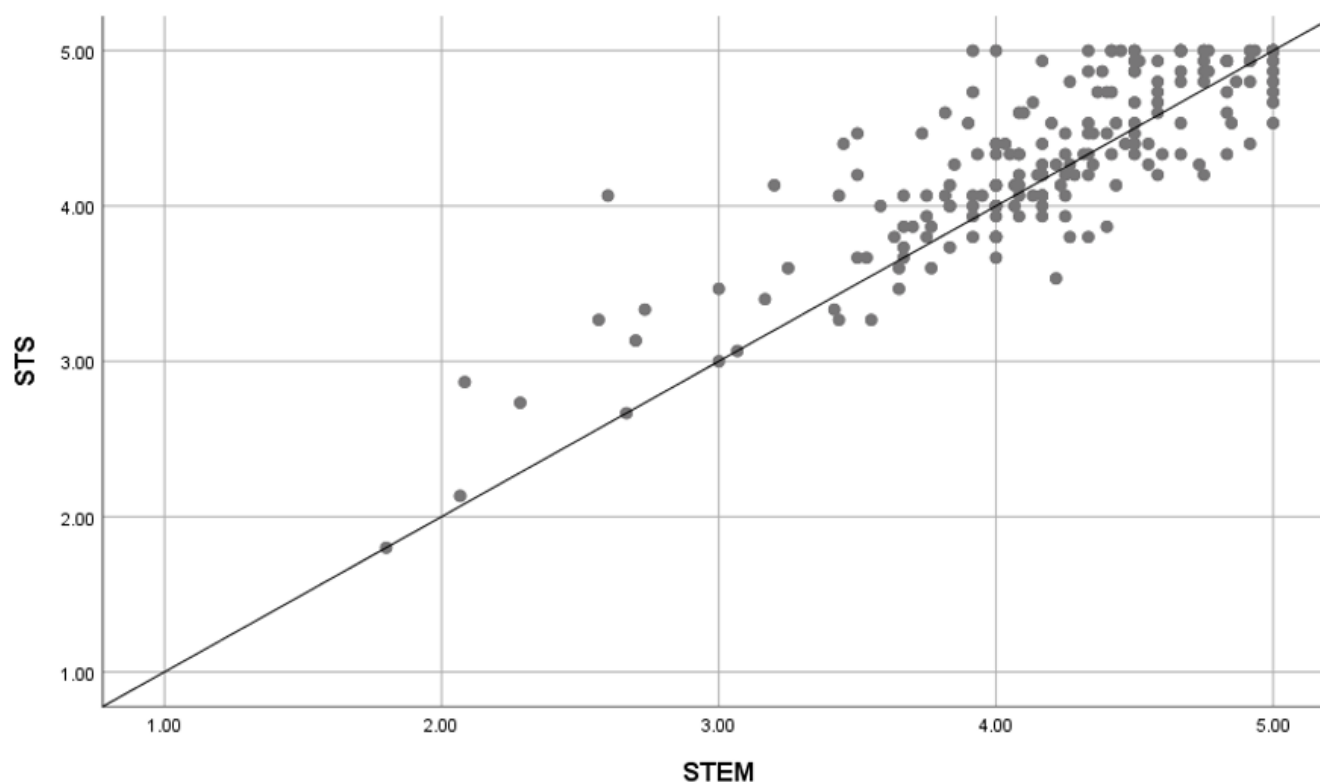


Figure 4. Pearson correlation analysis (STS vs. STEM) (Amos output)

DISCUSSION

The findings indicate that physics teachers in Saudi secondary schools demonstrate relatively high levels of implementing both STS and STEM teaching practices. This result reflects the increasing emphasis on innovative teaching methods as part of recent educational reforms in Saudi Arabia. The high average scores in the STS constructs, particularly in science-technology relevance and societal connections, suggest that teachers frequently attempt to link scientific concepts to real-world situations. This aligns with the principles of STS education, which focus on helping students understand the broader societal implications of scientific knowledge (Yager, 1996).

Similarly, the relatively high implementation levels observed for STEM practices, especially in inquiry and interdisciplinary problem-solving, support previous research highlighting the growing integration of STEM approaches in science education. According to Bybee (2013), effective STEM instruction encourages authentic learning experiences that motivate students to apply scientific knowledge to complex real-world problems.

The deep integration of these models reported in this study is consistent with findings reported in other educational systems, in which teachers' self-reported use of reform-oriented practices tends to be high. Comparable Saudi evidence, however, suggests that positive self-reports may not always fully reflect actual classroom practices. For example, secondary science

teachers have been found to have only moderate perceptions of STEM education despite significant knowledge of its implementation requirements (Alslamat, 2024), and earlier work documented substantial contextual constraints on STEM integration in Saudi schools (El-Deghaidy et al., 2017).

Additionally, the relatively low mean score observed for the modelling, simulation, and emerging technologies (MSET) construct, which is engineering-oriented, indicates that integrating engineering thinking into physics instruction still may be challenging for some teachers. Previous research has identified engineering integration as one of the most difficult parts of STEM education to implement effectively (El-Deghaidy et al., 2017; Honey et al., 2014).

Consistent with this broad pattern, the comparatively low implementation of the MSET dimension observed in the present study is consistent with findings reported internationally. For example, Shambare and Jita (2024) found that life sciences teachers demonstrated high competencies in content knowledge, pedagogical knowledge, and pedagogical content knowledge but substantially lower competencies in the technology-related domains of the technological pedagogical content knowledge framework. A similar pattern emerged in the present study, in which teachers reported high implementation across the pedagogical dimensions but comparatively lower use of digital modelling, simulation software, electronic sensors, and virtual and augmented reality. Taken together, these findings

suggest that the observed gap may reflect a broad limitation in teachers' technological pedagogical content knowledge rather than a feature specific to the Saudi context.

The strong association between STS and STEM implementation supports theoretical accounts that treat the two approaches as complementary rather than competing traditions. Both are grounded in the premise that learning is most meaningful when it is situated in authentic contexts (Kelly & Knowles, 2016). The present findings extend this literature by demonstrating that high implementation of one approach was associated with significant implementation of the other.

Theoretical Implications

This study contributes to current science education research in multiple ways. First, it examines STS and STEM together using the Saudi professional licensing standards for physics teachers. The results support the notion that STS and STEM work well together as reliable, interdisciplinary, and context-based approaches to science learning rather than as competing methods (Bennett et al., 2007; Kelley & Knowles, 2016; Pedretti & Nazir, 2011). Second, the study suggests psychometric evidence for a six-factor measurement structure based on the competencies in the Saudi physics teaching standards. This demonstrates that national professional standards can offer a practical framework for studying how teachers employ modern teaching methods. Finally, the study provides new data from Saudi secondary physics education, helping to broaden the reach of research on STS and STEM in standards-based settings.

Practical Implications

This study's findings carry significant implications for educational policy and the professional development of teachers in Saudi Arabia. First, they underscore the need for ongoing professional development initiatives that assist teachers in adopting innovative teaching methods such as STS and STEM education (Aldahmash et al., 2019). Second, the lesser focus on engineering-related skills indicates that teacher training should prioritize engineering design and practical problem-solving in science instruction. This low performance might be due to a constraint in Saudi secondary schools for instance, the limited school resources, laboratory equipment, and the instructional time allocated to science classes (Alsalamat, 2024). Moreover, Albadi et al. (2019) reported that physics teachers were concerned about the insufficient availability of learning resources for student-centered teaching. This suggests training should be practice based rather than theoretical, such as hands on workshop for modelling, simulation, and technology tools that underpin engineering-oriented practice within the STEM framework. Additionally, designing learning tasks that require students to

develop, test and refine real world problem-solving skills should be emphasized. Thus, the Saudi Ministry of Education should equip school laboratories with the specific materials required for engineering design activities, contributing to an appropriate learning environment for integrated STEM project.

Lastly, aligning STS and STEM teaching practices with teacher licensing standards could ensure that educators acquire the necessary skills to facilitate interdisciplinary and real-world learning experiences.

CONCLUSION

This study explored how physics teachers in Saudi secondary schools implement STS and STEM teaching methods and assessed the psychometric strength of the measurement scales used. Results indicate that teachers reported fairly high levels of implementing STS and STEM practices in their classrooms, especially regarding technology integration, societal links, and inquiry-based learning. However, these results are based on self-reported perception of teachers' practice rather than classroom observation. Reliability and validity tests confirmed that the measurement tools have solid psychometric properties. However, the adoption of engineering-focused practices seems somewhat less prevalent. Future research could explore ways to boost engineering integration in STEM education. Overall, these findings enhance understanding of how physics teachers adopt modern science education models and offer insights that could support the ongoing development of science education in Saudi Arabia.

Limitations

Several limitations to this study should be noted. First, the study used teachers' self-reports regarding their teaching, which may not always mirror what happens in the classroom, even though these reports offer useful insights. Second, while the sample included many teachers with varying levels of experience, the results should be interpreted carefully because the study used a convenience sampling method. Third, this research considered only teachers' views and did not include classroom observations or other examinations that could confirm the reported teaching practices. Finally, the data was gathered through an online survey link (Google Forms) that was distributed online through professional teacher communities, a common channel of communication among teachers in Saudi Arabia. Participation was voluntary and limited to the members who were digitally active. However, the respondents may not be representative of all physics teachers, which may limit the generalizability of the findings to physics teachers in Saudi schools.

Future Research

Future research could build on the present study in numerous ways. First, future studies may combine questionnaire data with classroom observations, teacher interviews, and lesson-plan analyses to examine the extent to which teachers' reported practices are reflected in actual classroom implementation. Second, validating the proposed six-factor measurement model in future research can expand on this study in significant ways, such as testing the six-factor with diverse groups, educational levels, science subjects, and countries would help illustrate how reliable and useful it is. Moreover, future research could explore teachers' use of how STS and STEM practices affect student outcomes, such as concept understanding, problem-solving, scientific literacy, and engagement in physics. Finally future research could explore ways to boost engineering integration in STEM education.

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