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Promoting UAE entrepreneurs using E-STEM model

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ABSTRACT
Although students' STEM designs are widely admired by teachers, relatively little attention has been given to making use of these designs by incorporating a basic understanding of the market to create new values for communities. The E-STEM model was developed to promote entrepreneurial practices into STEM disciplines and prepare students for the market. Yet, little is explored regarding the teaching pedagogy of E-STEM model and its outcomes. A qualitative case study was conducted to explore E-STEM experiences of high school students and to further explore teachers' perceptions regarding the teaching approach of E-STEM model. A total of twelve teachers were trained to understand the concept of E-STEM, and five of them were selected purposefully to implement E-STEM model with 42 students. Through analyzing and interpreting students' projects and teachers' interview transcripts, this study concluded that the effective practices of E-STEM model require a development-oriented instruction to enhance students' outcomes over time.

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Introduction

Entrepreneurship has acquired new significance in the context of the knowledge-based economy. Cultivating an entrepreneurial mindset in students can result in higher productivity, creativity, and diversity of business ideas (Hitt et al., 2001) because introducing new products and valuable services could potentially enable companies to expand into new markets.

Through entrepreneurship, one can commercialize knowledge generated in one field into another field (Van Horne et al., 2012). The complexity of applications integrating STEM (Science, Technology, Engineering and Mathematics) knowledge and skills are associated with enhanced STEM outcomes and practices. This makes the STEM classroom the best context to integrate diverse activities of entrepreneurial learning. STEM students are inventors, while entrepreneurs can translate innovation into services and economic impacts. Hence, practicing entrepreneurial activities in STEM classes becomes essential to increase students' knowledge, skills and self-efficacy of STEM careers instead of abandoning their creative ideas after leaving their schools' exhibitions.

The economic growth is hindered by two main obstacles: high unemployment rates among STEM degree graduates and a lack of the ability to apply the skills and knowledge gained into real-life applications later on. According to Waite and McDonald (2019), the lack of meaningful learning experiences for developing students' lifelong skills has contributed to STEM recruitment difficulties. The strength of the economy is determined by the successful STEM students who can pursue STEM-related careers. Despite this, the number of students who show interest in studying STEM as a major in the United Arab Emirates (UAE) is still limited, resulting in a lack of professionals in the STEM fields (AlMurshidi, 2019). This deficit is one of the reasons STEM subjects have become a national priority in the UAE. The significance of involving teachers in shifting the learning paradigm to focus on STEM-based practices was emphasized by Abu Dhabi Education Council (ADEC). In addition to teachers' efforts, a recent study found that parents' role is essential in stimulating adolescents' intrinsic motivation in STEM learning (Jungert et al., 2020).

Through closing the skill gap between students' learning outcomes and the needs of the market, a sustainable culture of education will be created to produce more innovators and entrepreneurs in various fields (UAEinteract, 2015). UAE education is being called to act in this regard through investment in STEM education that elaborates students' intellectual abilities to be prepared in the long run for competitiveness in the job market (MOE, 2010).

Purpose of the study

The Entrepreneurial-STEM (E-STEM) model was designed by Eltanahy et al. (2020b) to guide teachers to incorporate entrepreneurial learning and integrate its activities into STEM education to develop students' skills (E-STEM stands for Entrepreneurial learning + Science, Technology, Engineering, and Mathematics). The purpose of the current exploration is to answer the following questions:

- What are teachers' perceptions regarding the E-STEM model?

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- What are the students' outcomes from the E-STEM model that are valued by teachers?

Literature review

A report regarding STEM reform published by the Education Bureau (2016) recommended that integrated curricula of STEM disciplines should be aligned with the ongoing renewal of school curriculum updates and society's needs. This alignment will pave the way for fostering students' entrepreneurial spirit through adopting pedagogies of student-centered learning. STEM teachers have been encouraged to adopt a context-based framework to entrepreneurial learning (EL) within the STEM framework in order to promote and extend the greater entrepreneurship system (Barth & Muehlfeld, 2022).

The STEM field is broad, and teachers cannot always know how to be innovative and forward thinking because integrating knowledge and practices from different disciplines has no end point or stereotypical steps to be followed. Integrated STEM learning that focuses on the engineering design process (EDP), for example, has proven its effectiveness in enhancing students' abilities to handle the complexity of learning tasks and address its problems, through planning, sketching and transforming their prototypes into 3D models (English et al., 2017). The approach of EDP creates opportunities for high school students to move from prototyping (initiation stage) to designs (implementation stage) in a creative environment that nurtures STEM imagination (Siew, 2022). Despite that success, developing contextualized learning programs in STEM disciplines (Shaer et al., 2019) is one of the primary obstacles identified in the latest report from the Mohamed Bin Rashed School of Government (MBRSG) concerning the problems that UAE teachers face while implementing integrated curricula.

Teaching approaches of E-STEM

Entrepreneurial STEM learning (E-STEM) aims to promote students' entrepreneurial practices through STEM education and disciplines. Teaching approaches to entrepreneurship differ according to the main learning goals. First, educating students to act entrepreneurially requires a teaching approach adopting a pedagogy-oriented perspective to focus on developing high school students' competencies to confidently enter the market (Johannisson, 2010). Drawing on this perception, the term '*Education through E-STEM*' is inspired in part by the appropriate features characterized by this teaching approach. The design assumption of PjBPS (project-based problem solving) requires adequate time for experiencing many E-STEM activities to produce investigators, problem solvers, and designers who can act entrepreneurially; yet Shemwell et al. (2015) adopted the developmental view of teaching such a long-term outcome.

Second, educating students to become entrepreneurs requires applying a teaching approach with a content-oriented perspective to support ventures created by students in higher education who can communicate more intently with the market (Katz, 2008). Drawing on this perception, the term '*Education for E-STEM*' is proposed by the authors to refer to teaching approaches that traditionally introduce EL as a knowledge supply in each lesson, not as a method applied during a whole course, yet Shemwell et al. (2015) adopted the non-developmental view of teaching such a short-term outcome.

Development-oriented instruction

Literature concerning the progression of learning inspired the expression of "Developmentally oriented instruction" (Shemwell et al., 2015, p. 1165). This development-learning approach assumes that for students to attain a deep understanding of certain ideas requires regular and consistent practices over an extended period to enhance their reasoning skills and abilities, and to apply the new knowledge in different situations. Hence, the more students go forward in their practices, the more knowledge will be added, constructed, and learned efficiently (Duncan & Rivet, 2013). Each period of the developmental instruction is essential as an integral part of this accumulation approach to progressively develop more a sophisticated understanding of the content provided, and gradually extend practices to better theoretical depth that enhances students' intellectual capacity. Thus, previous research has shown that learning the fundamental knowledge of an advanced learning content of science requires enough time to address its difficulty because it does not follow a linear process or a strict predictable path (Carey, 2009). More characteristics of the instruction required to teach a development-oriented curriculum (DOC) were listed in Shemwell's (2015) study explaining the need for long period growth and deep immersion in learning experiences to expect gradual change while focusing on a big idea rather than memorizing unnecessary details. Therefore, prominent instructional approaches such as open inquiry-based learning (National Research Council, 2000) and project-based learning (Lu et al., 2022) were recommended to support teaching any DOC. The literature expressed teachers' tendency to practice knowledge-accumulation strategies that focus on the teaching and learning process and allow them to identify students' progress in a limited time, rather than constructivist strategies that might not help them to identify short-term improvements because they emphasize longer-term outcomes (Banilower et al., 2013).

E-STEM impact on career decision

Research has concluded that students' career choices are influenced by the learning experiences offered in high school because these activities are a necessary base for steering STEM students to their desired occupations (Sheldrake et al., 2017). Learners should be consistently exposed to authentic and experiential learning through meaningful and contextualized projects to be able to use their newly acquired competencies in real-life settings.

Although STEM students' job desires are frequently linked to teaching and learning methodologies, the solo implementation of a project-based approach in a short term cannot clearly affect this inspiration (Van et al., 2018). It is critical for high school learners to relate their learning objectives to real-world job requirements, despite being distant from work obligations or employment. Moreover, it is difficult to determine the needed abilities for future occupations that do not yet exist (Falco, 2017). When workplace demands rise, there will be an increase in the amount of knowledge, life skills, career-related skills and talents needed to prepare students for a variety of professional options, whether in established companies or as self-employed entrepreneurs. Since school activities improve students' STEM identity, abilities and confidence, engaging them in enrichment STEM models is necessary to influence their career choices (Collins, 2017). In light of this, acquiring a strong STEM-scholar identity as well as fundamental entrepreneurial abilities might eventually result in new STEM entrepreneurs.

In this sense, The European Commission (2003) proposed that infusing entrepreneurial practices and experiential learning into different existing courses ought to be a broad learning attitude because it creates a set of lifetime entrepreneurial abilities for students (Kuratko & Morris, 2018). Despite all the benefits of this incorporation, teachers might subscribe to it in the abstract with no real tendency to apply it in practice as it is challenging for them (Banilower et al., 2013).

Theoretical framework

The contribution of integrating STEM knowledge and experiences through experiential learning in promoting students' life skills is highlighted in the literature (Asghar, Ellington, Rice, Johnson & Prime, 2012). Restructuring STEM education to accommodate entrepreneurial activities was suggested by Larsen (2022), and Eltanahy et al. (2020a) argued that infusing entrepreneurial practices into STEM education is not only applicable, but it leverages STEM endeavors by bringing its learning outcomes to the market through involving business teachers who are knowledgeable enough to incorporate appropriate entrepreneurial practices into an existing STEM course. Accordingly, Eltanahy et al. (2020b) developed an interdisciplinary E-STEM model (Figure 1) that introduces a framework to integrate the knowledge and practices of entrepreneurial experiences (EE) into STEM education. This model illustrates the main pulleys (entrepreneurial practices, science inquiry, technological literacy, mathematical thinking, and engineering design) of the five E-STEM disciplines that should be integrated through a competency-based approach. This requires creating an experiential learning environment to enhance students' acquisition of the core entrepreneurial competencies, including knowledge, skills, and attitude. The proposed pedagogical strategy of E-STEM is project-based problem solving (PjBPS) because it allows students to actively achieve STEM goals as well as exploit new opportunities to

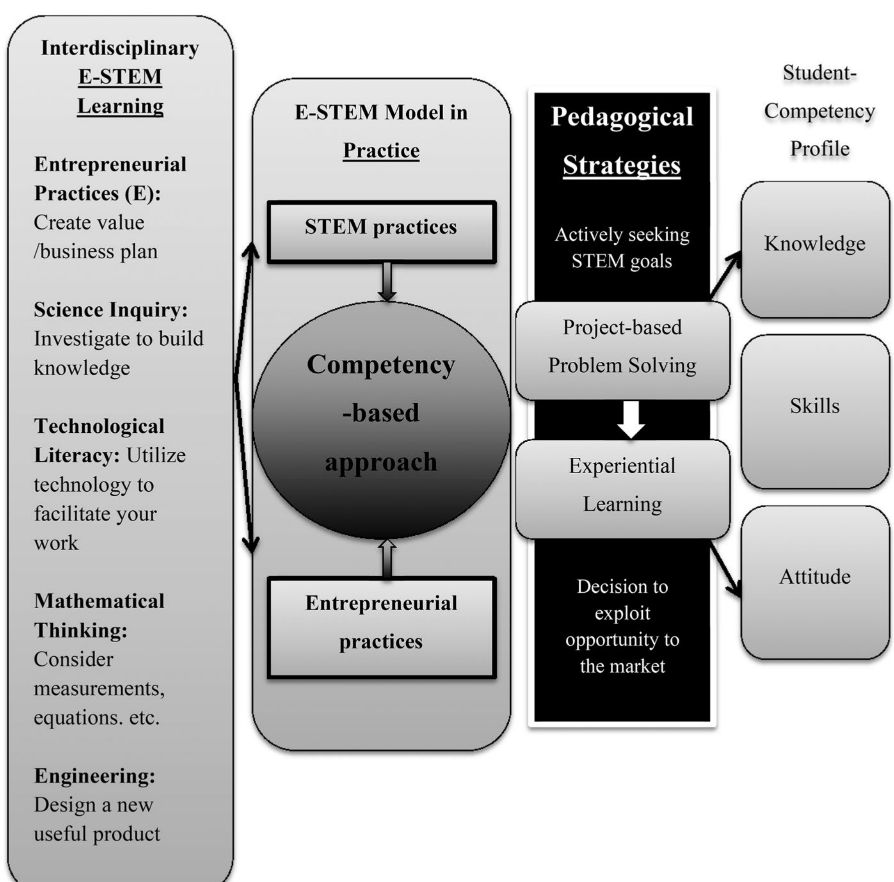

Figure 1. Interdisciplinary E-STEM model (Eltanahy et al., 2020b).

the market. The E-STEM model emphasizes practices of creating value while designing STEM projects to benefit the community and to avoid losing students' efforts (Hershman, 2016). Eltanahy et al. (2020b) recommended implementing the proposed E-STEM model in schools through utilizing a systematic strategic plan of E-STEM that includes six main stages: ability determination, brainstorming, Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, prototyping, designing E-STEM projects, and planning to add value to the community through a business plan for marketing the produced E-STEM projects.

The implementation of the E-STEM model relies on the social constructivist perspective of learning, and supporting students to engage in a social learning environment and construct their own knowledge and skills (Vygotsky, 1987). The E-STEM model creates opportunities for the students to work and cooperate together. In this sense, the E-STEM model is applying and promoting contextualized active learning using the principle of Zone of Proximal Development (ZPD) and the situated cognition theory. According to this theory, knowledge is situated and embedded in contextualized learning experiences bound to socio-cultural and institutional settings (Lave, 1988). The model of entrepreneurship intention was guided by Ajzen's (1991) theory of planned behavior which helped identify the theoretical concepts needed for promoting students' entrepreneurial behavior and experiential learning (Kolb & Fry, 1975).

Methodology

A qualitative case study using interviews and classroom observations was used to develop an in-depth understanding of the implementation of an interdisciplinary E-STEM model. The Consolidated Criteria for Reporting Qualitative Studies (COREQ) checklist was used in this study to ensure the consistency and coherence of the different aspects of the study including research team, study methods, context of the study, findings, analysis and interpretations. For example, the COREQ helped to promote explicit and comprehensive reporting and interpreting of qualitative data (interviews and focus groups) (Tong et al., 2007).

Participants

The sample of the study included STEM teachers and students at secondary schools. Eleven STEM teachers and one curriculum coordinator (CC) working for an American curriculum high school in Sharjah participated in this study eight teachers out of those 12 took part in the implementation of the E-STEM model (five female teachers implemented the E-STEM model in the classroom + two female teachers and one male act as observers). Additionally, two grade 11 classes comprising 42 STEM students (24 boys and 18 girls) were recruited to practice E-STEM learning. All participants were nominated by the school administration and were recruited voluntarily. The demographic information of the teachers and their E-STEM related backgrounds are summarized in Table 1.

Table 1. Demographic information of the participating teachers.

Category	Elements	No.	Percentage %
Gender	Male	2	17%
	Female	10	83%
Previous STEM Training	Yes	12	100%
	No	0	–
Previous E-STEM Training	Yes	0	–
	No	12	100%
Position	Science Teacher	3	25%
	Technology Teacher	2	17%
	Engineering Teacher	1	8%
	Mathematics Teacher	3	25%
	Business Teacher	2	17%
	Curriculum Coordinator	1	8%

This study was conducted in three sequential stages in one academic year: teachers' training, E-STEM implementation, and finally interviewing the participants, as follows.

E-STEM training

To construct an accessible vision of E-STEM implementation in a high school, features of an interdisciplinary E-STEM model were introduced and explained to the participating teachers of STEM in professional training that was carried out in five sessions over two weeks at the beginning of the academic year. The average duration per session is three hours including a short break. Contextual factors like teachers' availability, timetable, and their interest in implementing E-STEM into their classes were considered before the start. Accordingly, the participating teachers who attended the training were divided into three groups (practitioners, observers, and advisers). Table 2 introduces the content of the training and the focus of each session provided to teachers.

E-STEM implementation

As mentioned earlier, five out of the twelve teachers were nominated to apply the E-STEM model because they teach the same grade 11 classes. Students were divided into seven groups, each group consisting of six students who worked collaboratively on an E-STEM-based project to design innovative products. The five teacher-practitioners were identified as being specialists in one of the five main disciplines (Business, Science, Technology, Engineering and Mathematics) that form the E-STEM acronym and who teach the regular STEM course to their students. Another three teachers were selected to act as observers of E-STEM implementation because they teach different grades. The last three teachers

Table 2. The content of E-STEM training for teachers.

Training sessions	Content	Focus
Session 1	Rationale of Interdisciplinary E-STEM Model	Advantages of integrating E-STEM disciplines
Session 2	E-STEM Pedagogical strategies	Project-based problem solving and experiential learning
Session 3	Competency-based Approach	Student-competency profile
Session 4	E-STEM Strategic Plan	Six main strategies developed by Eltanahy et al. (2020b)
Session 5	E-STEM Strategic Plan	Planning for E-STEM lessons

and the CC who attended the training were not able to implement the E-STEM model or observe classes, so they acted as advisers to discuss, guide and give ideas to practitioners. The implementation lasted approximately two terms (6 months) of the academic year. The E-STEM model was implemented during STEM sessions (eight sessions/week) that were formally scheduled in the participating school. To support students to gain positive entrepreneurial experiences and be skillful in E-STEM designs, teachers were trained and guided to apply the E-STEM strategic plan, considering both the pedagogical practices of STEM education and active learning embedded in EE. Table 3 shows the role of teachers who attended the training to support E-STEM implementation in the school.

Interviews

The eight E-STEM teachers (five practitioners and three observers) who implemented the E-STEM model, as well as one advisor (CC), participated in focus group interviews to reflect on their teaching and planning experiences while carrying out the E-STEM model in their classes. Two face-to-face meetings (one for practitioners and one for observers and advisors) were conducted by the first author and lasted for 40 to 60 minutes to allow for probing and to provide E-STEM participants with enough opportunities to freely consider the entire run of their E-STEM experiences. As requested by practitioners, the interviews were carried out near the end of the academic year, based on teachers' availability and time preferences. Five main questions were put to both practitioners and observers:

- To what extent does the E-STEM model guide teachers to facilitate the learning process?
- How were disciplines restructured in light of the E-STEM model?
- How do you perceive E-STEM learning instruction?
- To what extent were you able to observe students' acquisition of entrepreneurial knowledge in each stage of the E-STEM strategic plan? Why?
- What is the most valuable E-STEM project produced by grade 11 students?

Table 3. Roles of participating teachers in E-STEM implementation.

E-STEM teachers	Number	Implementation role	Interview attendance
Practitioners	5	Implemented E-STEM model collaboratively with 42 Gr 11 students	All attended first face-to-face interview for data collection
Observers	3	Observed E-STEM sessions to give feedback and recommendations to practitioners and students	All attended second face-to-face interview for data collection
Advisers	4	Conducted weekly meetings with practitioners and observers to discuss E-STEM implementation, its challenges and give advises	One CC attended the second meeting. Three teachers did not attend any of the interviews conducted

Validity and credibility

Data was collected in two semi-structured interviews conducted with eight STEM teachers (five practitioners and three observers). Data was collected through triangulation of multiple resources (practitioners' interview, observers' interview, and students' E-STEM projects) to address the limitation of each data resource, and to enhance credibility and validity of the qualitative findings. The interview protocol was reviewed and evaluated by two professors of education to enhance its content validity. The consent form was signed by the school principal and interviewees, and explained the purpose, methodology, and the level of confidentiality of their participation in the study (Johnson & Christensen, 2014).

Data analysis

Qualitative data was collected from teachers regarding the implementation of the E-STEM model. Outcomes were analyzed, compared, and interpreted through cross-case analysis to determine patterns across teachers' views, then represented in a narrative form to review the manifestations of agreement and controversy between practitioners and observers. Miles and Huberman (1994) three components of data analysis and interpretation were used in this study:

- Data reduction: transcript of each teacher was analyzed, and dialectical properties regarding developmental or non-developmental characteristics of the E-STEM model were highlighted in coherent narrative summaries.
- Data display: similar views of both practitioners and observers were compared, and contrasting quotations were elicited and classified according to features of the two main teaching approaches of E-STEM, 'Education through E-STEM' and 'Education for E-STEM' with attention to developmental and non-developmental views as far as possible to avoid the hazard of bias, and to display key ideas of the tentative results in a logical manner.
- Conclusion: the in-depth analysis ended by using the implied and inferred information to make clear meaning as presented in the discussion (including tables). Students' E-STEM projects and documents were also illustrated and discussed to represent the main outcomes of the E-STEM model.

Participants' names were not used; however, E-STEM practitioners were given numbers to refer to their responses (P1, P2…P5), while E-STEM observers were mentioned as (O1, O2, O3).

Education through E-STEM

CC, P1, P2, and P5's views of the E-STEM model went further than the views of P3 and P4. The former saw E-STEM as a more development-oriented course. For example, P1 explained that "E-STEM aims to produce young entrepreneurs who are scientifically, technologically and mathematically literate." Accordingly, P2 advocated "the need for consistent practice to expect gradual improvement," while P3 argued that "the instructional sequence of the E-STEM strategic plan focused on an entrepreneurial investigation-based STEM design requires consistent revision and repetition of any of the six stages to acquire scientific and entrepreneurial skills." Nevertheless, P3's suggestion strongly resembled O2's understanding that "infusing entrepreneurial practices was a big, interesting challenge to students as many of them experienced failure and reflected on their loss to request more time to re-plan for further trials." In line with this view, O1 observed that "students needed to expand their networking to help achieve their E-STEM goals. Members of their families and friends offered great assistance to facilitate students' projects and to identify the gaps or mistakes to be put right first." All observers admitted that "both students and their parents were interested in the E-STEM model and were cooperating by providing the unavailable materials to the whole group to address unexpected challenges, especially in the stages of designing the project and business plan."

Meanwhile, O3 observed that "students gain better understanding, and practice more entrepreneurial habits, through giving more focus to the learning approach than the content knowledge, to cope with the back-and-forth experiences." In this essence, P5 justified his view saying "students' ability to design and to investigate entrepreneurial opportunities was clearly developed. However, the diffusion of entrepreneurial practices into STEM classes is necessarily a long-term endeavor of learning." Interestingly, all participating teachers agreed on P2's suggestion that "extended E-STEM experiences are preferred for at least one academic year of implementation to promote students' continuous learning and gradually develop their entrepreneurial knowledge and thinking." This meaning aligns with Duncan and Rivet (2013), who believed that the more practices are implemented, the more knowledge is acquired.

In line with that, O3 observed that, "students' engrossment in the E-STEM strategic plan and its activities made them interestingly expand the track of learning time; obviously, they needed more than being exposed to E-STEM practices for a limited time." This is consistent with Shemwell's (2015) conception of immersion, which argued that exposing students to developmentally oriented instruction is inadequate; instead they should be fully immersed in some learning experiences to foster the development of the required skills. In addition, P1 believed that "activities conducted through E-STEM were advanced to high school students, and obviously sustained experiences through project-based learning are highly required to avoid counting on definite progress on the near term." This is sharply equivalent to the argument of Carey (2009), that advanced learning content does not follow a linear process of implementation and progress. P2 found that "studying the market to design a useful STEM project that adds value to the society is a key stage that guides the E-STEM path, and it is the most difficult one because students faced many barriers while collecting the required data and had to change their decisions many times." Consequently, a majority of responses reflected agreement with P2's explanation that "stages of an E-STEM strategic plan are developmental oriented, so students should be provided with as many E-STEM opportunities as possible to develop the required competencies over time."

Education for E-STEM

In contrast to P3's preference of long-term practice, P4 was inclined to apply and complete the E-STEM model in two terms of instruction as it was designed. "In spite of all [their] efforts to do so, students had to keep working in the third semester on their entrepreneurial opportunities to better conceptualize different meanings independently." This was clarified further by O3 who argued that "teachers were successfully guided by the instructional design of the E-STEM strategic plan, while students were challenged because the problem-based E-STEM project was critical and negatively affected the time required for each design cycle and its business plan." Thus, P4 criticizes the E-STEM model, saying, "it was not easy to recognize a definite increase in students' entrepreneurial knowledge from one stage to another." This was asserted by P1 who was not able to "identify the discrete knowledge constructed in each stage of the E-STEM strategic plan" as it was necessary for "some students to repeat some stages of the strategic plan to be able to make meaning of their learning to proceed." Thus, P4 explicitly rejected the idea of giving more time to experience a new model that is not embedded in the school curriculum. Rather, she appreciated "modifying the STEM course along with reducing the curriculum load to integrate entrepreneurial practices more comfortably in the educational setting, to eliminate students' misconceptions." In this essence, P4 argued that "students were fully aware that the E-STEM model is not graded, so they were not serious enough to submit work on time." Accordingly, they believe that "it would have been more productive if the E-STEM model was embedded in their grading scheme."

Table 4 presents a display matrix of cross-case analysis linking practitioners', observers' and advisors' perceptions to explore how E-STEM instruction is perceived. Time required for E-STEM implementation, recognition of students' development of abilities, and the most valued E-STEM projects are presented, alongside features of Education through E-STEM.

The most valued E-STEM projects of students

The following results show four examples of students' E-STEM projects valued by teachers because they achieved the purpose of E-STEM: to enhance students' ability to act entrepreneurially. These projects indicate that high school students can bridge the gap between their STEM outcomes and the market's needs. Grade 11 students were divided into seven groups (four groups of boys and three groups of girls) where each group had six students. O2 explained that "all students were able to integrate knowledge and practices

Table 4. Matrix of cross-case analysis linking views of practitioners and observers.

Trained teachers	Nature of E-STEM learning model	Academic background	E-STEM practice time	Students' development recognition	Students' valued projects	Education through E-STEM
CC	Development-Oriented nature	English	It needs consistent practice & long time	Acquisition of knowledge & skills can be observed over time	Four valuable E-STEM projects	Practice-based more than knowledge-based
P1	More development-oriented nature	Engineering	One semester is not enough for sustained E-STEM experiences	Cannot identify knowledge gained in each stage	• Vending machine • Smart bus • Virtual Reality Lessons	The process was focused more than the knowledge
P2	Requires lots of critical analysis	Business	At least one academic year is needed for implementation	Gradual improvement was noticed	• Vending machine • Smart bus	Learning is embedded in the E-STEM implementation
P3	Not sure! The process is growing and connected	Math	Long term time and practice are essential	Consistent revision and repetition are needed to develop students' abilities	• Vending machine • Smart bus • Blind currency	It is not easy to test students' acquisition of knowledge after each stage in the plan
P4	Should be embedded in the curriculum	Technology	2 semesters of instruction should be enough	Not easy to recognize a definite increase in knowledge	• Vending machine • Smart bus	Consistent practices of this model will ensure improvement in skills
P5	Developmental nature overtime	Science	Long term endeavor of learning	Students' investigation abilities were clearly developed	• Vending machine • Smart bus • Virtual Reality Lessons	The whole E-STEM method was effective to enhance students' learning
O1	More developmental than definite	Business	Students needed to expand their networking	Family and friends help identify mistakes and put them right	• Vending machine • Smart bus • Blind currency	E-STEM is structured through learning by experience
O2	All activities are dynamic	Math	Require more time to re-plan for further trials	Students experienced failure many times	• Vending machine • Smart bus • Blind currency	It is not possible to concentrate on the acquisition of knowledge
O3	Definitely, it has a moving, and developing nature	Science	Students needed to expand the learning time to complete the project	Students gained better understanding of entrepreneurial habits	• Vending machine • Smart bus • Virtual Reality Lessons	It is more learning-by doing to acquire knowledge than memorizing it

from the five main subjects of E-STEM. However, four E-STEM groups out of seven were able to effectively complete their problem-based tasks in about 6 to 7 months."

E-STEM project 1

The first group of E-STEM students created a school vending machine to offer various basic commodities such as stationery, books and uniforms to the school community. This could save students time and money by allowing them to avoid lines and purchase their necessities from a vending machine. Those students were able to develop a modest prototype of their project to sell educational supplies at the school and they were able to make a profit from the community (Figure 2).

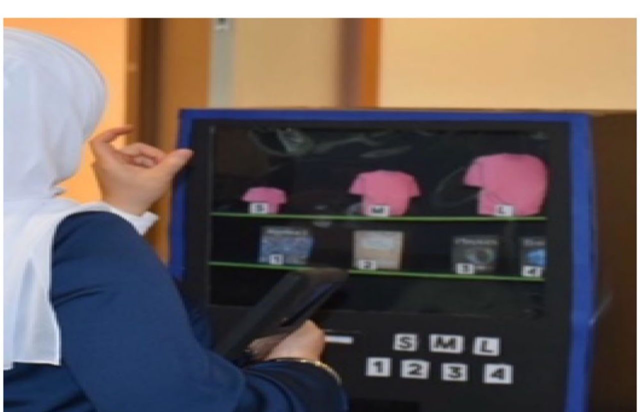

Figure 2. E-STEM project 1-school vending machine.

E-STEM project 2

'Smart bus' is the second valuable project. It seeks to address a significant issue: accidentally leaving children on buses, which can result in several problems due to overheating. Students in the E-STEM program used a chip that has a motion sensor, a SIM card, and a temperature sensor. Each part has a function. The motion sensor detects the movement of the youngster who has been forgotten on the bus, while the SIM card sends a message to the driver and bus attendant. Furthermore, the temperature sensor is set to activate a fan in order to minimize the high temperature inside the bus. The exhibition of Think Science Day in Dubai was a good opportunity for those students to present their project and to discuss their business plan. More impressively, they were able to create a sticker with a sensor that was linked to an application to allow parents to track their children on the school bus or in other public locations. This group made a profit by selling the stickers of their project to parents of young pupils (Figure 3).

E-STEM project 3

'Blind currency' is the name of Project 3. Its purpose is to assist blind people in determining how much money they have or receive in change, to avoid any fraudulent

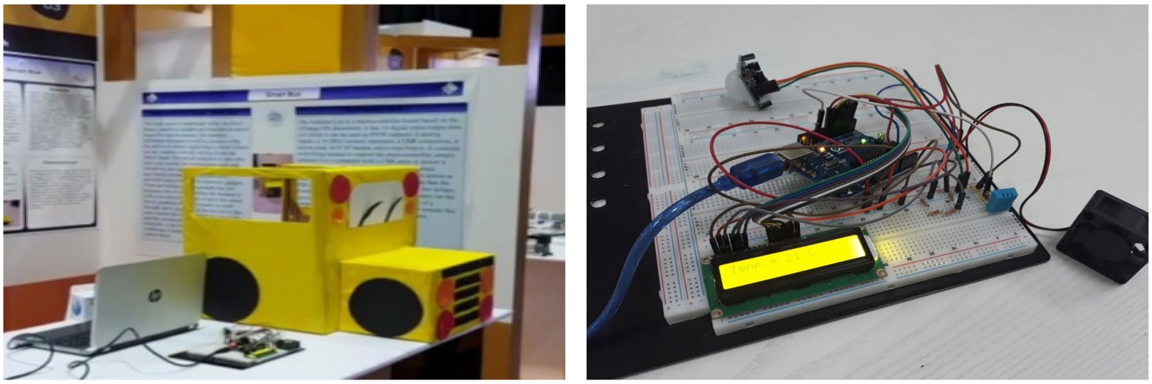

Figure 3. E-STEM project 2-smart bus.

transactions by identifying types of denominations and fold them differently. This group presented the prototype as part of a new schools' competition launched in a program called Taqaddam, which is a collaboration between the HSBC bank and British Council. This initiative assists students in realizing their full potential and developing life skills in order to better serve the community (Figure 4).

E-STEM project 4

'Virtual Reality Lessons' is the title of project 4. Its goal is to employ technology to create a simulated-educational environment in which students can immerse themselves in any school subject. Instead of viewing blackboards or smart screens, VR brings the learning experience to life by allowing students to engage with the three-dimensional (3D) reality. In comparison to similar products on the market, students were able to produce this project with less cost. Furthermore, the prototype and business strategy were introduced in the Taqaddam program, and it was nominated as one of the top educational concepts that should be implemented (Figure 5).

E-STEM projects presented in this study indicate that participating students were able to produce high quality E-STEM projects through planning, organizing, managing, designing, developing, seeing business opportunities, and converting them into workable ideas to add value to their communities. These skills are equivalent with the lifelong entrepreneur's characteristics identified by Kuratko and Morris (2018). A key insight from the current findings is that high school students were responsive to the strategic plan of the E-STEM model. The interactive constructivist techniques of E-STEM learning provided students with opportunities and challenges to learn as a team and successfully apply the content information studied in different STEM disciplines to solve real problems when designing and creating the prototypes of their STEM projects in an experiential learning environment (Kolb & Fry, 1975) that promotes their entrepreneurial behavior (Ajzen 1991).

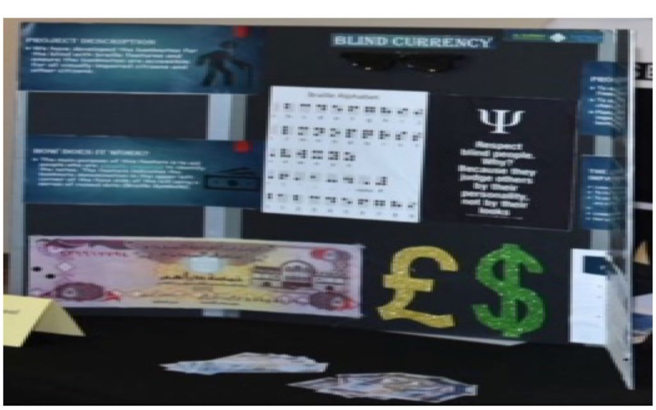

Figure 4. E-STEM project 3- blind currency.

Drawing on the learning progressions, E-STEM projects produced by the participating high school students indicate that the daily tailoring of the strategic plan of the E-STEM model supported students' evolving envision of integrating E-STEM disciplines. Over more than two academic semesters of E-STEM implementation, students were able to experience steady accumulation of knowledge and long-term development of entrepreneurial skills, which allowed some of them to produce such wonderful E-STEM projects. Four groups of students out of seven were able to achieve the desired results of E-STEM, while the other three groups acquired different knowledge and skills through the implementation of the E-STEM strategic plan and needed more time in the third term to deepen their understanding of E-STEM integrated practices. As per teachers' insights and experiences regarding unsuccessful projects, one group changed the idea of the design many times because of unforeseen challenges they experienced. The second group was not able to complete their E-STEM design within the time frame although they studied the market and collected data to support their project. The third group struggled to work as a team as per E-STEM strategic plan, and they had to swap their roles many times to proceed.

This is roughly consistent with Shemwell at al. (2015), who proposed that implementing the same learning experiences over extended periods is highly recommended to apply and achieve a DOC because it is not anticipated to manifest reliable improvements to the intellectual capacity of all students over short periods of time. This reflects that entrepreneurial knowledge is embedded in the development-oriented activities of E-STEM that create a new situated cognition platform for developmental learning (Lave, 1988).

Figure 5. E-STEM project 4- virtual reality lesson.

Some teachers such as P3 and P5 criticized E-STEM practices in relation to traditional assessment of knowledge acquisition; their views were defined in similar ways to the argument of Banilower et al. (2013), that teachers prefer to implement strategies that accumulate knowledge and quickly make students' progress visible in each lesson. Hence, they were not able to clearly observe and measure the extent to which entrepreneurial knowledge was developed in each stage in the strategic plan.

Integration of E-STEM disciplines

The integration of E-STEM disciplines required a great deal of coordination and collaboration among the practitioners. An E-STEM project looks like a puzzle where each teacher should do their job successfully to guide students to complete a part of the E-STEM puzzle in their class. CC explained that "the five teachers had to discuss and reflect daily on the process because each of them takes the lead in his/her session to continue working on the E-STEM projects." Teachers confirmed that the E-STEM model was integrated effectively through an experiential learning approach in their daily teaching activities that supports project-based E-STEM learning and practices. Teachers agreed that the E-STEM strategic plan effectively guided teachers to apply ill-structured E-STEM tasks in their classrooms where there is no specific path to address its problems. This result can help teachers to overcome the challenge reported by the MBRSG regarding the difficulty in applying integrated teaching programs in the UAE (Shaer et. al., 2019). Meanwhile, the six stages require many trials to achieve its educational purpose. For example, O2 mentioned that "ability determination, SWOT analysis and prototyping are critical activities where students struggled at the beginning and needed more time than planned." This is consistent with P1's and P2's views, that "students were not able to determine their competencies at first" but after two terms "they become more confident about what they developed and what they need to work on, so the progress rate was unpredictable, but the learning process was more visible to them." Accordingly, students were guided to discuss their E-STEM projects and how they meet and satisfy the requirements and challenges of the market, as presented in Table 5.

Although high school students are not directly linked to the labor market, their E-STEM outcomes presented in Table 5 show how they were able to reduce the gap between STEM designs and the market, as suggested by Anwari et al. (2015), where the paradigm of the teaching approach was shifted from memorizing the content to emphasizing the pedagogy. For P2, the E-STEM learning objective was that "designing innovative projects through integrating E-STEM contents can solve complex real-world problems. The designs should be introduced to the community to provide real value to both target customers and designers" (Larsen, 2022). In this regard, P3 highlighted that when students build a design, they intend to extend their learning activities to reach a larger audience, and they should not accept their efforts being overlooked or unused in the classroom (Hershman, 2016). Thus, the value of incorporating entrepreneurial practices into STEM education was recognized.

Observers added that learners were able to recognize the benefits and the value of their E-STEM designs to the society. Accordingly, students' E-STEM outcomes as shown in Table 5 indicate that scientific and technological knowledge were used well by the students through EDP to make sense of the scientific concepts and the materials necessary to the problems they faced and to create prototypes to present their designs (Siew, 2022). In addition, students successfully applied mathematical knowledge and processes including measurements, distances or statistics to solve the problems in their projects, while they competently integrated technology to select and understand the features of the materials used in their tasks and projects. After the students completed their projects, they tested the functionality of their STEM designs. Then they refined and improved their designs accordingly. A key impact of the E-STEM course on students was that they were able to act as entrepreneurs, calculating the costs, preparing their business plans and confidently and professionally presenting their engineering designs to the market. The CC explained that E-STEM activities were interesting to parents, who became involved in the process and supported their children to focus on the

Table 5. Outcomes of interdisciplinary E-STEM model.

	Experiential learning through E-STEM project-based problem solving					
	Integrated E-STEM disciplines					Entrepreneurial endeavor
Projects STEM	Science	Mathematics	Technology	Engineering	Entrepreneurship	Connection to the market
Vending Machine	Materials used: wood, foam, cartoon, plastic	Measurements and data calculation	Search to select and understand the usability of materials	Designing the vending machine and test its functionality	Identifying the value, calculating the cost & making a business plan	Project used in the school. Used uniform, stationary & books were sold. Profit was achieved
Smart Bus	Simple electric circuit, transformation of energy, elements used, and diagrams needed, chips and sensors of temperature and motion	Determining the measurements and the distances needed for the project feasibility	Usability and making an application to follow the chips found in the school bus	Designing the project by connecting the chip to the mentioned sensors	Value identified Cost calculated Business plan designed Target customers selected	Project was displayed in the Think Science Day. Presented to parents and teachers. The application was sold to customers from parents. Achieved Profit
Blind Currency	Understanding the concept of eye, colors and visually impaired person	Measurements Calculation and value of different currencies. Low vision population statistic in UAE	Usability, research, presentation and data collection	Designing the project	Value identified, Cost calculated, Business plan designed, and project presented to audience	Prototype was presented in Taqqadam program. Market feedback was considered. Possible modifications were studied.
Virtual reality	Eye lens, materials	Measurements, calculations of distances	Usability and making 3Dimention lessons. Making application for simulation environment.	Designing the project in the shape of 3D glass	Value identified, Cost calculated, Business plan designed, and project presented	Prototype was presented in Taqqadam program. Market feedback was considered. Possible modifications were studied

entrepreneurial objectives. More importantly, they utilized their relationships in the market to facilitate the E-STEM projects, which enhanced students' motivation to proceed (Jungert at al., 2020). Additionally, students participated in diverse events in different contexts and settings, including activities organized inside or outside the school, like Think Science Day and the Taqqadam program, where they got the chance to present the structure, function and value of their projects to the audience, and then to receive feedback to improve their designs.

These findings reflect that the use of an E-STEM model as an interdisciplinary model helps students through authentic learning experiences and challenges by incorporating practices from the five main E-STEM disciplines, including scientific inquiry, mathematical thinking, technological tools, engineering design, and entrepreneurial acts in each project they created (Eltanahy et al., 2020a; 2020b). Hence, for this implementation, teachers relied on the abundance of learning materials now available for their students whether provided by the school or from personal supply because there is no dishonor in learning and teaching through resources and materials accessible to any member in the group to support the whole team. Existing STEM course curricula could usefully address strong disciplinary frameworks to adopt an entrepreneurship context, noting that both disciplinary literacies and thinking are critical to the development of practical competencies such as creative problem solving in STEM-related fields.

The vital role of E-STEM learning is to open a communication link between high school students in peer groups and the market so they can learn over time by experimenting. Students should have enough E-STEM opportunities to explore and share best practices because the current results revealed that some of them are being quite innovative and resourceful, with the support of the school, their families, and friends.

Implications

While it is essential to orient high school students to STEM practices, it is also crucial to maintain their interest in EE by providing them with varied E-STEM opportunities that enhance their skills. Curriculum developers should take into consideration such successful initiatives to accommodate E-STEM learning in their programs. Sustained engagement of STEM students in EE will ensure a deep immersion in essential experiences to promote their abilities. Moreover, teachers should be given the discretion to choose the relevant standardized content from the five main disciplines while keeping the learning objectives in mind. Thus, the current results should help researchers decide what makes an effective E-STEM course and how to integrate it into the curriculum. Although the school under investigation is partway through their E-STEM implementation, the students achieved interesting results. Incorporating entrepreneurial practices has a developmental orientation within STEM education. Therefore, the development of an E-STEM course should be consistent, to have better indications of how assessment schemes of E-STEM projects will be conducted in the future practice. Additionally, teachers should be well-trained to apply 'Education through E-STEM' as an appropriate teaching approach to focus on learning pedagogies rather than learning content. Professional development programs are essential to enhance the transformation of teachers' thinking to help shift the paradigm of their practices to become more developmental. STEM course curricula should be made more rigorous to accommodate EL, and to provide the required change. An explicit and effective impact of the implementation of the E-STEM model was on restructuring, planning, and developing the current STEM-based curricula. In this sense, the findings of this study can guide and inform the decisions and practices of policymakers, curriculum developers and teacher training. This accordingly will facilitate and ease using project-based problem solving, which promotes experiential learning to introduce meaningful learning experiences to high school students, and enriches their self-efficacy and skills to gain market and life skills.

Limitation & recommendation

The current study has a limitation in different aspects; first, all participants are females except one male. Second, a very limited number of teachers (eight) implemented the E-STEM model. To rectify these limitations, further studies are needed to expand the depth and breadth of data collected from more teachers and high school students in different grades regarding the E-STEM model pedagogies. Additional investigations are required to explore and explain the most appropriate assessment strategies, as well as for the development and innovation of E-STEM models and pedagogies, to support E-STEM implementation in high school.

Conclusion

E-STEM learning requires consistent integration of effective practices that are aligned with constructivist pedagogical strategies, such as PjBPS, over a year as an effective period of E-STEM implementation. Teachers adopted the developmental view of teaching an E-STEM model. They perceived the E-STEM project as a puzzle where each of them had their part to help students complete the picture and produce a valuable model. Education through E-STEM is considered as the most appropriate teaching approach to prepare high school students for the labor market. The well-designed E-STEM model guides teachers to successfully facilitate E-STEM classes; however, an ill-structured problem that has no single or direct path to solve its dilemma is necessary because it inspires students to produce useful E-STEM projects to benefit others.

Considering E-STEM practitioners' contextualized views, the current results perceive E-STEM as a development-oriented course and instruction that prioritizes the long-term growth of students' entrepreneurial competencies. Furthermore, it anticipates a gradual deepening of entrepreneurial abilities through constant E-STEM learning experiences over an extended period of learning time. Special attention should be given to skills-based learning that targets students' entrepreneurial capabilities, like the E-STEM model, because high school graduates with such desirable skills will have a vital role in economic recovery. The implementation of the E-STEM model was interesting to parents who played a vital role in enhancing students' motivation to continue working on their projects until the end of the academic year. Finally, the current study provides recommendations supported by data to emphasize the importance of hands-on entrepreneurial activities in high schools to promote high-quality STEM education and enhance students' market skills. This will have substantial and valid impacts to lessen the gap between theory and practice in science and math education in general and to eliminate the gap between the outcomes of STEM education and the needs of the economic-based society.

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