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STEEEM MODEL: A THEORETICAL FRAMEWORK TO ASSESS STEM-BASED LEARNING IN SCIENCE EDUCATION

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Abstract:
The current study aims to propose the **STEEEM** model for assessing students' learning in science according to the STEM approach, bridging the gap between authentic assessment practices and traditional classroom methods. The study applied analytical and descriptive methodologies, gathering empirical data via a structured questionnaire and evaluating pertinent literature for the last ten years. The sample consisted of 89 female pre-service science teachers who were enrolled in Sohar University's Teacher Preparation Program during the 2024–2025 academic year. They were chosen based on their solid backgrounds in biology, chemistry, physics, and teaching procedures. A 30-item questionnaire to gather data covering six dimensions of assessment: **S**cientific skills, **T**echnological skills, **E**ngineering design processes, **E**ntrepreneurial skills, **E**xtended skills, and **M**athematical skills. The significance of the study falls in line with the direct potential to guide science curriculum development and equip teachers with practical skills to implement performance-based assessments aligned with STEM philosophy and its educational aspects.

Keywords: STEM Approach, STEEEM Model, performance-based assessment

1. Introduction

Science, Technology, Engineering, and Mathematics may appear to be disparate in concept and practice, yet their integration forms the foundation of the STEM approach. Science (as a material and a technique) seeks to understand scientific phenomena by inquiry, data collecting, pattern discovery, generating hypotheses and explanations based on experimental evidence. While technology refers to equipment and devices created to suit human requirements, examples include thermometers, mass, pressure, wind speed, earthquake strength, and others. Engineering is concerned with the methods and techniques required to design tools, equipment, and systems. Lastly, mathematics is

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the study of employing models and quantitative computations to express scientific phenomena.

As a result, the STEM approach is an interdisciplinary method that blurs the distinctions between science, technology, engineering, and mathematics by organizing many facets of knowledge. In order to help students develop skills of the 21st century and future labor market, it introduces knowledge in the form of real-world challenges and experiences (Maric *et al*., 2023). Also, the STEM approach focuses on project-based learning, conceptual expertise acquisition, inquiry activation, practical activity application, and group collaboration. Additionally, it emphasizes critical and scientific thinking as well as the development of technological solutions that rely on a variety of scientific sources (Elayyan, 2021).

The emergence of several economic crises in industrialized countries, particularly the United States of America, sparked interest in the STEM approach. This interest coincided with scientific initiatives that emphasized the importance of integrating applied sciences into real-world situations (Hacıoğlu *et al*., 2016). Project 2061 emphasized the importance of incorporating social and technical themes into science education. The National Standards for Scientific Education (NSES) also emphasized the importance of recognizing the interconnectedness of science, technology, and society, which helps students develop their skills in engineering design, group work, and publishing their findings and ideas (Green, 2016). The National Generation Science Standards NGSS also focused on reforming science curricula to prepare a qualified generation of students for the future labor market by training them to understand global issues and provide appropriate solutions using survey science processes (Avery, 2013).

The STEM-based curriculum is designed so that the modules and activities include scientific inquiry that stimulates the real world, resulting in a more integrated and in-depth understanding of scientific concepts. Several studies (Christensen *et al*., 2014; Stevens, 2012) emphasized that including STEM in the scientific curriculum requires introducing the content in a real and realistic context related to local and global issues, using modeling, integrating technology into science teaching, providing students with engineering design skills, and involving science concepts in future jobs that require engineering and technical skills.

Many studies have pointed to science teachers' perceptions of integrating STEM into teaching-learning processes. Margot and Kettler (2019) try to investigate teachers' perceptions of STEM by analyzing articles published from 2000 to 2016. Findings showed that teachers have positive attitudes towards STEM, as well as students' acceptance of the idea of inclusion, but there are still some outstanding issues and challenges related to curriculum and performance evaluation. Another study, which was applied to a sample of 144 science teachers in the UAE emphasized the importance of applying STEM in students' acquisition of scientific knowledge (Chaya, 2023). Also in South Korea, a study of 729 science teachers working in 252 STEM schools indicated that integrating STEM into science education requires overcoming difficulties such as time management, teacher teaching loads, and lack of financial support (Park *et al*., 2016). In addition, several studies focused on STEM by considering economic challenges, teacher competencies, practical activities, and performance-based assessment. (Permanasari, 2021; Kearney, 2016; Lynch *et al*., 2014).

Performance-based assessment (PBA) in science is a method of evaluating students that demands them to demonstrate what they know and can do through authentic, task-oriented activities rather than just selecting answers on standard tests. Unlike multiple-choice or short-answer formats, PBA stresses the application of information and skills in contexts that are similar to real-world scientific practices, such as conducting experiments, addressing complicated problems, developing investigations, and explaining results (Dogra, 2015). This shift consists of broader educational aims that prioritize meaningful learning over rote memory, and it reflects contemporary views of science as a practice-based field.

In the science classroom, performance-based assignments are purposefully designed to engage students in higher-order thinking and science process skills, which are essential for comprehending scientific inquiry. These abilities include seeing, classifying, inferring, measuring, forecasting, analyzing data, and performing controlled investigations, which are challenging to assess using standard paper-and-pencil assessments alone (Osin & Sahoo, 2022). Compared to traditional assessments that mainly test recollection, performance-based exams give science teachers richer evidence of student competency by asking students to create and convey responses.

STEM and PBA are closely related because they both place a high emphasis on problem-solving, authentic learning, and the application of knowledge across disciplines. While PBA assesses students by having them complete tasks that show these integrated competencies, STEM education aims to integrate science, technology, engineering, and mathematics through real-world challenges that reflect professional practice (Honey *et al*., 2014; English, 2016).

PBA and STEM share the same focus on real-world, actual challenges, which is one of their main linkages. Complex challenges like finding solutions, creating models, evaluating data, or optimizing systems are frequently the focus of STEM education, which makes them ideal for performance-based assignments (English *et al*., 2017). For instance, a STEM project might involve students testing physical principles (science), designing an energy-efficient structure (engineering), computing materials and expenses (mathematics), and using digital tools for presentation or simulation (technology). By witnessing how students organize, carry out, defend, and explain their solutions, performance-based evaluation enables teachers to analyze these processes comprehensively (Darling-Hammond *et al*., 2019).

The current study is based on Constructivism, which is an educational theory that supports formative and performance-based assessment and views learning as a process in which learners actively build knowledge through interaction with their environment, prior experiences, and social collaboration (Vygotsky, 1978). STEM-based assessment aligns closely with this perspective by focusing on problem-based, inquiry-driven, and interdisciplinary tasks that require learners to apply concepts from science, technology, engineering, and mathematics to real-world problems. Rather than assessing isolated facts, STEM assessments emphasize reasoning, design thinking, collaboration, and the integration of knowledge, which are core principles of constructivist learning environments (Fosnot, 2013). According to Constructivism & STEM, assessment becomes part of the learning process itself, promoting deeper conceptual understanding and transferable skills such as critical thinking and problem solving (Black & Wiliam, 2009).

2. Statement of the Problem

Despite increased attention to STEM approaches and their assessment practices, there are significant disparities in how various stakeholder groups perceive STEM-based assessment. Several studies view performance-based STEM assessments (i.e. collaborative projects, problem-solving, and performance tasks) as valuable tools for fostering critical thinking, creativity, collaboration, and real-world problem solving (Nabillah *et al*., 2025). In contrast, STEM teachers at different school levels often prioritize traditional assessment methods like tests with open- and closed-ended questions over authentic performance portfolios (Akiri *et al*., 2021; Fairhurst *et al*., 2023). This divergence shows a clear knowledge gap between recommended formative assessment practices and classroom realities based on professional background, learning environment, and school culture.

The current study aims to provide a proposed model to assess students' learning according to the STEM concepts and procedures. This model is based on assessing scientific and mathematical thinking skills, as well as evaluating students' performance in applying technology and building engineering designs related to the scientific phenomenon. In addition to evaluating students' ability to communicate and disseminate their conclusions, the extent of their awareness of the entrepreneurial skills that lead to integration with future jobs. Specifically, the current study tries to answer the following two questions:

- **RQ1**: What are the methods of assessing science learning based on the STEM approach in light of the relevant literature review?
- **RQ2:** What is the proposed model for assessing science learning according to the STEM approach?

3. Research Significance

The importance of the current study falls in line with the importance of the STEM approach. It tries to introduce a proposed model that paves the way for the development of science curricula according to the STEM approach, providing the necessary practical skills for science teachers to reduce the traditional methods of assessing science learning. Also, the study adopted a unified list of assessment skills, which is understood by all science teachers, to enable them to assess students' learning in appropriate practical ways that are compatible with STEM philosophy.

4. Study Design

4.1 Methodology

The study was based on analytical method of the relevant studies that investigated the assessment of science learning based on the STEM approach. The studies were selected according to their relevance and recentness, as the analysis was limited to studies published over the last ten years. Also, the descriptive method was applied that aims to describe educational phenomena with respect to their current reality. (Gay, Mills, & Airasian, 2013).

4.2 The Study Sample

The sample consists of 89 pre-service science teachers in the Teacher Preparation Program at Sohar University in the academic year 2024/2025. All individuals in the sample were female with 22–24-year-olds. They were chosen as pilot techniques to collect their perceptions about the model standards and indicators because they graduated with a bachelor's degree in physics, chemistry, and biology before attending the program. So, they have a good background in science and technology which qualified them to react to STEM ideas and procedures.

4.3 Data Collection Tool

The current study applied the quantitative survey method with a questionnaire as the main tool to collect data. The questionnaire was constructed by revising the related literature (Halawa *et al*., 2024; Ješková *et al*., 2022; Elayyan, 2021; Rahman, 2021; Gao *et al*., 2020). Then, constructing a draft copy of 32 items that were distributed into six dimensions: scientific skills, Technological & digital skills, engineering design processes, mathematical and analytical skills, entrepreneur & Future Skills, and communication and idea publishing skills. To check validity, the questionnaire was submitted to 18 specialists in science curricula, Instructional technology, and science supervisors to put their comments about the suitability and accuracy of items to be applied. After collecting the experts' points of view and implementing their modifications, 2 of these items were deleted, and the final version of the questionnaire consisted of 30 items (5 items for each standard) with 5 points Likert scale (strongly agree = 5, agree = 4, neutral = 3, disagree = 2, strongly disagree = 1). Finally, to check reliability, the final version of the questionnaire was applied to a pilot sample of 25 pre-service teachers out of the study sample, and then calculate the self-constancy was calculated using Cronbach's Alpha formula was used to calculate the value, which was 0.89, which means that the study tool is applicable.

5. Findings

5.1 Findings and Conclusions of the First Question

To answer the first question, RQ1, which is stated that: "What are the methods of assessing science learning based on STEM approach in the light of relevant literature review"? A survey of relevant studies has been conducted for the last ten years. Table 1 shows an overview of these studies in terms of STEM-based assessment procedures.

Table 1: An Overview of Processes to Assess Science Learning in the Relevant Literature

Authors	Year	Assessment Procedures
Halawa et al.	2024	Referred to assessment integration into design, including literacy measures and science performance indicators embedded in STEM tasks.
Ješková et al.	2022	Used digital tools, rubric-based performance tasks, and peer evaluation to examine formative assessments related to inquiry activities in order to record inquiry skills across integrated STEM activities.
Rahman	2021	Proposed a comprehensive assessment scheme for STEM outcomes, including standardized tests, work sampling, Likert-scale observations, attendance, teamwork rubrics, and practical performance assessments to benchmark learning in robotics-based STEM contexts.
Dewanti et al.	2021	Applied project assignments and performance criteria to assess critical thinking (hypothesizing, reasoning, problem solving). Includes instrument reliability testing and validity indices to evaluate outcomes.
Permanasari et al.	2021	Referred to the project-based assessment where students solved contextual problems and were evaluated on their final presentations and reports using criteria integrating science content mastery and product design
Gao et al.	2020	Developed a two-dimensional framework categorizing assessment by discipline nature (mono/ inter/ transdisciplinary) and learning objectives (knowledge, affective, and psychomotor). Emphasizes the need to assess beyond monodisciplinary tests toward integrated tasks and performance assessments.
Dare et al.	2018	Examined field notes from classroom observations to see how assessments were enacted during integrated activities.
Thibaut et al.	2018	Documented the use of authentic assessment methods by teachers, including peer assessment of design projects, self-assessment reports on the inquiry process, and portfolio assessments that compiled evidence of learning across science, technology, and engineering domains.
Walker et al.	2018	The proposed three procedures of assessment include Scenario-based assessments presenting complex problems, Design portfolio reviews evaluating use of science and engineering practices, and Crosscutting concept prompts that ask students to identify patterns or cause-effect relationships in their integrated projects.
Guzey et al.	2016	Analyzed student engineering design notebooks using rubrics to evaluate application of science concepts and engineering design practices.

The ten studies shown in Table 1 all agree that assessment in integrated STEM education should shift away from traditional, monodisciplinary testing and toward authentic, performance-based approaches that capture both learning processes and outcomes. Most studies (Thibaut *et al.*, 2018; Walker *et al.*, 2018; Guzey *et al.*, 2016) emphasize assessments that are embedded in STEM activities rather than administered separately. Project-based tasks, design challenges, portfolios, notebooks, and scenario-based problems are common tools. These approaches aim to evaluate higher-order outcomes such as problem-solving, inquiry skills, critical thinking, and application of science and engineering practices. Similarly, several studies (Ješková *et al.*, 2022; Dare *et al.*, 2018;

Thibaut *et al.*, 2018) highlight formative assessment strategies, including teacher observation, peer assessment, self-assessment, and rubric-based evaluations. Collectively, these findings suggest a shared recognition that integrated STEM learning requires assessment methods that are continuous, contextualized, and aligned with authentic STEM practices rather than isolated content recall.

Despite these similarities, the studies differ significantly in the scope, structure, and rigor of assessment frameworks. Rahman (2021) proposes comprehensive and multi-method assessment systems that use standardized tests, surveys, teamwork rubrics, motivation measures, and practical performance evaluations to benchmark learning in robotics-based STEM contexts. Other studies take a narrower approach, focusing on specific competencies such as critical thinking (Dewanti *et al*., 2021) or inquiry skills (Ješková *et al*., 2022). Differences also emerge in the level of methodological sophistication: while Dewanti *et al*. (2021) explicitly report reliability and validity indices for assessment instruments, Dare *et al*. (2018) rely primarily on classroom observations and field notes to investigate how assessment is carried out in practice. Furthermore, Gao *et al*. (2020) refer to a conceptual framework as opposed to an empirical tool, classifying STEM assessments based on learning objectives and disciplinary integration. This provides a theoretical lens for assessment design and interpretation rather than specific measurement techniques.

The reviewed studies reveal an evolving but still fragmented landscape of STEM assessment. Earlier research (e.g., Dare *et al*., 2018; Guzey *et al*., 2016) tended to document existing classroom practices and tools such as notebooks and observations, whereas more recent work (Halawa *et al*., 2024; Ješková *et al*., 2022) increasingly incorporates assessment into instructional design and digital inquiry environments. A recurring gap is the lack of alignment between innovative assessment practices and large-scale, standardized accountability systems, as well as the inconsistent reporting of psychometric properties across studies. Nonetheless, the collective evidence points to a clear trend toward integrated, authentic, and multidimensional assessment approaches that better reflect STEM education's complex learning objectives. This convergence in the points of view shows that there is an increasing consensus on what constitutes good STEM evaluation, even while academics' implementation methodologies and levels of empirical validation differ.

5.2 Findings and Conclusions of the Second Question

The second question stated: "What is the proposed model for assessing science learning according to the STEM approach"? The study findings were obtained after applying the questionnaire to the sample of pre-service science teachers. The intervals of a typical 5 point Likert scale were also calculated to determine the pre-service science teachers' perceptions ratio about assessment of the students' learning in science based on STEM as in the following: calculating the Range (max. score – min. score = 5-1= 4), then calculating the category interval (=Range/max. score = 4/5 = 0.8), so we have 5 intervals as shown in Table 2.

Table 2: Teachers' Perceptions of Degrees vs. Average Intervals of the Questionnaire Items

Average Interval		The level of need
1.0 1.8		Very low
>1.8-2.6		Low
>2.6-3.4		Intermediate
>3.4-4.2		Large
>4.2-5.0		Very large

The means and standard deviations were calculated for each item in the questionnaire, and the level of needs was determined in terms of the categories that were shown in Table 2. All data are tabulated in Table 3.

Table 3: The Means, Standard Deviations, Item's Rank, the Level of Need and Chi Square Value of the Items that Represent the Levels of Needs to the Assessment Processes in Science Learning Based on STEM Approach

No.	Items	Average	Standard Deviation	Item Rank	The level of need	Chi square χ^2
Standard 1: Assessing Scientific Skills: The student will be able to…						
1	use key scientific terminology related to the project Accurately	4.18	1.23	18	Large	*28.34
2	ask relevant questions based on observations	4.31	1.60	15	Very large	*42.50
3	collect qualitative and quantitative data Systematically	4.49	0.79	9	Very large	*18.57
4	analyze data to form an evidence-based conclusion	4.36	1.49	13	Very large	5.36
5	predict outcomes based on scientific understanding	2.72	1.04	26	Intermediate	*20.45
	Mean of Standard 1	**4.01**				
Standard 2: Assessing Technological & Digital Skills: The student will be able to…						
5	use technology (e.g., sensors, simulations) to collect data	4.74	0.96	6	Very large	*36.70
7	employ smart software to analyze data	4.82	0.85	2	Very large	*45.11
8	create a clear digital product (report, portfolio) to document work	2.87	1.67	23	Intermediate	*26.12
9	use digital platforms responsibly for collaboration and research	2.31	0.58	28	Low	*28.96
10	evaluates information obtained from digital sources critically	1.67	1.18	30	Very low	*15.33
	Mean of Standard 2	**3.28**				
Standard 3: Assessing Engineering Design Processes: The student will be able to…						
11	define the problem and constraints for a design challenge	4.44	0.67	10	Very large	*22.87
12	generate and sketch multiple design ideas	4.64	1.02	7	Very large	*41.29

13	plan a prototype based on selected design	4.28	0.98	16	Very large	*32.21
14	test the prototype, collects data, and identifies failures	2.54	1.51	27	Low	8.05
15	analyze the prototype's test results to suggest specific improvements.	3.56	1.10	22	Large	*19.76
	Mean of Standard 3	**3.89**				
Standard 4: Assessing Mathematical & Analytical Skills: The student will be able to…						
16	take accurate measurements using appropriate units and tools	3.73	0.78	21	Large	*31.45
17	perform correct calculations relevant to the task	4.41	0.49	11	Very large	*24.92
18	interpret graphs/charts to identify patterns and trends in data	4.33	1.37	14	Very large	*29.54
19	use numerical data to justify a design choice or conclusion	4.87	0.59	1	Very large	*24.16
20	evaluate the reasonableness of quantitative results	2.05	1.42	29	Low	*43.32
	Mean of Standard 4	3.88				
Standard 5: Assessing Entrepreneur & Future Skills: The student will be able to…						
21	set realistic goals and create a simple project timeline	4.76	0.85	5	Very large	*16.45
22	identify ethical considerations in a scientific context	4.59	0.90	8	Very large	*25.12
23	discusses the potential societal benefits and risks of the solution	2.73	0.76	25	Intermediate	6.36
24	fulfill assigned team roles and responsibilities reliably	4.40	1.20	12	Very large	*11.89
25	describe various STEM-related careers connected to the project	3.85	1.00	20	Large	*34.65
	Mean of Standard 5	**4.07**				
Standard 6: Assessing Extending and Idea Publishing Skills: The student will be able to…						
26	organize information logically (e.g., problem, process, data, etc.).	4.21	0.56	17	Very large	*32.76
27	use appropriate methods (oral, written, visual) to present information	4.82	1.12	3	Very large	*42.81
28	support claims with relevant evidence (data, scientific principles)	2.85	1.08	24	Intermediate	*33.24
29	use models, diagrams, or prototypes effectively to aid explanation	4.77	0.78	4	Very large	*27.33
30	adapts communication style to the target audience (e.g., peer vs. community).	3.87	0.69	19	Large	*37.45
	Mean of Standard 6	**4.10**				

* Significant at the level 0.05

Table 3 shows different levels of means, which are m= 4.10 for standard 6 Communication & Publishing Skills, m= 4.07 for standard 5 Entrepreneur & Future Skills, and m= 4.01 for standard 1 Scientific Skills. However, while having two of the top five items overall (items 5 and 7), Technological & Digital Skills has a lower average score of 3.28, indicating a polarized distribution within that domain (i.e., some very strong items coexisting with weak ones).

The indicators with the lowest scores indicate an obvious low need for critical digital review, quantitative reasonableness assessment, prototype testing, and prediction. In particular, evaluate the reasonableness of quantitative results (Item 20: 2.05, Rank 29) and evaluate information obtained from digital sources critically (Item 10: 1.67, Rank 30). They are followed by testing the prototype, gathering data, and identifying failures (Item 14: 2.54, Rank 27), using digital platforms responsibly for research and collaboration (Item 9: 2.31, Rank 28), and making predictions based on scientific understanding (Item 5: 2.72, Rank 26). Together, these suggest that, while the sample feels confident using tools to produce and present results, they are much less confident in critiquing digital information, sanity checking numbers, and closing the loop on the engineering test as procedures to apply in assessing science learning based on a STEM approach.

Despite the variability in item means and the presence of items with low means, the responses show the overall significance of the standards as fundamental prerequisites for assessing student learning in science based on a STEM approach. Five out of six standards had a large mean, while only one (the second standard, with a mean of 3.28 out of 5) fell into the medium range. Furthermore, 22 of the 30 items had a mean interval between 3.4 and 4.2, indicating a large to very great demand for the assessment indicators listed in Table 3.

In order to find out the extent to which the results can be generalized to a population of science teachers with the same characteristics, the value of the Chi-square was calculated at the degree of freedom (4) and the significance level of (0.05) as shown in Table 3. The result is statistically significant in all items except for (4, 14 and 23), where the calculated chi-square value was less than its value in the Chi-square distribution table, which is equal to 9.48 at the same degree of freedom and same significant level. This indicates that there are significant differences in the response of the study sample to each item, and that the differences in the percentages of the sample are the same as those of the population, which means that the results of the study can be generalized to any population with the same characteristics and specifications.

6. Conclusions

6.1 An Overview of the STEEEM Model

Based on the findings, the current study proposed the STEEEM model to assess the students' learning based on a STEM approach. This model includes 6 standards (**S**cientific skills, **T**echnological skills, **E**ngineering design processes, **E**ntrepreneurial skills, **E**xtended skills, and **M**athematical skills), which were divided into three phases as shown in Figure 1.

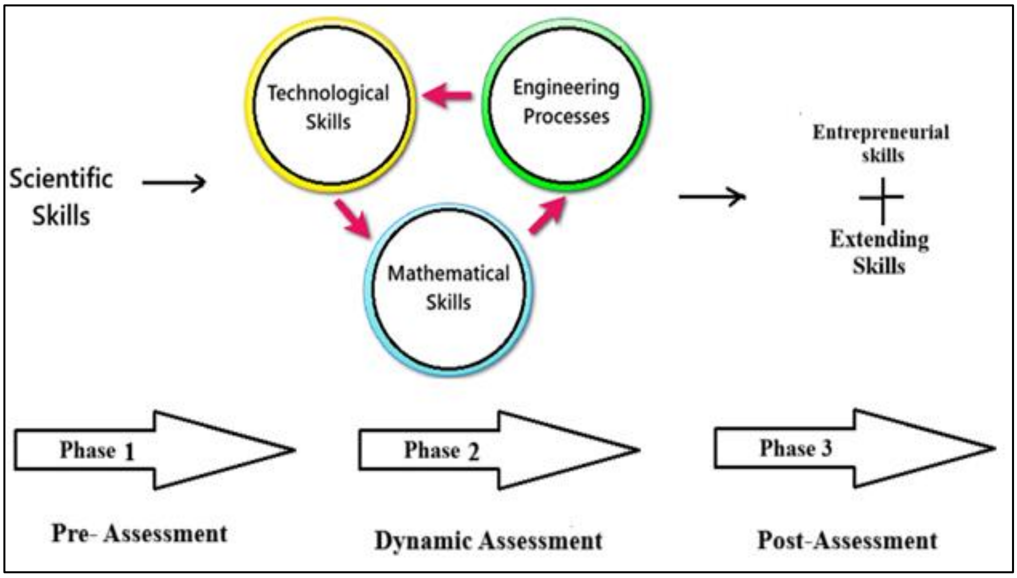

Figure 1: The Assessment Phases of the STEEEM Model

Phase 1 refers to assessing **Scientific Skills,** which represent the pre-assessment stage that provides a comprehensive measure of students' scientific literacy and inquiry competence. When students ask accurate questions based on detailed observations, they display the ability to detect problems and frame investigations scientifically. The systematic collecting of qualitative and quantitative data demonstrates procedural rigor and reliability in research operations. Analyzing data to draw evidence-based conclusions demonstrates students' abilities in critical thinking, pattern recognition, and logical reasoning. Finally, forecasting events based on known scientific understanding demonstrates conceptual integration and transfer of information. Collectively, these activities ensure that assessments reflect authentic scientific methods that are consistent with inquiry-based and skills-oriented science education.

Phase 2 includes three standards of assessment: Engineering processes, Technological-Digital skills and Mathematical-analytical skills. The three standards represent a **Dynamic Assessment** to identify the students' individual skills as well as their learning potential. They interact with each other in a circular relationship, as the actions of each standard depend on and influence the other.

Assessing **Technological-Digital Skills** through using technology to collect data, such as sensors and simulations, shows students how to choose and use appropriate digital tools for authentic problem solving. Using smart software to analyze data demonstrates skill in data processing, visualization, and interpretation. Clear digital products, such as reports or portfolios, demonstrate competence in documentation, communication, and knowledge organization. The responsible use of digital platforms for collaboration and study, combined with critical evaluation of information from digital sources, ensures ethical, informed, and successful engagement with technology in educational contexts.

Also, assessing the **Engineering Process** through defining the problem and identifying constraints demonstrates understanding of real-world limitations and design requirements. Generating and sketching multiple design ideas reflects creativity, ideation, and consideration of alternative solutions. Planning a prototype based on a selected design highlights strategic thinking and feasibility analysis. Testing the prototype, collecting data, and identifying failures emphasize iterative experimentation and evidence-based decision making. Finally, analyzing test results to propose specific improvements illustrates reflective thinking and optimization, which are essential components of authentic engineering practice

The last stage in Phase 2 is assessing **Mathematical Skills** through taking accurate measurements using appropriate units and tools to demonstrate precision and understanding of measurement principles. Performing correct calculations relevant to the task reflects procedural fluency and mathematical accuracy. Interpreting graphs and charts to identify patterns and trends highlights students' data literacy and analytical thinking. Using numerical data to justify design choices or conclusions shows the ability to apply mathematics in context and support decisions with evidence. Evaluating the reasonableness of quantitative results further indicates critical judgment and conceptual understanding of mathematical outcomes.

Phase 3 represents an advanced level of STEM-based assessment, where its two phases represent a link between assessing what students have learned and how they apply what they have learned in the entrepreneurial field and awareness of future skills. As well as linking the assessment of what students have learned and assessing their methods of extending their experiences and procedures of disseminating and documenting them.

Assessing **Entrepreneurial Skills** through setting realistic goals and developing a simple project timeline demonstrates organizational skills and strategic planning. Identifying ethical considerations within a scientific context reflects responsible decision-making and integrity. Discussing potential societal benefits and risks of a proposed solution highlights systems thinking and social responsibility. Reliably fulfilling assigned team roles indicates accountability, collaboration, and leadership. Finally, describing STEM-related careers connected to the project shows awareness of career pathways and the ability to link learning experiences to future professional opportunities.

Also, assessing **Extending and Publishing Skills** through organizing information logically demonstrates coherence and structured thinking. Using appropriate oral, written, and visual methods reflects flexibility in communication and media selection. Supporting claims with relevant evidence highlights scientific argumentation and credibility. Effective use of models, diagrams, or prototypes aids conceptual explanation and knowledge transfer. Adapting communication style to different audiences further indicates awareness of context, purpose, and audience needs, which is essential for meaningful knowledge extension and dissemination.

Conflict of Interest Statement
The author declares no conflicts of interest.

About the Author
Shaher Elayyan holds a PhD in Curriculum and Instruction with a Science Education specialization, as well as a bachelor's and master's degree in physics. He has published books in physics and science education. He has 20 papers published in several areas, including STEM-Based learning and developing science in the digital transformation era, and has supervised approximately 30 master's theses in science education. He has experience with the higher education systems of Saudi Arabia, Oman, and Jordan. In addition to memberships in reviewed journals and educational bodies, he has attended several academic events in Oman, Saudi Arabia, Jordan, Italy, the UK, and Singapore.

References

Akiri, E., Tor, H. M., & Dori, Y. J. (2021). Teaching and Assessment Methods: STEM Teachers' Perceptions and Implementation. *Eurasia Journal of Mathematics, Science and Technology Education, 17*(6). https://doi.org/10.29333/ejmste/10882

Avery, Z.K. & Reeve, E.M. (2013). Developing Effective STEM Professional Development Programs. *Journal of Technology Education, 25*(1), 55-69. https://doi.org/10.21061/jte.v25i1.a.4

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability, 21*(1), 5–31. https://doi.org/10.1007/s11092-008-9068-5

Chaya, H. (2023). Investigating teachers' perceptions of STEM education in private elementary schools in Abu Dhabi. *Journal of Education and Learning, 12*(2), 60–78. https://doi.org/10.5539/jel.v12n2p60

Christensen, R., Knezek, G. & Tyler-Wood, T. (2014). Student Perception of Science, Technology, Engineering and Mathematics (STEM) Content and Careers. *Computers in Human Behavior*, 173-186. https://doi.org/10.1016/j.chb.2014.01.046

Dare, E. A., Ellis, J. A., & Roehrig, G. H. (2018). Understanding science teachers' implementations of integrated STEM curricular units through a phenomenological multiple case study. *International Journal of STEM Education,* 5, Article 4. https://doi.org/10.1186/s40594-018-0101-z

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2019). Implications for educational practice of the science of learning and development. *Applied Developmental Science,* *24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Dewanti, B. A., Santoso, A., & Septaria, K. (2021). Assessment of critical thinking skills in STEM-based science learning through project assignments. *In Proceedings of the 6th International Seminar on Science Education (ISSE 2020)* (pp. 824–831). Atlantis Press. https://doi.org/10.2991/assehr.k.210326.119

Dogra, B. (2015). Performance-based Assessment for Assessing Science Learning. *The Primary Teacher,* *40*(2-3), p. 48-58. https://ejournals.ncert.gov.in/index.php/tpt/article/view/1225

Elayyan, S. (2021). The future of education according to the fourth industrial revolution. *Journal of Educational Technology & Online Learning*. 4(1): pp. 24-30. https://doi.org/10.31681/jetol.737193

English, L. D. (2016). STEM education K–12: Perspectives on integration. *International Journal of STEM Education*, *3*(3), 1–8. https://doi.org/10.1186/s40594-016-0036-1

English, L. D., King, D., & Smeed, J. (2017). Advancing integrated STEM learning through engineering design: Sixth-grade students' design and construction of earthquake-resistant buildings. *The Journal of Educational Research*, *110*(3), 255–271. https://www.jstor.org/stable/26586745

Fairhurst, N., Koul, R., & Sheffield, R. (2023). Students' perceptions of their STEM learning environment. *Learning Environments Research,* *26*(3), 977–998**.** https://doi.org/10.1007/s10984-023-09463-z

Fosnot, C. T. (2013). *Constructivism: Theory, perspectives, and practice* (2nd ed.). Teachers College Press. Retrieved from https://books.google.ro/books/about/Constructivism.html?id=-pIbAgAAQBAJ&redir_esc=y

Gao, X., Li, P., Shen, J., & Sun, H. (2020). Reviewing assessment of student learning in interdisciplinary STEM education. *International Journal of STEM Education, 7*(24). https://doi.org/10.1186/s40594-020-00225-4

Gay, L., Mills, G. & Airasian, P. (2012). *Educational Research: Competencies for Analysis and Applications.* 10th edition. New Jersey: Pearson. Retrieved from https://www.pearson.com/en-us/subject-catalog/p/educational-research-competencies-for-analysis-and-applications/P200000001512/9780137534944

Green, S. L. (2014). *STEM Education in a Competitive and Globalizing Word*. Nova Science Publishers.

Guzey, S. S., Moore, T. J., Harwell, M., & Moreno, M. (2016). STEM integration in middle school life science: Student learning and attitudes. *Journal of Science Education and Technology*, 25(4), 550–560. https://doi.org/10.1007/s10956-016-9612-x

Hacıoğlu, Y., Yamak, H., & Kavak, N. (2016). Pre-service science teachers' cognitive structures regarding science, technology, engineering, mathematics (STEM) and science education. *Journal of Turkish Science Education*, *13*(special), 88-102. Retrieved from https://www.tused.org/index.php/tused/article/view/625?articlesBySimilarityPage=27

Halawa, S., Lin, T.-C., & Hsu, Y.-S. (2024). Exploring instructional design in K-12 STEM education. *International Journal of STEM Education, 11*, 43. https://doi.org/10.1186/s40594-024-00503-5

Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM integration in K–12 education: Status, prospects, and an agenda for research*. National Academies Press. Retrieved from https://www.middleweb.com/wp-content/uploads/2015/01/STEM-Integration-in-K12-Education.pdf

Ješková, Z., Lukáč, S., Šnajder, Ľ., Guniš, J., Klein, D., & Kireš, M. (2022). Active learning in STEM education with regard to the development of inquiry skills. *Education Sciences, 12*(10), 686. https://doi.org/10.3390/educsci12100686

Kearney, C. (2016). *Efforts to increase students' interest in pursuing science, technology, engineering and mathematics studies and careers: National measures taken by 30 countries* (Report). European Schoolnet (EUN Partnership AISBL). Retrieved from http://www.eun.org/resources/detail?publicationID=783

Lynch, S. J., Peters-Burton, E., & Ford, M. R. (2014). Building STEM opportunities for all. *Educational Leadership, 72*(4), 54–60. Retrieved from https://www.ascd.org/el/articles/building-stem-opportunities-for-all

Margot, K.C. and Kettler, T. (2019). Teachers' Perception of STEM Integration and Education: A Systematic Literature Review. *International Journal of STEM Education*, *6*(1), 2-16. https://doi.org/10.1186/s40594-018-0151-2

Maric, D., Fore, G. A., & Nyarko, S. C. (2023). Measurement in STEM education research: A systematic literature review of trends in the psychometric evidence of scales. *International Journal of STEM Education, 10*. https://doi.org/10.1186/s40594-023-00430-x.

Nabillah, T., Hamdu, G., & Ramadhani Putri, A. (2025). Elementary school teacher's perceptions of STEM-based performance assessment across urban and rural contexts. *EduStream: Jurnal Pendidikan Dasar*, *9*(2), 189–201. https://doi.org/10.26740/eds.v9n2.p189-201

Osin, & Sahoo, M. (2022). Performance-based assessment in science at the elementary school level. *International Journal of Advanced and Applied Research, 9*(5), 646-650. Retrieved from https://www.researchgate.net/publication/363670572_PERFORMANCE-BASED_ASSESSMENT_IN_SCIENCE_AT_ELEMENTARY_SCHOOL_LEVEL

Park, H., Byun, S.-Y., Sim, J., Han, H.-S., & Baek, Y. S. (2016). Teachers' Perceptions and Practices of STEAM Education in South Korea. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(7), 1739-1753. https://doi.org/10.12973/eurasia.2016.1531a

Permanasari, A., Rubini, B., & Nugroho, O. F. (2021). STEM education in Indonesia: Science teachers' and students' perspectives. *Journal of Innovation in Educational and Cultural Research, 2*(1), 7–16. https://doi.org/10.46843/jiecr.v2i1.24

Rahman, S. M. M. (2021). Assessing and benchmarking learning outcomes of robotics-enabled STEM education. *Education Sciences, 11*(2), 84. https://doi.org/10.3390/educsci11020084

Stevens, R. (2012). Identifying 21st Century Capabilities. *International Journal of Learning and Change, 6*(3-4), 123-137. https://doi.org/10.1504/IJLC.2012.050857

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2018). The influence of teachers' attitudes and school context on instructional practices in integrated STEM education. *Teaching and Teacher Education, 71*, 190–205. https://doi.org/10.1016/j.tate.2017.12.014

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press. Retrieved from https://www.jstor.org/stable/j.ctvjf9vz4

Walker, W. S., Moore, T. J., Guzey, S. S., & Sorge, B. H. (2018). Frameworks to Develop Integrated STEM Curricula. *K-12 STEM Education, 4*(2), 331–339. https://doi.org/10.14456/k12stemed.2018.5