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Developing a rubric for assessing students' competencies in entrepreneurial-STEM learning context

Marwa Eltanahy [a] and Nasser Mansour [b]

[a]Faculty of Education, Higher Colleges of Technology, Dubai, UAE; [b]Faculty Of Education, Qatar University, Doha, Qatar

ABSTRACT

The increasing emphasis on a competency-based learning approach in entrepreneurial-STEM (E-STEM) necessitates competency-based assessment tools to track students' entrepreneurial development and enhance the quality of E-STEM projects. This study aims to create a valid analytical rubric for assessing students' E-STEM competencies. Using a mixed-methods approach involving semi-structured interviews and a questionnaire, 152 undergraduate students participated. The process of developing the rubric involved two main stages. Phase 1 focused on rubric development, where dimensions and criteria were established. In Phase 2, the rubric was implemented for user validation, including assessment experts, faculty, and students. The research provides a valuable tool for E-STEM teachers to align assessment practices with learning outcomes. Results indicate the effectiveness of the developed E-STEM rubric in offering constructive feedback on learners' competencies and performance. Additionally, the rubric establishes a more visible learning context, enabling students to self-regulate and explicitly assess their entrepreneurial competencies and projects.

KEYWORDS

Entrepreneurial-STEM learning; formative assessment; analytical rubric; competency-based assessment; constructive feedback, E-STEM competencies

Introduction

Education, on a global scale, has a primary aim of preparing students for successful integration into the workforce, including science, technology, engineering, and mathematics (STEM) education. STEM extends beyond knowledge transmission, seeking to empower students with entrepreneurial competencies (EC) for workplace success and positive societal impact through integrating entrepreneurship education (EE) and STEM practices that creates a new situated entrepreneurial-STEM (E-STEM) learning platform (Eltanahy et al., 2020a).

Hence, E-STEM specifically focuses on EC development (Eltanahy & Mansour, 2022; Eltanahy et al., 2021; Eltanahy, 2023), influenced by the Entrepreneurial Competence Framework (EntreComp) that, while not exclusively designed for STEM, offers a foundational assessment tool for entrepreneurship integration. The EntreComp was developed by (Bacigalupo et al., 2016) who encompasses 15 competencies that

CONTACT Marwa Eltanahy meltanahy@hct.ac.ae Faculty of Education, Higher Colleges of Technology, Al Nahda 2, Dubai, UAE

collectively empower individuals to translate their ideas into actionable initiatives (European Commission, 2016).

From a pedagogical point of view, there is a convergence of STEM and entrepreneurial learning (EL) opportunities that not only enhances the generation of innovative solutions to real-world problems but also highlights the mutually reinforcing nature of STEM and EE approaches (Davis, 2019). This symbiotic relationship enables students to concurrently develop EC and cultivate an entrepreneurial mindset. Eltanahy et al. (2020b, 2020a) explained that this combined approach emphasises innovation and value creation that provide students with a holistic platform for EC development. Moreover, Lau et al. (2012) conducted a comprehensive examination of 23 studies focused on EC exhibited by entrepreneurs. They identified key characteristics, including innovativeness, integration, proactiveness, and results orientation, which align closely with the foundational principles of STEM learning. Consequently, STEM education serves as a pathway for students to systematically acquire essential EC vital for nurturing an entrepreneurial mindset (Hynes et al., 2023). This logical inference allows students to navigate uncertainties, adapt to technological advancements, and manage risks effectively in an E-STEM context. As a result, E-STEM alignment underscores the intrinsic connection between STEM education and the development of competencies crucial for success in entrepreneurial pursuits (Eltanahy, 2023).

Competencies, as defined by Gibb (1990), involve interconnected knowledge, traits, attitudes, and skills crucial for job performance, with successful entrepreneurship requiring perseverance, determination, risk management, adaptability, initiative, creativity, and high motivation. However, assessing EC is complex due to their subjectivity and context-dependency (Fayolle et al., 2006), challenging traditional methods that may struggle with the dynamic nature of entrepreneurship (Ucbasaran et al., 2009).

In response, innovative rubrics have emerged as competency assessment tools in both EE and STEM education for assessing competencies like critical thinking, problem-solving, and communication skills (Reynders et al., 2020; Taylor, 2007). They should also be participatory, students-centred, and aligned with specific success criteria (Henri et al., 2017). While rubrics serve both formative and summative purposes in education, they are recognised for enhancing self-regulated learning, metacognition, and feedback processes (Ahankari & Jadhav, 2016; Rochford & Borchert, 2011).

Continuous evaluation and a focus on interdisciplinary collaboration are essential components of effective competency development in E-STEM learning. In an integrated disciplines context, the use of rubrics as structured assessment tools has gained attention to provide a comprehensive evaluation for capturing a spectrum of competencies (Kleine & Yoder, 2011). This goes beyond assessing solely technical proficiency, extending to the evaluation of entrepreneurial mindset, communication skills, teamwork, and other essential soft skills crucial for success in E-STEM practices. The infusion of an entrepreneurial mindset into integrated STEM experiences creates divergent learning opportunities within an authentic E-STEM setting. To ensure the efficacy of this approach, educators should employ effective mechanisms to monitor students' progress and offer guidance in an environment that promotes independent learning. A systematic review by Park et al. (2020) underscored the challenges inherent in rubric-based assessments within the STEM context due to the subjectivity of rating. However, it highlighted their significant role as a primary tool in directly assessing EC,

including value creation, collaboration, critical thinking, and problem-solving, necessitating sophisticated human judgement. Recent insights from Kaya-Capocci and Peter-Burton (2022) confirm the relevance of rubrics, particularly in the realm of digital formative assessments, as valuable tools for instructors to monitor the intricate learning processes associated with E-STEM knowledge and skills. The digital format, coupled with the application of rubrics, emerges as a strategic approach to navigating the complexity of assessing competencies in E-STEM learning.

Acknowledging the effectiveness of rubrics in EE and STEM implies their suitability for evaluating EC in an integrated E-STEM setting. This integration aims for a comprehensive skill set, necessitating a customised tool to assess the distinct EC arising from combining EE and STEM. Despite this logical need, there is currently a lack of rubrics tailored for evaluating EC in E-STEM, as pointed out by Eltanahy and Mansour (2022). Addressing this gap, the proposed study aims to create a dedicated rubric, guided by Brookhart (2013), not only to advance EE within STEM but also to align with European Commission (2016) objectives in fostering EC across diverse disciplines. Literature explained that validated rubric serves as a credible assessment tool, facilitating targeted interventions and contributing to the ongoing dialogue on tailored assessments in STEM education. Moreover, it promotes transparency, standardised evaluation, and fairness, providing educators with a valuable resource for constructive feedback and guiding students in their entrepreneurial growth (Isusi-Fagoaga & García-Aracil, 2020; Panadero & Jonsson, 2013; Park et al., 2020).

Purpose of the study

The purpose of the study is to create an analytical rubric to assess students' EC in E-STEM context.

(1) What are the dimensions of the analytical rubric needed to assess the students' entrepreneurial competencies?
(2) What are the users' views of the developed rubric as a tool to assess and support students' competencies in an E-STEM context?

E-STEM context

The validation process was conducted in a higher education E-STEM context at a group of public colleges in the United Arab Emirates (UAE), where students can independently enrol in E-STEM learning programmes offered for all students. E-STEM learning is consistent with UAE National Agenda that 'strives to instil an entrepreneurial culture in schools and universities to foster entrepreneurship, creativity, responsibility and ambition in the new generation' (National Agenda, 2021). In the E-STEM programme, students from different majors (Education, Computer Science, Engineering, and Business) are divided into groups of four to create E-STEM projects that add value to the community. The project should demonstrate a clear understanding of its benefits, articulate innovative ideas, include organised visuals, and have a comprehensive design of the proposed product or service.

Eltanahy and Mansour (2022) outlined that fostering EC in E-STEM learning requires consistent application of competency-based strategies through development-oriented instruction to promote students' entrepreneurial act. Based on this perspective, the E-STEM program incorporates pedagogies such as project-based problem solving (PjBPS), scaffolding, and flipped classrooms. This environment provides opportunities to students to collaboratively interact to plan, collect and analyse data, make decisions and finally create prototypes to be presented in a big exhibition as one of the important events in the colleges that develop students' entrepreneurial thinking (Hynes et al., 2023).

Methodology

The process of developing a validated rubric in E-STEM involved two main stages, as illustrated in Figure 1. Phase 1 focused on rubric development, where dimensions, clusters, and criteria were established. In Phase 2, the rubric was implemented for user validation, including students, assessment experts, and faculty members. This stage included testing and validating the rubric through a mixed-methods approach, incorporating questionnaires and interviews. Understanding users' assessment of rubric-based evaluation and their views on rubrics is crucial for improving assessment processes (Panadero & Jonsson, 2013).

Student feedback provides valuable insights into rubric effectiveness, fairness, and transparency (Andrade & Du, 2007; Isusi-Fagoaga & García-Aracil, 2020). Involving students in rubric design leads to more student-centred assessments (Shepard, 2000), as their perspectives inform the clarity and comprehensiveness of assessment criteria (Brookhart, 2013). Furthermore, student feedback enhances assessment validity and reliability. By considering student views, assessments in education become more meaningful and effective (Stiggins, 2001).

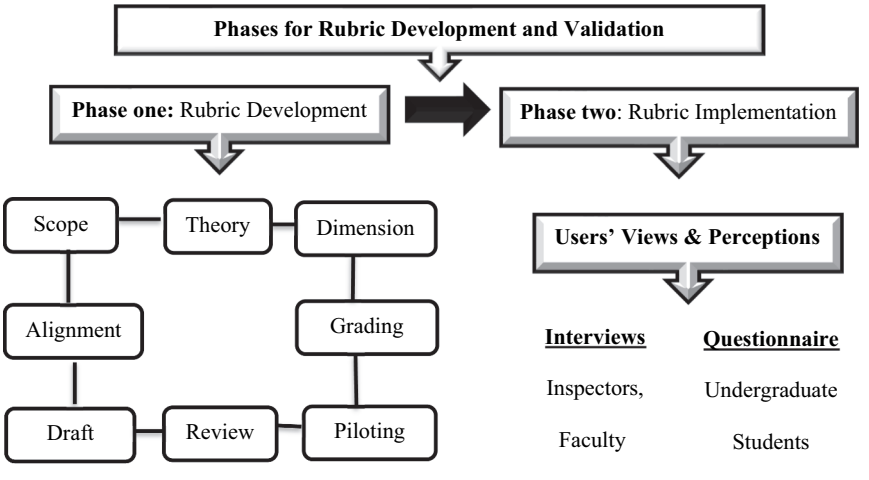

Figure 1. The procedures for developing and validating the E-STEM rubric.

Phase one: E-STEM rubric development

As shown in Figure 1, the development of the rubric was an iterative process that drew upon multiple sources, as outlined by (Rochford & Borchert, 2011). The sequence of this development involved several key steps as follow:

(1) ***Rubric scope:*** Defining the scope of the rubric as an assessment tool that intends to assess E-STEM outcomes including EC that are more likely to be developed in E-STEM context (Eltanahy, 2023).
(2) ***Theoretical underpinning:*** Consideration was given to three key theories that are Constructive alignment theory, as highlighted by Biggs (2014) and Zhou and Brown (2021), underscores the importance of aligning learning outcomes, instruction, and assessment to enhance independent learning. The Visible Learning theory, advocated by Hattie & Zierer (2019), focuses on rendering the learning path visible to students, promoting independence and self-regulation. Complementarily, self-regulated learning theory, outlined by Zimmerman (2002), emphasises self-reflection through planning, performing, and reflecting stages. Together, these theories collectively aim to foster students' independence in the learning process.
(3) ***Description of the E-STEM rubric:*** The development of the E-STEM rubric was grounded in the EntreComp Framework (European Commission, 2016) and established literature on EC and EE, emphasising the interconnected nature of competencies, encompassing knowledge, attitudes, and skills (Fayolle et al., 2006; Gibb, 1990). Additionally, insights from literature on competences essential for STEM projects and learning contexts informed the identification of four pertinent dimensions for the rubric (Eltanahy, 2023). Drawing on their prior research on EC in STEM and the developed E-STEM model (Eltanahy et al., 2020a), the authors specified four key dimensions for the rubric: E-STEM project, knowledge, skills, and attitude (Eltanahy et al., 2020b, 2021; Eltanahy & Mansour, 2022). Each dimension includes specific criteria and related indicators, providing a comprehensive assessment framework for E-STEM projects (see Table 1).
(4) ***Rubric grading***: Student performance assessment incorporates letter grades, representing achievement levels from F (fail) to A, signifying varying degrees of success in the evaluated criteria. Each letter grade is associated with percentage ranges, offering a quantitative measure; for instance, an A may correspond to 90-100%, while a D could encompass 60-69%. Within each letter grade, a five-trait scale is employed to further evaluate performance. This scale examines specific traits or indicators, with higher values within a given letter grade indicating a higher level of competency in the assessed dimension.
(5) ***Alignment:*** items of the rubric constructively aligned with the intended learning outcomes of E-STEM programme, and the instruction implemented in the classrooms that focus mainly on the process of designing the E-STEM projects.
(6) ***Draft creation:*** The initial version of the rubric was drafted and steadily reviewed by the authors before being shared with the participating experts in the E-STEM field for enhancing clarity and appropriateness of its language and for checking the validity of the rubric (Reddy & Andrade, 2010).

Table 1. Dimensions of E-STEM rubric.

		Achievement that does not meet the E-STEM requirements	Achievement that minimally meets the E-STEM requirements	Achievement that moderately meets the E-STEM requirements	Achievement that is mostly meets E-STEM requirements	Achievement that is significantly exceeds the E-STEM requirements
		(F) 59	(D) 60–69	(C) 70–79	(B) 80–89	(A) 90–100
		1	2	3	4	5
Dimension	Criteria	E-STEM ACHIEVEMENT INDICATORS				
E-STEM Project	Purpose	Limited or unclear understanding of the project's purpose	Partial understanding of the purpose with significant gaps.	Adequate understanding of the purpose, with some areas for improvement.	Clear understanding of the purpose, with minor areas for improvement.	Comprehensive and insightful understanding of the purpose.
E-STEM Knowledge	Content Mastery	lack of foundational knowledge in E-STEM concepts.	Shows minimal grasp of essential E-STEM knowledge, with numerous gaps.	Displays satisfactory understanding of core E-STEM concepts, but with room for improvement.	Exhibits a solid understanding of E-STEM principles, with minor areas for enhancement.	Demonstrates an exceptional and nuanced understanding of E-STEM concepts.
E-STEM Skills	Cognitive (C) & Non-Cognitive (NC)	Poor demonstration of both C and NC skills relevant to E-STEM.	Limited application of C and NC skills, with notable gaps.	Adequate application of both C and NC skills, but with room for improvement.	Proficient application of C and NC skills, with minor areas for enhancement.	Exceptional and well-refined application of both C and NC skills.
E-STEM Attitude	Entrepreneurial Mindset	Displays a negative or disinterested attitude towards E-STEM learning.	Shows a somewhat indifferent attitude, with sporadic positive engagement.	Exhibits a positive attitude overall, with occasional lapses.	Consistently maintains a positive attitude towards E-STEM, with minor areas for improvement.	Demonstrates an unwavering and highly positive attitude towards E-STEM learning.

(7) ***Iterative rubric reviews:*** The rubric underwent three rounds of review to ensure its effectiveness for the intended assessment purpose. In the first round, the authors conducted an initial review, incorporating feedback from four participating faculty members received via email. The focus was on enhancing the clarity of descriptors. The third round involved a review by two Ministry of Education (MOE) experts with a background in science education, who provided additional feedback via email. These review rounds aimed to improve content validity and eliminate the risk of measuring incorrect or undesired components (Moskal, 2000).

(8) ***Piloting and reliability:*** The rubric was tested in two E-STEM projects: 'Smart Vest for Bike Riders' and 'Autism Control Device'. The first project aimed to enhance the safety of delivery bike riders by regulating body temperature and included features like health monitoring sensors and proximity warning sensors. The second project focused on ensuring the safety of individuals with autism through a device tracking vital signs and aiding medical adherence. Three raters assessed each project, yielding high agreement across rubric components. The interrater reliability, measured using Filess' Kappa coefficient, was reported as 0.620 for project 1 and 0.606 for project 2, indicating substantial agreement among raters. The rubric effectively guided consistent project evaluation (Landis & Koch, 1977). Modifications were made based on feedback, including the addition of action verbs like 'demonstrate', 'identify', and 'connect' to clarify performance level descriptors.

Phase two: E-STEM rubric validation

In a 12-week period of daily group work and continuous assessment, instructors employed the developed rubric to provide constructive feedback to enhance students' entrepreneurial potential. The rubric assessed 15 E-STEM projects progressing through three stages. Stage 1, lasting 3 weeks, focused on choices and preparation, where students outlined project ideas and laid the groundwork. Stage 2, a 7-week development phase, involved active implementation, research, and project refinement. Stage 3, a 2-week period, included the submission of completed projects. Examples of these E-STEM projects encompassed diving sensors, composting bins, levelled reading platforms, pet trackers, and solar windmill energy generators.

Throughout these stages, the E-STEM rubric played a crucial role in the assessment process. Instructors used it to evaluate students' work, identify strengths, and pinpoint areas for improvement, providing tailored feedback to foster their entrepreneurial growth. During the final exhibition, where students presented their completed projects, three raters from different majors used the rubric for a summative assessment. This comprehensive evaluation allowed for a holistic review of each student's EC and the overall effectiveness of their E-STEM projects.

Participants were recruited through a non-probability sampling method. Due to the difficulty in accessing the population of MOE, two assessment experts were recruited through snowball sampling to review and validate the rubric's elements. Additionally, four members from faculties of education and business were conveniently recruited to review and implement the developed rubric. Purposeful sampling technique was employed to recruit 52 undergraduate students who were conveniently enrolled in the E-STEM programme and would use the rubric (Creswell, 2014).

Rubric validation tools

The research utilised three semi-structured interviews in focus group settings to gather qualitative data for validating the E-STEM rubric. The interview protocol underwent review and discussion with an education professor to enhance content validity. A student questionnaire, aligned with the theoretical framework, was developed to collect quantitative data from E-STEM students who implemented the rubric. Ethical considerations were prioritised to guarantee participant confidentiality and freedom (Creswell, 2014).

Interviews. During the qualitative data collection phase, interviews were conducted with participants at different stages of the E-STEM programme. The first interview involved inspectors who contributed to rubric development, lasting 40 minutes. At the end of the programme, two consecutive interviews were conducted with faculty members who implemented the rubric, and a focus group interview was conducted with four students who used the rubric. Each focus group interview lasted 45–50 minutes. Demographic information of the participants is provided, including their gender, major, and the number of participants in each interview. The participants included MOE experts, practitioners from the Faculty of Education and Faculty of Business, and students from various academic disciplines.

Questionnaire. Data were collected from 52 E-STEM students using a paper-based questionnaire administered in a single session, utilising a 5-point Likert scale. ***It*** consists of 12 items organised into three sub-scales that was strategically designed to assess specific aspects of the E-STEM rubric's impact as follow:

(1) *Rubric effectiveness and alignment with E-STEM (4 items)*: This sub-scale gauges the extent to which the rubric aligns with the goals and principles of E-STEM, guided by the constructive alignment theory. It focuses on ensuring the harmonisation of learning outcomes, instruction, and assessment practices to facilitate knowledge construction.
(2) *Rubric impact on assessment and learning progress (4 items)*: Rooted in visible learning theory, this sub-scale explores how the rubric influences students' assessment capabilities and learning progress. It aims to measure the effectiveness of the rubric in enhancing students' understanding and advancement in E-STEM.
(3) *Rubric impact on self-regulated learning (4 items)*: Informed by self-regulated learning theory, this sub-scale delves into the rubric's role in fostering feedback reception, reflective practices, goal setting, and learning procedures. It emphasises the importance of these aspects in shaping students' competencies and overall learning experience in E-STEM.

To ensure content validity, three professors in education and assessments reviewed the rubric elements, and feedback regarding vocabulary simplification was considered. The questionnaire's reliability was tested through piloting with 20 students experienced in E-STEM programmes, yielding a high reliability coefficient (Cronbach's Alpha = 0.87) using SPSS 28.

Findings

Qualitative results: users' views about the E-STEM rubric

The results obtained from the interviews strongly support the effectiveness of the rubric as an authentic, reflective, and supportive tool for evaluating, learning, and nurturing EC in E-STEM. A cross-case analysis (Table 2) was employed to scrutinise qualitative data, unveiling patterns and discerning similarities or differences in how participants perceived the suggested E-STEM rubric.

Table 2 reinforces the favourable perception of the rubric among the interview participants. The table reveals unanimous agreement among participants regarding the rubric's benefits. Both E1 and E2 emphasised the alignment between the rubric's criteria and the primary objectives of E-STEM learning, where the development of competencies, including E-STEM knowledge, skills, and attitude, aligns with the creation of meaningful interdisciplinary projects. Furthermore, FE1 and FE2 observed that the rubric is focused, providing clear descriptors that enable multiple raters to offer well-structured guidance to students. FB1 highlighted that the clusters are distinct, facilitating the assessment process for both

Table 2. Matrix of cross-case analysis linking views of participating experts, faculty & students.

Participants	Formative Tool	Summative Tool	Advantages	Disadvantages
E1	It can guide teachers to provide constructive feedback. It has clear criteria to define good performance	It is authentic, examines real-world competencies, gives an opportunity for multiple raters to evaluate and compare results	Rubrics' elements are aligned with the E-STEM objectives, and promotes metacognition	Needs time to apply because it is comprehensive
E2	Allows teachers to identify students' gaps and creates a visible learning path.	Maps the grading scales of different systems which allows different institutions to use it	It is divided into focused clusters that includes clear descriptors with no redundancy.	Inexperienced raters will need training to use it
FE1	It is a process-oriented tool, seeks to improve learners' E-STEM achievements.	Facilitates final evaluation of work as a product-oriented tool	Guides teachers to align assessment with the instruction	Very detailed
FE2	Focuses on the desired management skills, cognitive and affective skills.	Facilitates different grading systems using percentage, letter grade or a scale	As a formative tool, it is designed with great effect in conjunction with summative evaluation.	Requires time to evaluate each student
FB1	Guides us to shape teaching and learning purposefully and improve its quality	Evaluates proficiency and success of E-STEM outcomes	Rubrics have no overlapping between E-STEM competencies	Takes time to be familiar with
FB2	Focuses on the entrepreneurial learning goals and actionable feedback	Allows students to deeply explore E-STEM concepts and make broad connection of the content	Helps students to take ownership of their learning. Encourages peer dialogue for further learning	More business competencies are needed
S1	Reflection	Judge our performance	Assessment capable learner	Many details to learn
S2	Next step strengths	Expect our grade	Independent student	Long
S3	Performance, progress	Multiple raters	Visible like a GPS	Takes time
S4	Improve work submission	Stay focused not to miss any criterion	Tracking progress and eliminate misconceptions	Many items

E* Assessment Expert from MOE FE* Faculty member from Education FB* Faculty member from Business S* Student.

teachers and students, while FB2 added that the rubric enhances students' independent learning abilities and offers a clear roadmap for monitoring their learning progress.

The qualitative analysis demonstrated that all participants effectively applied various features, encompassing both formative and summative assessment types, using the E-STEM rubric. E1 and E2 characterised the rubric as an 'authentic assessment tool applied in real-life learning practices to provide feedback for improvement and grades for evaluation to students'. FE1 and FB2 noted that 'the 5-Likert scale system was suitable for multiple raters, enabling the calculation of composite scores from each assessor. More importantly, it facilitates an open discussion with students to understand the strengths and deficiencies of their projects for further development' (Taylor, 2007). FE1 perceived the rubric as 'a process-oriented tool guiding students step-by-step through a comprehensive and practical learning process to develop their competencies'. FB1 recommended "using the same rubric multiple times across academic years to assess students' progress in developing entrepreneurial competencies over time". Both students and teachers found the rubric helpful in making learning visible, identifying their abilities, and setting personal goals through ongoing reflection. However, students acknowledged the need for consistent practice to enhance their independent assessment skills.

All faculty members agreed on FE2's explanation that 'the rubric provides a good indication to improve the quality of the teaching instruction provided'. Consequently, the rubric was useful to 'validate whether or not students' STEM ideas can become a business'. Interestingly, Students' perceptions were consistent with teachers as they agreed that 'they were into more cooperation mode than competition' which is consistent with the characteristics of CAT tools mentioned by (Henri et al., 2017). S3 and S4 believed that 'the rubric was like a global positioning system GPS to track their learning progress'. Similarly, S1 and S2 clarified how the rubric promoted their abilities to 'become assessment-capable learners' who 'independently self-assess their performance and identify their next steps to improve [their] projects'. In this regard, S3 added that she was guided by 'the rubric as scoring tool that describe expected levels of performance'. However, most of the participants referred to the length of the rubric and time consumed to assess the projects as a disadvantage.

Quantitative results: users' perceptions about the E-STEM rubric

Conversely, the questionnaire responses were descriptively analysed, computing mean values and percentages to explore students' perspectives on the rubric's validity, as presented in Figures 2–4. This section provides a concise summary and discussion of the main findings, offering evidence regarding the validity of the E-STEM rubric.

Rubric effectiveness and alignment with E-STEM

Figure 2 shows that the developed rubric is perceived to be effective in guiding students towards the development of their EC (95%). Students also perceive a high level of alignment between E-STEM learning objectives and main clusters of the rubric (94%). Additionally, they perceive a relatively high level of alignment between the rubric items and E-STEM learning activities applied in the classroom (89%). Finally, the rubric is perceived to be useful in guiding students towards independent work on their projects (83%).

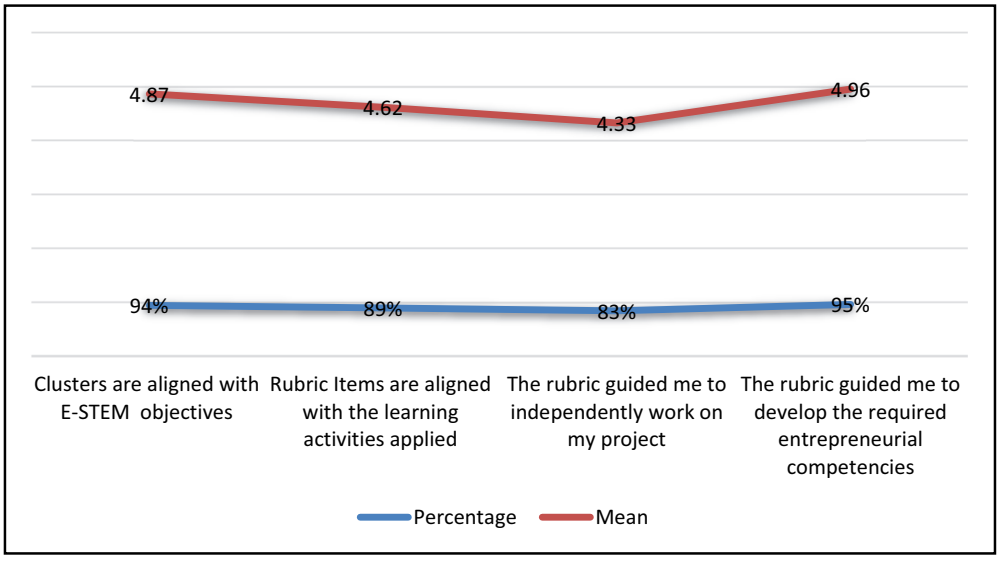

Figure 2. Rubric effectiveness and alignment with E-STEM.

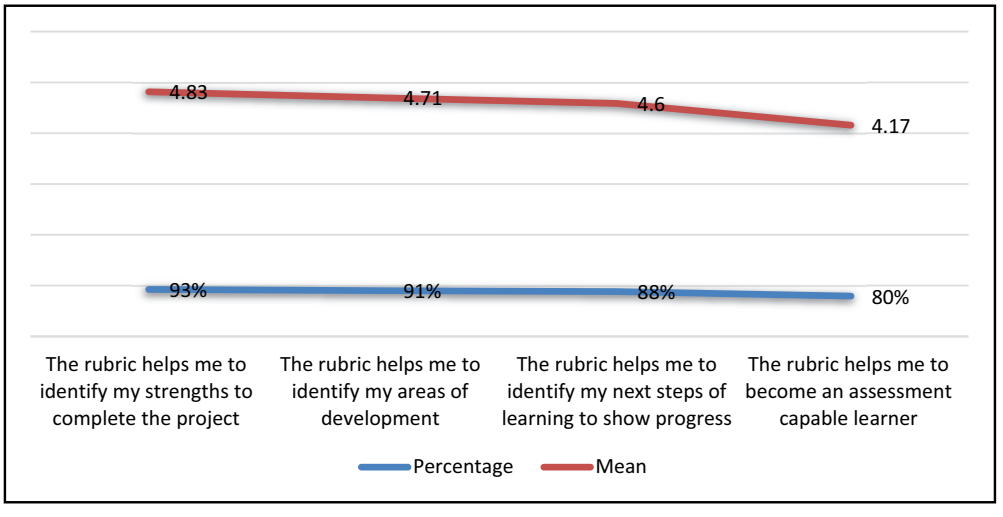

Figure 3. Consistency of the rubric to assessment and learning progress.

Rubric impact on assessment and learning progress

Figure 3 illustrates that the majority of students perceived the rubric as beneficial for recognising their strengths (93%) and areas for development (91%), as well as identifying next steps for learning (88%). However, 80% of students believed the rubric contributed to their development as assessment-capable learners. These findings indicate the rubric's effectiveness in fostering student self-reflection and identification of areas for improvement. The high percentage of students acknowledging the rubric's assistance in identifying strengths and areas for development suggests its efficacy in promoting self-awareness and self-evaluation. While a slightly lower percentage found

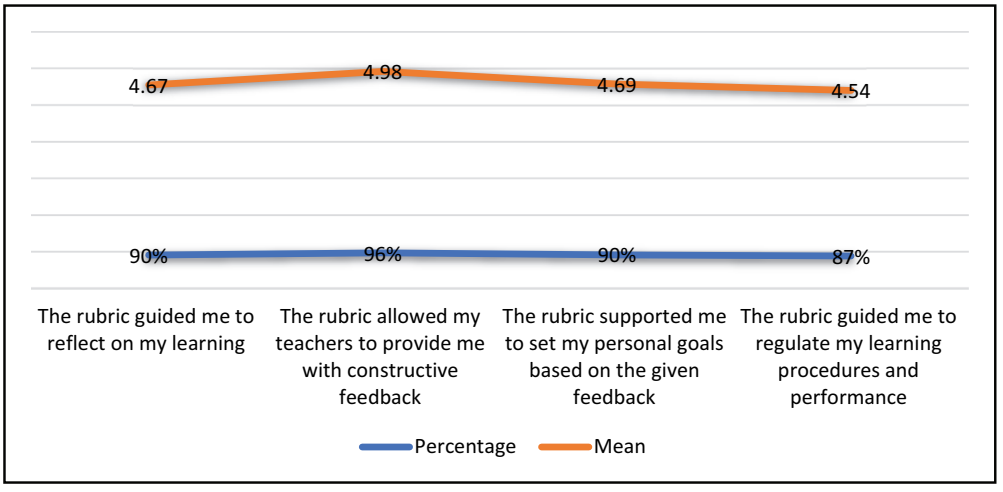

Figure 4. Consistency of the rubric to self-regulated learning.

the rubric helpful in identifying next steps for learning, it implies the need for additional support to assist students in formulating clear plans for progress. The 80% of students who believed the rubric helped them become assessment-capable learners highlights its effectiveness as a visible learning tool (Hattie & & Zierer, 2019). However, it also indicates a potential for improvement in providing students with a more comprehensive understanding of the rubric and their role in the assessment process.

Rubric impact on self -regulated learning

The questionnaire results in Figure 4 indicate the effectiveness of the developed rubric in promoting self-regulated learning among undergraduate students. Firstly, the high percentage (96%) of students who agreed that the rubric helped their teachers provide constructive feedback is a positive indication of the rubric's usefulness in promoting self-regulated learning. Feedback is an essential component of self-regulated learning, helping students identify strengths and weaknesses, set goals, and adjust their learning strategies accordingly. Secondly, (90%) of students agreed that the rubric guided them to reflect on their learning and supported them in setting personal goals based on the given feedback. Moreover, the rubric assisted them in engaging in goal setting, another key component of self-regulated learning involving the development of clear, specific, and achievable goals. Students who engage in this practice are more likely to regulate their own learning processes and improve their academic performance, as indicated by the (87%) of students who found that the rubric guided them in regulating their learning procedures and performance.

The influence of students' majors on their perceptions about the E-STEM rubric

ANOVA analyses were conducted to explore the influence of students' majors across four distinct programs or pathways (Education, Computer Science, Engineering, and Business)

Table 3. The influence of students' majors on perceptions about the E-STEM Rubric.

Dimensions of the perceptions about the E-STEM Rubric		Sum of Squares	df	Mean Square	F	Sig.
Rubric Effectiveness and Alignment with E-STEM	Between Groups	7.772	3	2.591	3.151	.073
	Within Groups	39.459	48	.822		
	Total	47.231	51			
Consistency of the Rubric to Assessment and Learning Progress	Between Groups	9.464	3	3.155	2.540	.067
	Within Groups	59.613	48	1.242		
	Total	69.077	51			
Consistency of the Rubric to Self-Regulated Learning	Between Groups	1.280	3	.427	.487	.693
	Within Groups	42.027	48	.876		
	Total	43.308	51			

on their perceptions of rubric effectiveness and alignment with E-STEM, consistency with assessment and learning progress, and consistency with self-regulated learning. However, despite the diversity in majors and pathways, the results consistently presented in Table 3 showed that the significance levels exceeded the typical threshold of 0.05. This suggests that students' choice of major within these programs did not significantly influence their perceptions of rubric effectiveness, alignment with E-STEM, or its reliability in supporting assessment, learning progress, or self-regulated learning.

Discussion

Through the perspectives of assessment experts, faculty members, and students, the rubric demonstrates several strengths and potential advantages that enhance its effectiveness and validity in assessing EC within the context of STEM education (Reynders et al., 2020). The participants' insights revolve around several themes, shedding light on the rubric's validity and functionality as an effective tool for E-STEM assessment. The findings from both the questionnaire and interviews offer compelling evidence regarding the effectiveness of the developed EC in STEM. The rubric's comprehensive and well-designed nature caters specifically to the intersection of entrepreneurship and STEM subjects, making it a valuable and authentic instrument for evaluating students' performance and progress in these areas.

The study findings provide robust evidence supporting the rubric's effectiveness and alignment with E-STEM learning objectives (Biggs, 2014). Findings revealed that students perceive a high level of alignment between the various components of the constructive alignment theory, including the learning objectives (planning), activities (instruction), and rubric items (assessment) to develop students' E-STEM competencies (Zhou & Brown, 2021). The positive perceptions of students and participants further reinforce this alignment, underscoring the rubric's value in guiding students' development of EC and facilitating independent project work.

Both faculty and students highly commend the rubric for its ability to foster assessment capabilities, facilitate effective progress tracking, and enhance EC (Henri et al., 2017). Moreover, the rubric's impact on assessment and learning progress aligns well with visible learning theory (Hattie & Zierer, 2019). It emerges as a crucial factor in promoting self-awareness, self-evaluation, and empowering students to identify their next steps for

improvement. The qualitative analysis lends additional support, substantiating the rubric's authenticity and its ability to foster continuous improvement in students' learning processes.

The rubric was successful in promoting self-regulated learning, which involves the ability to monitor and control one's own learning processes and performance. In this sense, the findings indicated that the rubric facilitated metacognition, which is an important aspect of self-regulated learning. Metacognition refers to the ability to reflect on one's own learning processes and outcomes.

The developed rubric makes a significant positive impact on various aspects of students' learning, including self-regulated learning, feedback, reflection, and goal setting, leading to the development of EC in the E-STEM context (Biggs, 2014; Hattie & Zierer, 2019). To further enhance its effectiveness in E-STEM education, there is a need to improve support for students' understanding of the rubric and address concerns related to its length and assessment time (Henri et al., 2017). By doing so, the rubric will continue to play a pivotal role in guiding students' learning, development, and ultimate success in the E-STEM disciplines as it provides valuable insights and benefits for both educators and students alike.

Integrating the qualitative and quantitative results provides a comprehensive understanding of the E-STEM rubric's impact. Qualitatively, participants express a positive perception of the rubric, praising its clarity, real-life applicability, and role in fostering self-assessment skills. Faculty and students acknowledge its effectiveness in guiding interdisciplinary competencies and project development. Concerns about the rubric's length and assessment time are noted. Quantitatively, the results reinforce the rubric's alignment with E-STEM objectives, with students valuing its guidance in developing entrepreneurial competencies. The rubric's impact on assessment and learning progress is substantiated by high percentages, indicating its effectiveness in fostering self-regulated learning and recognising strengths and areas for development. The cross-sectional analysis of data from students in four different programs (Education, Computer Science, Engineering, and Business) provides additional evidence supporting the validity and utility of the rubric in influencing E-STEM learning and projects. The findings reveal no significant differences among students from these programs in terms of their perceptions about the rubric's effectiveness, its alignment with E-STEM, or its reliability in supporting assessment, learning progress, and self-regulated learning (Reddy & Andrade, 2010; Reynders et al., 2020; Zhou & Brown, 2021). Collectively, the findings affirm the rubric's validity and underscore its pivotal role in fostering EC within the E-STEM context, emphasising the need for ongoing support to optimise its effectiveness.

Conclusion

This study makes a substantial contribution through the development of an E-STEM rubric that effectively evaluates students' entrepreneurial performance and outcomes. Creating the four main dimensions (E-STEM project, entrepreneurial knowledge, skills and attitude) of this assessment tool enhance the constructive alignment with the objectives of E-STEM learning, promoting students' EC. The rigorous and collaborative rubric development process involved various stakeholders in the E-STEM field. Serving both formative and summative assessment purposes, the rubric fosters self-awareness, self-evaluation, and metacognition

among students. Offering ongoing feedback, it supports continuous improvement in entrepreneurial competencies (EC) and enables comprehensive project evaluation, accommodating different raters and institutions. The rubric's versatility aligns seamlessly with E-STEM learning objectives, aiding educators in enhancing student outcomes and refining teaching approaches. Its mapping of grading scales facilitates assessment in diverse E-STEM environments, providing valuable insights for informed decision-making to optimise programs and elevate the quality of E-STEM education for student success.

Recommendation & implication

The creation of a validated analytical rubric for assessing E-STEM student outcomes holds practical and theoretical significance. It improves assessment precision and consistency, serving as a valuable tool for educators to evaluate and enhance student performance. Beyond its immediate application, the rubric contributes to the theoretical framework of E-STEM education, providing a structured approach for interdisciplinary outcome measurement. Its potential impact extends to influencing educational policies and practices, fostering effective strategies for student success in E-STEM disciplines. While this study is limited to a specific higher education E-STEM context in the UAE, there's a need for validation across diverse institutions and student populations. Future research should explore the impact of providing professional development to educators on E-STEM learning and rubric application. Additionally, integrating technological tools for enhanced accessibility and ease of use warrants further investigation.

Disclosure statement

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Notes on contributors

Marwa Eltanahy, Assistant professor in education. She developed the first E-STEM model and published a series of research concerning STEM entrepreneurship in different educational stages. She has an extensive experience in the educational field with specific expertise in teaching, coordination, training teachers, and school accreditation. Her research interest includes STEM, Science education, curriculum, and instruction.

Nasser Mansour is at Qatar University. Previously he was at Exeter University, UK. He is Fellow of the Higher Education Academy (HEA) in UK. He is a developer and designer for the Physics and Chemistry curricula and STEM for Cambridge International Examinations, Cambridge University, UK. His research involved STEM, teacher learning and, cultural issues related to science education.

ORCID

Marwa Eltanahy http://orcid.org/0000-0002-0615-9691
Nasser Mansour http://orcid.org/0000-0001-5707-7373

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