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Understanding Science Teachers' Implementations of Integrated STEM: Teacher Perceptions and Practice

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Abstract: This study examines how science teachers experience integrating science, technology, engineering, and mathematics (STEM) approaches into their teaching. In addition, it further examines the encountered challenges in this regard to shed light on STEM current practices within the context of United Arab Emirates (UAE). This study consists of two stages; the first involved collecting qualitative data using semi-structured interviews to explore three science teachers' perceptions and lived experiences having infused STEM into their regular teaching in cycle 2 for more than two years. Quantitative data were collected and analyzed in the second phase via the developed closed-ended questionnaire to examine teachers' perceptions across a larger sample regarding "challenges encountered by teachers when implementing STEM teaching". Research findings showed that science teachers generally have a positive attitude towards using STEM-based activities. In addition, data revealed that participants implement integrated STEM into their teaching frequently and regularly. Results also indicated teachers encounter challenges while implementing STEM: documentation, the vast curriculum content, and lack of time. Moreover, external challenges (i.e., the lack of supportive guidelines) rather than teachers' competency (i.e., having sufficient knowledge and skills for implementing STEM teaching) appeared to have the highest impending impact. Finally, we discuss findings and presented implications for teachers, educators, and policymakers.

Keywords: science; science teacher; STEM education; attitudes; phenomenology

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1. Introduction

Science, Technology, Engineering, and Mathematics (STEM) education focuses on the production of STEM-literate graduates with the necessary skills for excelling in the technologically oriented future workforce [1]. Although STEM has received global attention and calls; research on science educators has revealed several concerns about the science education current situation, such as that (1) many students find little of interest or even dislike science; (2) science is taught as the transmission of facts of little relevance, and is too complex; (3) school experience leads to loss of interest in science and technology as career possibilities [2]. Moreover, the international assessment results revealed how students in UAE scored below the average score in science assessment of both Trends in International Mathematics and Science Study (TIMSS) and Programmed for International Student Assessment (PISA) [3].

Those findings can be related to the concerns raised earlier in the research on science educators and how science is being taught and learned. In contrast, Herro et al. [4] argued that the purpose of science programs in schools is to develop scientifically literate citizens. In particular, science, mathematics, and technology are interdependent human enterprises with strengths and limitations. To be scientifically literate means to understands critical concepts and principles of science, be familiar with the natural world and recognize both its diversity and unity, and to be able to use scientific knowledge and scientific ways of thinking for individual and social purposes [5]. However, Johnson [6] reported that the integration of STEM implementation faces several challenges: (1) STEM integration requires restructuring of interdisciplinary curriculum and lessons; (2) integrated STEM education often requires numerous materials and resources for students, such as construction tools; (3) creating a school culture and environment that supports an integrated STEM approach to teaching and learning can be costly and time-consuming; (4) effective STEM education relies on qualified teachers who can teach and implement the interdisciplinary approach [5].

Today, STEM integration is a widespread teaching approach. It has an essential role in providing students with a vital education in science and other subjects [2,3,6]. For this purpose, the UAE education system is moving toward STEM education in its education reforms plans, aiming to develop an innovative education system for knowledge and a globally competitive society by coping with the global market demands [7]. Various innovation conferences and festivals have been held to highlight the finest approaches in attaining the STEM integration objective [8].

However, this is still in an early phase, involving decision-making concerning how science teachers will help their students understand science and develop competencies associated with science practice by integrating STEM in science education [9]. Accordingly, this study will clarify teachers' perceptions about the integration of STEM in science education to shed light on the current practices in STEM integration in the science classroom [10]. Teachers' thoughts and ideas will give the complete picture related to the nature of STEM integration and all the factors impacting the implementation process. Moreover, those views will enlighten the decision-makers, curriculum developers, teachers [11], and all the stakeholders about the strengths and limitations of the integration process to facilitate improvements [12]. Consequently, this study explores science teachers' experiences, beliefs, and thoughts regarding integrating STEM education in a science classroom [13].

1.1. Purpose of the Study

The purpose of the current study was to understand the lived perceptions and experiences of science teachers who have adopted integrated STEM into their teachings through exploring their current self-reported practices and beliefs in this regard [1]. STEM education has received significant attention over the last few years. The current policy and educational vision in the UAE advocate developing and implementing STEM education at all government and public schools. However, little is known about the current status quo of STEM implementation. It is essential to provide insights on the current practices and challenges based on teachers' perceptions within the local context of UAE [14]. This study attempts to examine whether STEM is effectively infused into science classes, in line with the school curriculum, the adapted science education standards, and the educational vision of UAE country [15].

1.2. Research Questions

The central question the study has addressed is as follows:

What attitudes and experiences do science teachers have towards implementing an integrated STEM approach in UAE schools?

We looked at the following sub-questions:

(A) What current practices or methods do science teachers use for implementing STEM into their teaching?
(B) To what extent does the school support the implementation of STEM in terms of resources and training?

(C) What concerns or challenges do science teachers encounter when implementing STEM into their teaching?

2. Literature Review

This part presents an overview of STEM integration in education based primarily on the finding of previous literature. In particular, this section reveals evidence related to the definition of STEM [16,17], the nature of the integration process, and students' interests and future career readiness. Moreover, the review focuses on the challenges that prevent effective STEM integration and studies conducted in the UAE context [18].

2.1. STEM Definition

Science, technology, engineering, and mathematics or STEM abbreviation was introduced at National Science Foundation (NSF) in 2001 [19], by the assistant director of the Education and Human Resources Directorate [20]. At that time, she described STEM as an educational inquiry process where the learning process was modeled by students solving a real-world problem. In contrast, Joyner [21] defined STEM as a meta-discipline integrating the four disciplines.

Another definition considered STEM integration as a widespread teaching approach. It has an essential role in providing students with a vital education in science and other subjects [22]. Jolly [23] looked at STEM from a different angle as innovation pursuits. Alternatively, Johnson [6] reported that STEM integration refers to students participating in the engineering design process to develop technologies that require meaningful learning through integration and application of mathematics and science. On the other hand, refs. [17,24] asserted no consensus regarding the definition of STEM in terms of nature, degree of integration, and connections between the different STEM disciplines. At the same time, other researchers [4,20,25,26] focused on the importance of applying equal attention to two or more STEM disciplines and explicitly assimilating concepts from various STEM disciplines.

2.2. Nature of STEM Integration

There were several views regarding integrating STEM education in science education in the previous studies. Some focused on bringing together all STEM disciplines through explicit content area connections or interdisciplinary content, providing more relevant, less fragmented, and more stimulating experiences for learners [27–30]. Other researchers emphasized that STEM integration must shift toward student-centered teaching that relies on authentic, real-world problems that promote active learning [31,32].

Many studies focused mainly on incorporating specific instructional strategies for integrating STEM with inquiry-based learning, problem-based learning, or design-based learning [33–36]. On the other hand, the opponents of the integration process have rebelling vision related to adopting such an approach that requires the restructuring of many elements, ranging from the training of STEM teachers to changing the structure of education programs from the revision of measurement-evaluation methods. In particular, the time cost of making such significant changes stands as a barrier in front of this reform [37].

Moreover, education researchers indicate that teachers struggle to connect the STEM disciplines [38]. We are in support of with implementing STEM integration through student-centered teaching. That will promote more engagement and active learning strategies by focusing on an authentic real-life problem, enabling students to connect knowledge from the four disciplines with the permanency of acquired knowledge [39].

2.3. Interest and Career

Several research studies discussed that STEM integration impacts students' interest and engagement in science learning and toward STEM careers [40–43]. Xie et al. [44] cite that STEM education focuses on the production of STEM-literate graduates with the necessary skills for excelling in the technologically oriented future workforce. Kant et al. [45]

believed that integrated STEM education could be a platform for developing essential personal and professional competencies, including research inquiry, problem-solving, critical and creative thinking, entrepreneurship, collaboration, teamwork, and communication. Herro and Quigley [46], in their study, found that STEM programs in the USA have three primary and inclusive goals for STEM education: (a) increase the number of STEM innovators and professionals, (b) strengthen the STEM-related workforce, and (c) improve STEM literacy in all citizens. Dori et al. [47] presented a contradictory argument about a STEM workforce shortage in the United States. He argued that science and engineering workers had increased at a steady rate of 2.7%, sufficient to increase job growth. However, he postulated concern centered on the United States' decreasing global dominance in science and engineering, national security, research, and development logjams in research universities, and changing demographics.

On the other hand, references [48–50] reported that learning science and mathematics through an integrated engineering design process enhances knowledge and critical thinking skills and promotes interest in science and engineering careers. Moreover, other studies assert that integrated STEM education leads to increased interest in STEM field careers and is essential for student success as they progress into the future [48]. STEM courses and programs can increase students' competencies for STEM-related occupations and understanding of scientific and engineering work [51]. Improved STEM education may necessitate a change in the structure of higher-education institutions by restructuring curricula to produce graduates who are versatile, adaptable, and highly employable, specifically, graduates in engineering, health sciences, computer sciences, and natural sciences [52].

2.4. Challenges of STEM Integration

Haesen and Van de Put [53], in his study, reported teachers' barriers that prevent the successful implementation of STEM integration in a science classroom: (1) classes become crowded and are hardly managed; (2) science content is too significant to adopt the STEM approach as it is time-costly, and (3) teachers lack the needed knowledge to teach using the STEM approach. On the same track was [21], who discussed several challenges that highly hinder the implementation process: (1) STEM integration requires restructuring of interdisciplinary curriculum and lessons; (2) integrated STEM education often requires numerous materials and resources for students, such as construction tools; (3) creating a school culture and environment that supports an integrated STEM approach to teaching and learning can be costly and time-consuming; (4) effective STEM education relies on qualified teachers who can teach and implement the interdisciplinary approach.

3. Materials and Methods

The current study employed an exploratory sequential mixed-method design. The design consists of an explorative qualitative strand and a second quantitative strand. The selected approach is appropriate as it best fits the intended purpose, which requires in-depth exploration of the examined issue from a few individuals who have experienced it and then generalization of the initial qualitative findings [24]. Moreover, the design is needed as it allows identifying variables from participants' accounts, developing an instrument on its basis, and then testing the initially obtained data to see whether they apply to other groups. Neither quantitative nor qualitative methods alone are sufficient to capture the essence and details of the current examined issue. Accordingly, using both quantitative and qualitative data enhances the validity of findings as it offsets the weaknesses of qualitative data with more empirical-based quantitative data [53].

The methodology consisted of two separate phases; the first involved collecting and analyzing qualitative data (via interviews) to explore teachers' perceptions and views of the examined phenomena "STEM implementation in schools". From the emerging themes, "challenges encountered by teachers when implementing STEM teaching" were identified and used to develop a survey instrument. Subsequently, and in the second phase, quantitative data were collected and analyzed to assess trends of individuals across a larger sample [33].

A range of data were collected using two main techniques: interviews and questionnaires with teachers to answer research questions. By incorporating and comparing teachers' inputs obtained from the qualitative results with that of statistical findings, it is believed that the overall findings will provide a more well-rounded and comprehensive understanding of the examined issue than would be obtained by either type of data separately [3].

Accordingly, the interface point for mixing data occurred after the first-phase analysis was completed. Specific qualitative results that called for further examination were identified and then used to construct a survey instrument for the second subsequent quantitative data collection. This step connected the first strand with the subsequent second one. Finally, both outcomes were combined during the final discussion [16].

3.1. Local Context

The educational system in UAE comprises three levels: cycle 1 (grades 1–4), cycle 2 (grades 5–8), and cycle 3 (grades 9–12). All students study a compulsory general science subject until grade eight. After then, students choose between an integrated path or an advanced path. The international assessment results of TIMSS and PISA revealed that students in UAE perform below the average score in science assessment of both TIMSS and PISA. More specifically, those findings can be related to the concerns raised earlier in the research on science educators and on how science is being taught and learned. Consequently, UAE has introduced STEM in science education to all cycle two students to fill the gap in the students' education as an intervention plan to improve the students' performance. Some schools were chosen to implement STEM education to cycle two students [4,7,33].

Arab countries such as Egypt [2] and the United Arab Emirates [54] have prioritized integrated STEM/STEAM (Science, Technology, Engineering, Art, and Mathematics) education as part of ongoing curriculum reform in line with national goals and governments' visions for advancing twenty-first-century capabilities. In Egypt, schools are urged to promote STEM/STEAM education by obtaining certification and accreditation [2]. The Ministry of Education of the United Arab Emirates, the Department of Education of Abu Dhabi, and the Mohammad Bin Rashid School of Government in Dubai have all emphasized STEM/STEAM education through various programs, such as the Advanced Science Agenda, Think Science, and National Agenda, and the UAE vision is to be one of the top twenty high-performing nations in PISA and of the top 15 high-performing nations in PISA.

3.2. Qualitative Phase

The first qualitative strand explored the phenomena (the implementation of the integrated STEM approach into science teaching) from the perspective of the science teachers involved in the experience. This approach helps to identify the essence of human experiences as described by participants [37]. Therefore, the chosen framework was most suited to capture the essence of involved teachers through their perceptions.

3.3. Sample and Sampling Procedure

Participants who met the purposeful sampling criteria were chosen from one school to secure valuable required data. Access to participants was easily obtained via one teacher who already worked in the school (gatekeeper) [53]. A sample size between three and ten participants is recommended for a phenomenological study. Therefore, in the current study, the convenient sample involved 3 participants (females), all of whom embodied the characteristics specified by the research and agreed to participate in the study. These were science teachers who were teaching cycle 2 science classes during the 2018–2019 school year. The following criteria applied:

- All are science teachers holding a scientific degree in science education.
- All are teaching science subjects during the 2017–2018 school year in the selected school.
- All have background experience regarding the integrated STEM approach.

- All are implementing an integrated STEM approach via the science curriculum during the 2018–2019 school year.

The participant teachers held at least one Bachelor's degree and had teaching experience ranging from 12 to 14 years. This was to ensure that the participants had received relevant training offered during the first week of every semester. The training aimed to support their implementation of STEM in their classes. In addition, it guided how to infuse particular scientific concepts with STEM activities and projects. In addition, online material was offered that was designed for this purpose [23].

3.4. Ethical Considerations

The research was conducted according to ethical guidelines set forth by the U.S. Department of Health and Human Services (HHS) Regulatory and National Institute of Health (NIH). On this basis, an interview protocol was developed to encourage participants to reflect on their experiences openly. Accordingly, the researcher clearly explained the study's purpose, significance, and associated procedures and implications before beginning the interview. The interviewees were asked to give their agreement to record the interview verbally at the beginning of the interview. In addition, participants were guaranteed that their identities would be kept private since pseudonyms were employed to safeguard their anonymity (none of their real names are disclosed in the final research).

3.5. Instrumentation

The instrument implemented in this research was a semi-structured interview. The semi-structured interview questions were firstly piloted with three teachers to ensure their clarity. Then, an interview guide was created and piloted with doctoral colleagues, whose feedback was used to clarify the ambiguity of some questions. Actually, due to limited time, the instrument was not piloted again. The instrument was written in English to accommodate the participants' native tongue. Each participant interview lasted about 15 min after taking the participant's permission to record the interview.

Using an interview guide (Appendices A and B), the research questions were answered by conducting in-depth semi-structured interviews with participants. The rationale behind using interviews is that it allows to capture more fully the essence of thoughts concerning the teacher's experiences regarding the examined phenomenon [55].

The interview consisted of three sections, each with sub-questions to address one of the research questions. Open-ended questions were designed under each section to stimulate detailed responses from teacher participants. These questions were derived from the primary research questions. In this regard, the first section explored teachers' attitudes and experiences toward STEM implementation in terms of current practices. Then, in the second section, respondents were asked to reflect on the availability of resources and support to back up their implementation attempts. The interview's last half focused on the obstacles and issues that instructors had while introducing STEM.

3.6. Data Analysis

Analysis procedures started with transcribing the interviews from the audio recordings into a script format within a word document. This process was done twice to check for accuracy. Then, the transcribed scripts were analyzed using a coding system. For the coding process, the used method identified and labeled meaning segments that emerged by highlighting codes for concepts, activities, opinions, feelings, and other relevant information. We attempted to remain objective throughout the process, paying equal attention to each segment of the transcripts, putting aside our judgments about the importance of each perspective or contribution, and ensuring that no material was ignored, discounted, or excluded. Next, and after identifying the codes, we started to sort different pieces of text under the relevant codes. Finally, cross-case analysis was done by comparing descriptions across the cases, which allows to identify patterns across each of the participant's data and highlight commonalities or points shared among participants. The contrasted issues, which reflect different, divergent, or opposing opinions, were also identified.

This was followed by the identification of topics and the development of literary descriptions. After reviewing all of the codes generated in the previous stage and determining which codes were required, this was accomplished. As a result, several codes were eliminated (i.e., statements that were not representative of the phenomenon, did no align with the research questions, or were not considered fundamental to the examined experience).

Then, relevant codes were combined and then placed into one group. Each group was labeled, and then we decided which of them was more important than the other; thus, they were ranked by relevance and importance. These are later presented in the discussion section. By the end of this step, we had five major categories, which were then reduced into three: nature of the implementation, availability of resources and support, and encountered challenges. This taxonomy helped to reduce the text to a manageable size. Connections were made between and among these categories. Moreover, in comparison to the previously given literature, various assertions were provided for the emerging themes and replies.

3.7. Validity and Reliability

To ensure the study's validity, the following validation procedures were used: clarifying researcher bias and member checking [6].

Clarifying researcher bias (Epoch), which is known as the act of "bracketing", is achieved when the position of the researchers is described while explaining any biases, prejudices, or pre-assumptions that may impact the research. The researcher's own experiences and opinions were revealed, with the participants, so they were aware of any influence that directed their responses. In addition, and to ensure the authentic engagement in the process, during interviews and while transcribing them, the researcher wrote down his preconceived ideas and expectations of the phenomenon, then set those ideas aside to release any bias as much as possible. For member checking, each transcript of interviews was examined twice by different researchers to identify similarities and differences and ensure that all viewpoints were illustrated as the participant intended with as much accuracy as possible [10].

In addition, care must be taken when transferring the results from a phenomenological study because there is a chance that information may be misinterpreted or misunderstood. Due to that, the findings' trustworthiness was improved by ensuring conformability. Confirmation of data is a central validation strategy for the descriptive phenomenological approach [6]. This was achieved by sharing interpretations and conclusions with participants for their review. In this respect, the participants were given a chance to re-read the interpretation to judge the account's accuracy and validity [56].

4. Results

Participants had a range of teaching experience, from a minimum of 12 years to a maximum of 14 years of teaching. All participants were science teachers. Teacher A is a science teacher for grades 8 and 9 and has two Bachelor's degrees, one in middle-grade science and the other in psychology, with a licensed degree in STEM. Teacher B teaches grade 7 and has two academic degrees, bachelor's degree in Chemistry and postgraduate academic degrees in secondary science education. Teacher C holds a Bachelor's degree in physics and teaches science to grades 6 and 8.

Overall, three themes have emerged from the data analysis: (1) nature of implementation, (2) availability of resources and support, and (3) encountered challenges. Findings obtained under each of these categories are presented and discussed below.

4.1. Nature of Implementation

When discussing teachers' experiences regarding implementing the integrated STEM approach into their teaching, there was obvious consensus among participants that they regularly implement activities that incorporate STEM into science teaching. Teacher B's statement exemplifies this: "it's a regular part of my teaching". The same expression was also echoed by teacher A: "we are required to do it every day". This was followed by a remark from teacher C, who expressed worry that the implementation of STEM is becoming more of an obligation because there are expectations established to shape the school in this respect: "The expectation needs us to prove that we are doing it", she stated. Although teachers agreed that they implement STEM activities regularly, all participants attracted attention to making students aware of what they are doing while performing these activities and for what purpose. This is congruent with the work of [7], who stressed that teachers connect STEM disciplines. In this regard, teacher B stated, "I believe it's useful to tell students that we are incorporating these aspects together when doing so, so they can see how these subjects come together". The same teacher had also indicated that she used to do STEM activities even before teachers required it officially. However, she made the case that now, it is necessary to tell students that these are STEM activities explicitly. Likewise, participants A and C mentioned the same point, suggestion that while emphasizing other dimensions, it is necessary to write this clarification clearly on the board. Hence, students know what particular STEM aspect was implemented during that specific day. On the other hand, a question arose as to whether clarifying the act of performing the STEM activity in an explicit language was weird for some participants. In this respect, teacher A reflected her belief that the act of integration is supposed to be understood without the need to write it down or to say it to students: "now orally, and during the lesson, we are required to point out that we are doing this as part of math subject and that as part of art subject, and so on, I mean, this should be something that is understood".

In addition, responses indicated that the school had allocated particular time and events for performing STEM activities. For instance, they have an innovation week every semester. Based on teachers' perceptions, the nature of the implemented practices concerning STEM involves many features. The most prominent feature is its practical nature. Teacher A illustrated this notion by saying "it's very hands-on". In addition, participants noted that STEM activities help students develop new skills that they did not have before, like design skills. In addition, all participants stressed the importance of dimensions concerned with engineering, which is not an easy task. Education researchers indicate that teachers struggle to connect the STEM disciplines [29]. Teacher A stated, "engineering must be there, we should not miss that part, all other pieces naturally come together in a science subject, but engineering is something else, it is where we create a product of science". One last feature highlighted was clarifying the "value" of performing STEM activities to students. According to the participant, it is essential to stress the importance of these activities, the "why they should be doing it" element beside the "what they should be doing".

While participants shared many features that characterize STEM activities, they also described how these are useful to students learning. For instance, teachers drew attention to building the student's character and good virtues in her personality and attitudes. The example one teacher used to illustrate this point concerned how the actions involved in STEM activities are similar to some extent to those we have to do in real life:

"You know, it's more real life, in real life and when we try something for the first time, we don't make it perfect, or it's not usually the best time, so at this point, we might decide to give up, or we may decide to continue and try once again, the same is when we experiment, design or build things".

Aziz [2] and Campbell [35] agreed with this response, contending that integration must shift toward student-centered teaching that relies on authentic, real-world problems that promote active learning. Moreover, regarding the types of STEM activities usually practiced in the school, one teacher provided three examples; the first one was the marshmallow challenge. Students need to draw an initial design and then build a structure using the provided materials (like a tower). After they finish, they make some measurements (like the height of their tower). The teacher expressed that this activity enables students to develop more advanced and effective strategies to create and build their designs [29]. This point was expressed in her statement: "after students build their design for the first time, they are then given a chance to build it again for the second time, and in the second time they usually build it much better than the first one because they know what they have to do and how".

In addition, the teacher pointed to another important practice involved in the activity: viewing and evaluating other students' work. In this respect, after all, students are done with their structures; they move around to see other towers. While doing so, they gain new insights into their work, give and receive feedback, and recognize other possibilities of performing the same task but in different ways [55].

The second reported example of a STEM activity was the egg drop. In this activity, students are asked to think of a way that protects their eggs from breaking when dropped from somewhere high. Such exercises, according to her, encourage kids to think outside the box and utilize their imagination and creativity to come up with fresh ways to achieve the goal; in her words, "they try their hardest to succeed, and you will be astonished with the concept they can come up with". The third activity involved incorporating aspects from design into the atomic makeup structure of the elements. In the same line, the interdisciplinary approach of teaching STEM disciplines enables students to explain many situations in everyday life and solve problems [2,3].

Regarding considering STEM activities in the planning process, all participants indicated that it is included in their lesson plan. They even, in some cases, do the planning around a central topic (theme) cooperatively with other teachers from other subjects. Teacher B expressed how this way of teaching is beneficial because it allows her as a science teacher to follow up on what teachers from different subjects are doing with the same class, which ensures that they all are on the same line [9]. Unsurprisingly, results from this question strongly coincide with the idea mentioned earlier in this study, of bringing together all STEM disciplines through explicit content area connections or interdisciplinary content and providing opportunities for more relevant, less fragmented, and more stimulating experiences for learners [2,3,19].

The current STEAM education emphasizes a performance that combines various talents to solve real-world issues, portray mathematical and scientific ideas as credible models, and transform engineering designs into arts and arts into aesthetics with deeper cultural significance and values [2]. As a result, the work of the arts leads to a deeper comprehension of mathematics and sciences. The arts are embraced by math and science in order to promote them through a scientific and logical structure or pattern [2]. As a result, the pedagogical process in STEAM education is a symbiosis of the different disciplines, with cross-disciplinary activities serving to inform one another [2].

4.2. Availability of Resources and Support

When discussing the availability of resources that support the implementation of STEM in their school, participants agreed that the required resources are secured to a large extent. In this respect, all participants indicated that many STEM activities can be completed with simple, low-cost supplies—spaghetti noodles, marshmallows, and eggs, for example. Another example was given to justify this claim: building a helicopter is a STEM activity. Students need to cut pieces of paper using scissors with other materials like glue or tape [1].

Moreover, responses indicated that the school had assigned a person to fulfill this mission, providing the needed materials ahead of the activity time.

In addition, and regarding the availability of training for effective implementation of STEM activities, all participants reported receiving external training in which particular teachers are elected to be involved (one teacher from each subject). The selected team is given relevant supportive materials (guided book with instructions about effectively implementing different STEM strategies). In addition, it was noted that those teachers who complete the entire training course are later eligible to train other teachers in their schools (to become certified STEM trainers) [19]. Similarly, participants expressed the need to have expert practitioners of STEM who can demonstrate practically how STEM is best applied and practiced. Research revealed that adopting such an approach requires restructuring many elements, starting from the training of STEM teachers [48]. A critical note was also reported: the importance of having "females" representing these activities in school (i.e., female engineers) especially in the Gulf area, which can alter the common mindset regarding female capabilities and interests. This is similar to the research that discussed the impact of STEM integration on students' interest and engagement in science learning and toward STEM careers [22,25,49,50].

Finally, arranging field trips for students to be exposed to other students and schools' experiences in this regard was also noted. This includes active participation in STEM-related competitions or events (i.e., science fair). Moreover, participants indicated that they have a particular job position (STEM coordinator) to supervise and support teachers in this regard. However, they noted that they have not yet established a position for "design teacher" or "innovation teacher" [23].

4.3. Encountered Challenges

This section emphasizes the challenges faced through the implementation of STEM. When discussing participants' concerns regarding the challenges they face while implementing STEM activities, they reported documentation, vast curriculum content, and the lack of time.

Regarding the first concern, teacher A indicated the issue of documentation as the main challenge. Although teachers implement STEM activities regularly, they are requested to prove it (provide evidence), and this mission of documentation, by itself, consumes much time and effort. Moreover, one critical aspect of the documentation issue was the need to do the documentation well, in her words, "to fashion it". Although this teacher is an expert in effectively conducting STEM activities, she reported weakness in her ability to document it: "I'm still learning how to document those activities". Another noted challenge was the large amount of content that must be covered within a relatively short period (as in the case of the Ministry of Education (MOE) science curriculum). Many researchers reported that one of the barriers to adopting STEM approaches in science classes is the significant science content [38,57,58].

STEAM education faces a number of difficulties. Some of them are related to teacher training in order to implement integrated lessons and teacher professional development in order to upgrade the transdisciplinary technique and philosophy for use in the classroom [57]. This project will necessitate appropriate preparation time as well as the assistance of qualified experts. Arts-based transformation is constantly hampered by a lack of meaningful collaboration among departments and colleges [58]. One of the most significant roadblocks to integrating the arts into science and math curricula is teacher and student perceptions that engineering and the arts should/cannot interact and support one another [38]. This viewpoint reveals a lack of mutual respect and trust among faculty members from various fields.

4.4. Quantitative Phase

The qualitative interviews were used to develop the scale of "challenges encountered by teachers when implementing STEM teaching in their schools". Thus, this second quantitative strand was used to test these specific initial qualitative results. The method used in this strand was a closed-ended questionnaire as it provides the opportunity to collect data from many teachers. Accordingly, a survey instrument was administered to determine teachers' perceptions in this regard. No specially designed instrument was available to assess this specific dimension (challenges of STEM teaching). Due to that, the researcher developed the survey instrument used in the present study based on the initial qualitative results (self-developed) following guidelines suggested by [31].

The survey consists of two sections: the first section concerns the participant's demographic data, which include school type, school cycle, gender, years of teaching experience, the taught subject matter, and teacher education level [37]. The second section has seven structured items. Five of these represent the main challenges reported by teachers from the initial interviews:

- ○ The lack of competence required to teach using an interdisciplinary approach in science, mathematics, technology, and engineering classrooms.
- ○ The lack of necessary knowledge for teaching using an interdisciplinary approach (specialized knowledge of how to teach).
- ○ The lack of guidelines or agreed instructions for effectively implementing the interdisciplinary approach.
- ○ The lack of required resources.
- ○ The overloaded teaching demands and tasks.

The following two items represent other additional factors that were identified based on a review of the prior literature concerning the targeted issue:

- ○ The lack of supportive school culture and classroom environment.
- ○ The lack of co-operation between teachers across different associated subjects.

Participants were asked to reply to each of these questions on a Likert scale. Teachers were asked to rate these statements using a five-point Likert scale by indicating whether they strongly agree (SA), agree (A), are neutral (N), disagree (D), or strongly disagree (SD). Thus, responses to these items were used to explore degrees of "agreement or disagreement" on each corresponding item. These generalizations were thought to relate to the initial findings obtained from interviewing a limited number of teachers. Thus, initial responses were compared to the average scores obtained from these surveys [59].

The advantage of the closed questions is that they make coding straightforward and leave no space for rater subjectivity [48]. To secure the content validity, the developed survey was critically examined by an internal faculty professor for content, readability, and ease of use, then piloted and tested with a group of teachers (different from those at the sample school). The questionnaire items were revised and refined based on their feedback and recommendations.

An overall number of (N = 61) participants was selected via "convenient sampling" from three different schools, all of which were public schools in Al-Ain city in UAE. Teachers were informed ahead about the importance of the study, the purpose of using the questionnaire, and their role and rights in the process. In addition, it was acknowledged that their participation was voluntary and they were assured about the confidentiality of their inputs. This was achieved via the provided informed consent, which is a necessary step to make sure that participants "enter the research of their free will and understand the nature" [18].

The questionnaire was constructed in the "English language" as all targeted sample populations could read and understand the statements written in English. Surveys were conducted during the first semester of 2018–2019. Teachers completed the surveys in their natural setting (inside the school site). Surveys were distributed to teachers, and then they were asked to meet at their convenience during their free periods. Collecting back surveys took five days from the first day of distribution. Thus, the data collection was complete after these two visits to the participating schools. The teachers' survey response rate was higher than 70%, which is acceptable to represent the broader population [58,60].

The reliability and validity of the questionnaire were measured using descriptive statistics, frequency distributions, and internal consistency reliability indexes. Once the surveys were completed, data checking and entry procedures took place, following by analysis using Statistical Package for the Social Sciences (SPSS) 24.0 (IBM Corp., Armonk, NY, USA) via descriptive statistics (frequency, mean average, average percentage, and standard deviation). Tables and bar graphs were used to represent the obtained results [41].

After analyzing the teachers' perspectives on implementing STEM in schools, there was a deep need to explore the challenges for implementation from the teachers' perspectives. The central theme of these responses was challenged. The researcher developed the STEM challenges questionnaire based on the seven challenges recognized from the theme of the teachers' perspective. The average of 64 teachers' responses was calculated for each of the seven items, as seen in Table 1, on a five-point Likert scale, where the teachers' responses ranged from 1, which is "strongly disagree" to 5, which is "strongly agree" [22,25,46].

Table 1. Mean scores of challenge items.

		I Believe There Are No Clear Guidelines or Agreed-on Instructions for Effectively Implementing the Interdisciplinary Approach.	The School Culture and Classroom Environment Do Not Support Teaching through an Interdisciplinary Approach.	I Lack the Knowledge Necessary for Teaching an Interdisciplinary Approach (Specialized Knowledge of How to Teach).	I Lack the Competence Required to Teach Using an Interdisciplinary Approach to Science, Mathematics, Technology, and Engineering Classrooms.	It Is Challenging to Work with Teachers from Other Disciplines (Lack of Co-Operation between Teachers).	The Teaching Demands, Load, and Tasks, Such as Assessment and Examinations, Make It Challenging to Implement New Ideas.	The Lack of Resources, Such as Money and Time, Makes It Challenging to Implement New Approaches.
N	Valid	63	64	64	64	64	64	62
	Missing	1	0	0	0	0	0	2
Mean		3.3968	3.1406	2.6563	2.5781	2.7188	3.3125	3.2903
Std. Deviation		1.02453	1.16656	1.23724	1.12412	1.11936	1.24563	1.35969

The means of the items revealed mostly agreement about the challenges, as all the means were above 2.5. More descriptive data about the teachers' responses frequency were calculated for the seven challenges, in order to be more specific. Table 2 shows the frequency of each of the challenges.

Table 2. Frequency of challenges on a five-point Likert scale.

No	Items	SD	D	N	A	SA	Total
1	I believe there are no clear guidelines or agreed-on instructions for effectively implementing the interdisciplinary approach.	2	10	21	21	9	63
2	The school culture and classroom environment do not support teaching through an interdisciplinary approach.	5	16	16	19	8	64
3	I lack the knowledge necessary for teaching an interdisciplinary approach (specialized knowledge of how to teach).	13	20	11	16	4	64
4	I lack the competence required to teach using an interdisciplinary approach to science, mathematics, technology, and engineering classrooms.	8	30	12	9	5	64
5	It is challenging to work with teachers from other disciplines (lack of co-operation between teachers).	10	19	16	17	2	64
6	The teaching demands, load, and tasks, such as assessment and examinations, make it challenging to implement new ideas.	7	11	11	25	10	64
7	The lack of resources, such as money and time, makes it challenging to implement new approaches.	9	10	10	20	13	62

The frequencies showed that few responses reflected the two extreme ends (SD and SA). Moreover, the teachers' responses focus on the three-centered evaluation (D, N, and A). However, looking deeply at the teachers' responses revealed that the neutral responses numbered the highest, making it hard to realize the actual status of the teachers' responses.

To reach a deeper understanding of which challenge was the most reported by a teacher, the percentages of only agree and strongly disagree responses to the implementation challenges were calculated, as shown in Table 3.

Table 3 shows that the most agreement for the challenges was 72%. The teachers believe that there are no clear guidelines or agreed-on instructions for effectively implementing the interdisciplinary approach. The teaching demands and the lack of resources came next with 54.7% and 51.6%, respectively, while 21.9% agree that the teacher's lack of competency to teach STEM was the least of the STEM implementation challenges.

Table 3. The percentages of agree and disagree of the STEM implementation challenges.

No	Item	Strongly Agree %	Agree %	Total
1.	I believe there are no clear guidelines or agreed-on instructions for implementing the interdisciplinary approach effectively.	40.1	32.8	72.9
2.	The school culture and classroom environment do not support teaching through an interdisciplinary approach.	12.5	21.7	34.2
3.	I lack the knowledge necessary for teaching an interdisciplinary approach (specialized knowledge of how to teach).	6.3	25.0	31.3
4.	I lack the competence to teach using an interdisciplinary approach to science, mathematics, technology, and engineering classrooms.	7.8	14.1	21.9
5.	It is challenging to work with teachers from other disciplines (lack of co-operation between teachers).	3.1	26.6	29.7
6.	The teaching demands, load, and tasks, such as assessment and examinations, make it challenging to implement new ideas.	15.6	39.1	54.7
7.	The lack of resources, such as money and time, makes it challenging to implement new approaches.	20.3	31.3	51.6

5. Discussion

This study reflects teachers' perceptions and experiences regarding implementing integrated STEM into their teaching. An additional goal of the research was to explore how this implementation is supported by resources and relevant training. Finally, the encountered challenges were also discussed.

The literature review and current findings revealed that participants successfully reached the level where different subjects are integrated with science smoothly and naturally as a regular habit since this is practiced regularly (an essential aspect of science teaching). Thus, it appears that STEM is implemented to a large extent. However, what is interesting here is that although some participants admitted that they regularly implement STEM into their teaching, none have shown any signs of resistance [30]. However, some reflected that it is more like a compulsory obligation, which they have to do and prove that they are doing. This critical finding raises the concern that, like many other instructional practices, when the pressure of "proving it" exists, the real "value" might be lost [19].

Moreover, the results provide evidence that the school has given the successful practice of STEM a priority. This was accomplished by making it a requirement for teachers to include it in their lesson plans, allocating specific days and events for working on STEM projects (the innovation week), providing professional STEM practitioners with training for teachers, and allocating a specific secure budget for the purpose of providing all necessary materials and resources [16,60].

In addition, they expressed feeling relieved that teachers seem ready for and capable of applying STEM. This reflected a high self-efficacy regarding their capability. Therefore, the lack of necessary knowledge or skills in this regard was not troublesome for them [31]. This could be due to the relevant experience and training they have had. Concerning the challenges they encountered while implementing STEM, the reported concerns included documentation, vast curriculum content, and the lack of time [20,61,62].

Overall, and based on the results of this study, some things could have been done differently: there was a need for sharing and transferring the knowledge and skills of STEM best practices through professional trainers. The school focused on preparing particular selected teachers to obtain certified degrees so that they can later train other teachers in the same school. The other point is the nature of such training. Since STEM activities are practical, they are best taught within this frame via active, engaging activities and spot demonstrations [4,13,15,54,63–65].

Moreover, integrated STEM education involves students exploring the interconnections between science, technology, engineering, and mathematics that will enable them to understand how those disciplines operate within real-world contexts. Consequently, students acquire extended life competence by engaging in active approaches that value students' real-life experience. In particular, a student gains an in-depth understanding of each subject's content and skills as integrated courses rather than as isolated content teaching. They are able to make deep connections between the four STEM subjects. Therefore, STEM interdisciplinary teaching practice leads to advanced critical thinkers who have more innovative thinking and can cope with nowadays complex technological demands. The value of STEM is emphasized by placing engineering standards into the Next Generation Science Standards [12,38,41].

Taking these research results for implementing STEM in cycle two science classes into consideration, and in light of President Obama's call that leadership tomorrow depends on how we educate our students today, especially in science, technology, engineering, and math [60], improved STEM education may require a change in the structure of higher-education institutions by restructuring curricula to produce graduates who are versatile, adaptable, and highly employable, precisely, graduates in STEM jobs [27,48].

Interestingly, among the seven challenges that teachers reported, most agreement was around facing challenges because of the guidelines that should be provided by educational administrators and the lack of resources, in addition to the additional teaching demands from academic administrators. It is worthy to note that all the challenges above were external to the teachers. When it came to the teachers' competency to teach STEM and their knowledge about it and their cooperation with other teachers and school culture and class environment, the teachers showed minor agreement. The last four situations reflect internal challenges. Therefore, the teachers strongly agreed with the external challenges that they have no control over, while they showed a minor agreement if the challenges related to their competencies or skills. Considering these results, a clear bias from teachers to themselves was shown. This result will be the focus of more investigation in the future [13,52,59].

6. Conclusions

In general, the results revealed an apparent consensus among participants that they can implement STEM into their teaching without serious concerns. Participants even indicated they implement STEM frequently and regularly. They shared almost the same satisfaction toward the support provided by the school to enable them to best practice it with their students in terms of availability of resources and relevant training.

The following were identified concerning the challenges teachers encounter while implementing STEM: documentation, the vast curriculum content, and lack of time. Moreover, external challenges (i.e., the lack of supportive guidelines) rather than teachers' competency (i.e., having sufficient knowledge and skills for implementing STEM teaching) appeared to have the highest impending impact.

7. Limitation

A limitation of the current study is that participants shared a range of teaching experience, A minimum of 12 years and a maximum of 14 years of teaching experience is required. All of the participants were instructors of science. Teacher A is an 8th and 9th grade science teacher with two bachelor's degrees, one in middle-grade science and the other in psychology, as well as a STEM license. Teacher B is a seventh-grade teacher with a bachelor's degree in chemistry and a master's degree in teaching (postgraduate academic degrees in secondary science education). Teacher C is a physics major who teaches science to students in grades 6 and 8.

8. Recommendations

STEM integration is still a controversial issue with a long history of debate, but most researchers agreed that STEM integration will have a positive impact on education. The reviewed literature indicated that the advantages of STEM integration outbalance the disadvantages. However, the research revealed several challenges that prevent the effective implementation of STEM integration, in particular, the complexity of the interdisciplinary approach, teacher reediness, and school culture. However, all those barriers can be controlled if a successful education reform process is adopted, in particular, a well-studied, unified reform plan with clear educational goals and outcomes.

Furthermore, all stakeholders that appreciate and believe in the influence of the new reform process must be involved. Additionally, preparation of the needed resources, such as the qualified human capital, specialized curriculum, and all the required material, is required. Finally, the reform process's implementation should be followed by testing and evaluation at different phases.

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Appendix A

Interview Guide

Thank you for agreeing to speak with me today. This interview is entirely voluntary. If at any time you do not want to answer a question, you want to skip a question or go back to one, you are free to do so. If you do not wish to continue, we can stop the interview at any point. This interview will be audio-recorded, and I can control the recording at any time at your request. The interview will last about 15 min. The purpose of this interview is to learn about your experiences in integrating STEM into your science classes. We want to understand what STEM courses were like for you.

Questions:

1. Tell me a bit about your teaching experience—years of teaching and taught grades?
2. Can you tell me about how STEM is implemented in your school?
    a. Is there a clear policy or guidelines?
    b. How often do you implement STEM in your science classes?
    c. Is it considered in your planning?

3. What kind of activities are implemented? Can you give me some examples?
    a. Are there available resources to support STEM teaching?
    b. Have you received any training regarding STEM teaching?
4. What challenges have you encountered while implementing STEM?

Appendix B

Examining Challenges Encountered by Teachers When Implementing STEM Teaching (Teacher Survey)

We would appreciate you taking the time to complete the following survey. This questionnaire asks about your personal beliefs regarding current practices of the interdisciplinary teaching approach. The multidisciplinary teaching approach teaches a particular topic by integrating the following subjects (Science, Mathematics, and Technology).

Your responses will be kept strictly confidential (will not be linked to you personally). This survey is expected to take 4–6 min to complete.

Part 1—Demographic Information:

Please tick the most appropriate response.

Q1. School Type
1. Private
2. Public

Q2. Gender:
1. Male
2. Female

Q3. School cycle
1. Primary (cycle 1)
2. Preparatory (cycle 2)
3. High school (cycle 3)

Q4. Teacher's qualification
1. Bachelor's degree
2. Master's degree
3. Ph.D. degree
4. Other

Q5. Teacher's experience
1. Less than 5 years
2. Between 6 and 10 years
3. Between 11 and 15 years
4. 16 years and above

Part 2—Questionnaire Items

The following items describe statements about current practices of the interdisciplinary teaching approach. Please put a checkmark "✓" in the box that best indicates the extent to which you agree or disagree with each of the following statements using the scale below:

SD = Strongly disagree
D = Disagree
N = Neutral
A = Agree
SA = Strongly agree

No	Items	SD	D	N	A	SA
1	There are no clear guidelines or agreed-on instructions for effectively implementing the interdisciplinary approach.					
2	The school culture and classroom environment do not support teaching through an interdisciplinary approach.					
3	I lack the knowledge necessary for teaching an interdisciplinary approach (specialized knowledge of how to teach).					
4	I lack the competence required to teach using an interdisciplinary approach to science, mathematics, technology, and engineering classrooms.					
5	It is challenging to work with teachers from other disciplines (lack of co-operation between teachers).					
6	The teaching demands, load, and tasks, such as assessment and examinations, make it challenging to implement new ideas.					
7	The lack of resources, such as money and time, makes it challenging to implement new approaches.					

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