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Learning Competencies of Grade 11 Stem Learners in Organic Chemistry: Basis for Strategic Intervention

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ABSTRACT

The aim of this study was to identify what were the not mastered, least mastered, nearly mastered, and mastered competencies in senior high school organic chemistry. This further sought to examine the Grade 11 STEM learners' self-efficacy beliefs to organic chemistry competencies. The study used a quasi-experimental research design using a test questionnaire as the primary data collection tool to describe the mastery level of Grade 11 STEM learners on the desired learning competencies. The instrument was validated by experts in content and methods prior to the revision. The pilot testing was done at the public high school located in Iligan City, Northern Mindanao, Philippines. The pilot testing was participated in by a total of One Hundred Twenty (120) students. After the pilot testing, an item analysis was done with considerations on the difficulty and discrimination indices. Consequently, another Forty-Five (45) Grade 11 STEM learners participated in the implementation of the validated test instrument in senior high school organic chemistry. The findings revealed that the mastery level of Grade 11 STEM learners in organic chemistry competencies was relatively low, with several competencies falling in the "not mastered" category and a few in the "least mastered" category. Students faced challenges particularly with competencies related to the special nature of carbon, functional groups, simple reactions of organic compounds, polymer and its properties, and biomolecules, indicating significant gaps in both foundational knowledge and applied understanding. This lack of mastery underscored the need for improved teaching strategies, focused interventions, and instructional materials tailored to address these deficiencies.

Keywords: learning competencies, organic chemistry, self-efficacy

INTRODUCTION

Science education in the Philippines aims to develop learners' skills and attitudes concerning Science, Technology, Engineering, and Mathematics (STEM). It plays a crucial role in society by defining the scientific literacy of individuals within a community. This education seeks to prepare every learner to meet higher performance standards, which has consistently challenged teachers. Specifically, educators strive to equip students with the competencies necessary for global competitiveness and functional literacy, particularly in the field of science education. Mastering these competencies is essential for academic success. It is important to recognize that higher-level learning relies on a solid understanding of the knowledge and skills acquired at the basic education level (Lapitan et al., 2021). A lack of strong foundational knowledge in basic chemistry can often create challenges for students and lead to misconceptions (Omiko, 2017).

In science education, accurately assessing students' comprehension of complex concepts is essential for effective teaching and learning (Ogden, 2017; Chen, 2023). Therefore, developing and validating assessment instruments is crucial for evaluating students' understanding and mastery of subject matter, allowing educators to address misconceptions effectively. Misconceptions refer to inaccurate or incomplete understandings of concepts, which can hinder the learning process and impede students' ability to grasp fundamental principles (Lucariello and

Naff, 2010). By acknowledging and addressing prevalent misconceptions in chemistry, educators can create a more effective learning environment that fosters conceptual understanding, critical thinking, and the application of organic chemistry principles across various scientific disciplines. Identifying specific challenging topics through valid and reliable assessments enables the implementation of targeted pedagogical interventions. Furthermore, to ensure effective instruction and assessment in chemistry, it is vital to employ instructional strategies grounded in rigorous research studies focused on student comprehension of fundamental chemistry concepts. This is particularly important in light of recent trends in science education, such as augmented reality and gamification strategies (Papadakis et al., 2023; Zourmpakis et al., 2023).

One of the components of senior high school chemistry is organic chemistry. Organic chemistry talks about the structure, properties, reactions of compounds containing carbon (Sibomana et al., 2021) and the preparation of carbon-containing compounds (Chang & Goldsby, 2016; Miheso & Mavhunga, 2020). Many studies in chemistry education revealed that this topic is quite challenging and difficult for learners (Miheso & Mavhunga, 2020; Sana & Adhikary, 2017; Anim-Eduful & Adu-Gyamfi, 2021; Hanson, 2017). Halford (2016) noted that teaching organic chemistry has long been a crisis, with learners consistently finding it difficult to comprehend. Although organic chemistry makes up only about 20% of the General Chemistry 1 subject, it remains an important topic for Senior High School (SHS) learners. In addition, Hanson (2017) reveals that adequate understanding of basic organic chemistry is crucial for students who will be taking Science-related courses. A solid grasp of organic chemistry enables them to recognize its applications in areas like food, medicine, and detergents (Walag et al., 2020).

The existing literature and studies prompted the researchers to conduct this study to identify what is/are the not mastered, least mastered, nearly mastered, and mastered competencies under organic chemistry through achievement tests. Researchers also seek to examine the grade 11 STEM students' self-efficacy beliefs to organic chemistry competencies. Thus, the results of this study aimed to become a basis for building an educational intervention. For educators, this study provides valuable insights and as a guide for refining teaching strategies and developing customized approaches. The study encourages teachers to adopt evidence-based practices that align with the needs of their students, ensuring a more effective and responsive teaching process that addresses common challenges and difficulties. For curriculum developers, the study highlights specific areas within the organic chemistry curriculum that need reinforcement or restructuring. By utilizing the findings of this study, curriculum designers can create more relevant and practical learning materials and activities that fill these gaps.

METHODOLOGY

The study used a quasi-experimental research design using a test questionnaire as the primary data collection tool to describe mastery level and the not mastered, least mastered, nearly mastered, and mastered competencies of grade 11 STEM students. Also, a self-efficacy questionnaire was done to describe how confident the students are in the different learning competencies under organic chemistry. Through achievement test results, the quasi-experimental approach provides baseline data to identify gaps in competencies that could serve as a foundation for future strategic interventions.

Participants

The research utilized purposive sampling techniques to select the grade 11 students in public high school pursuing the STEM strand. The pilot testing phase of the assessment tool was done at the public high school located in Iligan City, Northern Mindanao, Philippines. The pilot testing was participated in by a total of One Hundred Twenty (120) students. After reviewing all items that passed the evaluation criteria of the pilot testing based on difficulty and discrimination indices, another Forty-Five (45) Grade 11 STEM students were the source of the implementation of the validated test instrument in senior high school organic chemistry. All evaluation activities were conducted through traditional pen-and-paper tests. The participants voluntarily agreed on the condition that all the data gathered will be kept with utmost confidentiality; that their privacy will be considered; that they can withdraw anytime they want; that this activity is free of deception and that they will not be physically and psychologically harmed. These students were selected based on their grade level and willingness to contribute to the research, ensuring ethical standards were upheld throughout the study.

Development of the Assessment Instrument

The multiple-choice achievement test, designed by the researcher, initially consisted of 35 items and aimed to comprehensively assess targeted competencies in organic chemistry within the general chemistry curriculum. To ensure thorough structuring, a Table of Specifications (TOS) was created (Micheal, 2017; Lei et al., 2015; Smith and Holloway, 2020). This TOS was developed based on the levels of cognition outlined in Bloom's Taxonomy. It included aspects such as knowledge domains, levels of cognitive demand, and scientific literacy competencies (Makieiev, 2023; Hartono and Siahaan, 2023). To evaluate both the external and internal qualities of the test instrument, a rubric was established. This rubric was designed to assess the validity of the test's appearance and its construct. To validate the test items, three (3) skilled professionals who are knowledgeable and experts in pure chemistry and chemistry education were engaged for review. Their insights, suggestions, and corrections were incorporated into the refinement process, ultimately resulting in a reduction of the test to 30 items. Following this refinement, the TOS was adjusted to align with the revised test components.

The evaluation of the developed test questionnaire for senior high school organic chemistry utilized a structured set of criteria to ensure its effectiveness. One important criterion was the "level of difficulty," which determined that the test was constructed based on a detailed table of specifications. This approach ensured that the questions were systematically categorized into varying levels of difficulty, allowing for a comprehensive assessment of students' scientific literacy. Another key criterion was the "directions" provided in the test, ensuring that they were appropriately tailored to the learners' level. Clear and precise instructions for each section were essential to minimize misunderstandings and effectively guide students through the test. The "length of the test" was also a critical aspect, ensuring that it contained an appropriate number of items to enhance the reliability of results.

Additionally, the allotted time for completion was matched to the students' grade level capabilities. In terms of "structure," the evaluators confirmed that the test items were free of grammatical errors and faulty stems, and that they included effective distractors to adequately challenge students. Lastly, the "content" of the test was rigorously examined to ensure its alignment with the content standards of the chemistry curriculum. The test items were crafted to accurately assess students' achievement and proficiency, thereby providing a comprehensive evaluation of their understanding in this essential subject area (Munkh-Erdene et al., 2022; Lowmaster, 2023). Furthermore, validation of the items is based on the criteria presented in Table 1.

Table 1. **Parameters of item validation**

Parameters	**Description**
Clarity and balance	The questions are complete; only one question is asked at a time; the participants can understand what is being asked; the questions are unbiased; questions are used using a neutral tone.
Wordiness	The questions are concise and understandable; the use of technical language is minimal and appropriate; the terms used are comprehensible by the target population; the questions are asked using affirmative (e.g. Instead of "Which methods not used" …use "Which methods are used").
Appropriateness of responses listed	The choices listed allow the participants to respond appropriately; the responses apply to all situations or offer a way to respond to unique situations; no responses cover more than one choice.
Application to praxis	The questions asked relate to the participants; daily practices or expertise.
Relationship to the problem	The questions are sufficient to resolve the problem in the study.

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Data Analysis

This research employed a descriptive analysis approach in which each item on the questionnaire was meticulously reviewed by experts using a rubric based on Bloom's taxonomy. This process ensured a comprehensive evaluation of the items, considering both construct and content validity. The experts assessed each item for clarity, relevance, and alignment with the intended constructs, categorizing them into three groups: acceptance, revision, or rejection. Items deemed acceptable directly supported the framework, while those requiring revision were adjusted to better align with the research objectives and validity criteria. Items that did not meet the necessary standards were rejected. This thorough analysis provided a systematic method for refining the assessment tool, ensuring that each item was robust, valid, and effectively measured the targeted constructs.

An item analysis of the pilot group responses was also conducted to assess the performance of individual questions. Cronbach's alpha was calculated to measure the internal consistency among the items. This metric was essential for evaluating the coherence and reliability of the assessment instrument and for identifying items that could potentially be eliminated to enhance overall reliability. Additionally, the discrimination index and percentage of correct answers were analyzed to classify the difficulty level of the items, which was represented graphically. This comprehensive data analysis ensured the reliability and validity of the developed test questionnaire by confirming that the items consistently measured the intended constructs. It provided insights into how well the items correlated with each other and with the overall score, thereby validating the questionnaire's effectiveness in measuring the desired outcomes.

Visual summaries in tabular format were utilized to clearly present the percentage outcomes for each answer choice from the preliminary group that participated in the developed instrument. These tables included metrics such as frequency counts, the percentage of correct responses, and the percentage of commonly incorrect answers, providing a comprehensive overview of the results. This analysis aimed to identify specific organic chemistry concepts that posed challenges for the students, highlighting areas where proficiency was lacking. By visually capturing these data points, the study enhanced the understanding of the students' strengths and weaknesses, paving the way for targeted instructional improvements. After collecting and checking the questionnaires, the results were counted, tabulated, analyzed, and interpreted. The score and its interpretation below were used to describe overall performance, mastery level, and competency in each area.

Table 2. **Self-efficacy scale range and interpretation**

Scale Range	Interpretation
4.20-5.00	Completely Confident
3.40-4.19	Fairly Confident
2.60-3.39	Somewhat Confident
1.80-2.59	Slightly Confident
1.00-1.79	Not Confident at all

Interpretation adapted from the study of Timur and Tasar (2011)

Table 3. **Interpretation on learners' performance on the achievement test**

Percentage	Remarks
90-100	Passed

85-89	Passed
80-84	Passed
75-79	Passed
Below 75	Failed

Reference: DepEd Order No. 8 s, 2015

Table 4. **Mastery level and percentage equivalent**

Mastery Level	**Percentage Equivalent**
Mastered	80-100
Nearly Mastered	75-79
Least Mastered	51-74
Not Mastered	50 and below

Reference: DepEd PPST - Module 11

RESULTS AND DISCUSSION

Self Efficacy Results

The self-efficacy questionnaire consists of twelve (12) statements based on the Most Essential Learning Competencies (MELCs) for senior high school organic chemistry. These questions are designed to evaluate students' confidence levels and perceived abilities in mastering key topics such as the carbon atom, hydrocarbons, functional groups, polymers, and biomolecules. The questionnaire was administered to 45 Grade 11 STEM students, selected to represent the study's target demographic. Each question is aligned with specific learning outcomes to ensure that it effectively captures the learners' self-efficacy beliefs. After administering the questionnaire, the responses were collected, organized, and analyzed to identify trends and patterns in the students' confidence and self-assessment regarding their understanding of organic compounds. The summarized results presented provide a comprehensive overview of the students' self-efficacy levels and offer valuable insights into areas that need strategic intervention to enhance their understanding and performance in organic chemistry.

Table 5. **Self-efficacy summary of results (N=45)**

Statement	Not Confident at All (%)	Slightly Confident (%)	Somewhat Confident (%)	Quite Confident (%)	Extremely Confident (%)
1. I can describe the special nature of carbon in bonding.	**4** (8.9%)	**12** (26.7%)	**13** (28.9%)	**9** (20%)	**7** (15.6%)
2. I can list general characteristics of organic compounds.	**6** (13.3%)	**11** (24.4%)	**16** (35.6%)	**7** (15.6%)	**5** (11.1%)

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3. I can describe the bonding in ethane, ethene and ethyne and explain their geometry in terms of hybridization and σ and carbon- carbon bonds.	**8** (17.8%)	**19** (42.2%)	**10** (22.2%)	**4** (8.9%)	**4** (8.9%)
4. I can describe the different functional groups.	**6** (13.3%)	**16** (35.6%)	**12** (26.7%)	**7** (15.6%)	**4** (8.9%)
5. I can cite uses of representative examples of compounds bearing the different functional groups.	**6** (13.3%)	**15** (33.3%)	**11** (24.4%)	**8** (17.8%)	**5** (11.1%)
6. I can describe structural isomerism and give example/s.	**5** (11.1%)	**10** (22.2%)	**14** (31.1%)	**10**(22.2%)	**6** (13.3%)
7. I can describe some simple reactions of organic compounds: combustion of organic fuels, addition, condensation, and saponification of fats.	**5** (11.1%)	**10** (22.2%)	**14** (31.1%)	**12**(26.7%)	**4** (8.9%)
8. I can describe the formation and structure of polymers.	**6** (13.3%)	**12** (26. %)	**18** (40%)	**5** (11.1%)	**4** (8.9%)
9. I can give examples of polymers.	**4** (8.9%)	**7** (15.6%)	**9** (20%)	**14**(31.1%)	**11** (24.4%)
10. I can explain the properties of some polymers in terms of their structure.	**5** (11.1%)	**14** (31.1%)	**12** (26.7%)	**10**(22.2%)	**4** (8.9%)
11. I can describe some biomolecules: proteins, nucleic acids, lipids, and carbohydrates.	**4** (8.9%)	**10** (22.2%)	**10** (22.2%)	**15**(33.3%)	**6** (13.3%)
12. I can describe the structure of proteins, nucleic acids, lipids, and carbohydrates, and relate them to their function.	**4** (8.9%)	**10** (22.2%)	**11** (24.4%)	**14**(31.1%)	**6** (13.3%)

The results of the self-efficacy questionnaire reveal varying levels of confidence among the Forty-Five (45) Grade 11 STEM students regarding the different competencies in organic chemistry. For fundamental topics, such as the nature of carbon in bonding and listing the general characteristics of organic compounds, a significant portion of students demonstrated moderate confidence, with most categorizing themselves as “somewhat confident” or "slightly confident." However, a relatively low number of students reported feeling “quite confident” or “extremely confident” in these areas, indicating a need for improvement in foundational knowledge.

Topics requiring higher-order thinking, such as explaining the bonding and geometry in ethane, ethene, and ethyne, as well as describing functional groups and their uses, proved particularly challenging for the learners. These areas showed a higher frequency of responses in the "slightly confident" category, suggesting that targeted instructional strategies and practice are needed to enhance student confidence in these competencies. In terms of applied knowledge—such as describing structural isomerism, reactions of organic compounds, and polymer-related topics—students' confidence was distributed across all categories.

Competencies like providing examples of polymers and describing biomolecules had a more favorable

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confidence distribution, with notable percentages of respondents expressing that they were "quite confident." However, even in these relatively stronger areas, the responses highlighted the need to reinforce complex connections, such as relating the structure of biomolecules to their function. Overall, the data emphasizes the necessity for a strategic intervention to address these gaps, particularly in advanced topics, while also solidifying foundational concepts to boost both self-efficacy and mastery levels.

Performance of the Learners on the Achievement Test

Another important aspect being focused on the study is the performance of the students in organic chemistry. An achievement test was conducted, and data were interpreted using the descriptions in Table 3.

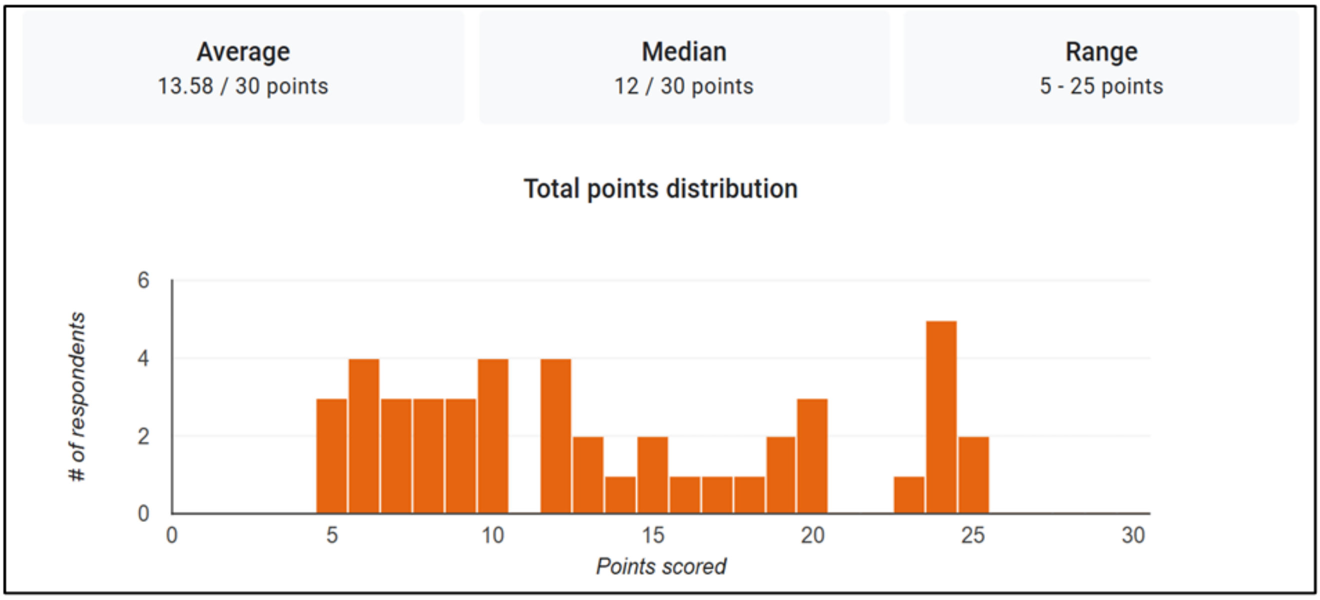

Figure 1. Total Points Distribution

The results from the assessment revealed interesting findings when analyzing the outcomes across different categories of questions. Figure 1 shows the total points distribution of the students on the achievement test. The scores illustrated in Figure 1 indicate that the majority of students achieved scores lower than 50%, highlighting their inadequate performance. The scores range from 5 (lowest score) to 25 (highest score). Meanwhile, the average score is 13.58 while the median is 12. The figure also revealed that the scores of the students are concentrated in the left side of the graph (low scores).

Mastery Level of Grade 11 STEM Learners on Organic Chemistry Competencies

The main highlights of this study were to determine the mastery level of the students on organic chemistry competencies. Their performance in different competencies is a critical indicator of their understanding of foundational concepts and applications. Assessing students' proficiency in these competencies provides valuable insights into their strengths and areas for improvement, which can guide targeted interventions to enhance their learning outcomes and overall performance in this challenging subject.

Table 6. **Mastery Level of Grade 11 STEM Learners on Organic Chemistry Competencies**

Learning Competency	**Item number**	**Frequency of error**	**Mean and %**	**No. of correct responses**	**Mean and %**	**Mastery Level**
Describe the special nature of carbon	2	25	25 (56%)	20	20 (44%)	**Not Mastered**

List general characteristics of organic compounds	1	21	21 (47%)	24	24 (53%)	**Least Mastered**
Describe the bonding in ethane, ethene and ethyne and explain their geometry in terms of hybridization and σ and carbon-carbon bonds.	3 4 5	20 24 25	23 (51%)	25 21 20	22 (49%)	**Not Mastered**
Describe the different functional groups	7 8 10 12	25 22 25 32	26 (58%)	20 23 20 13	19 (42%)	**Not mastered**
Cite representative examples of compounds bearing the different functional groups.	6 9 11 13 14	22 22 16 28 19	21 (47%)	23 23 29 17 26	24 (53%)	**Least mastered**
Describe structural isomerism; give example	15 16	16 29	22 (49%)	29 16	23 (51%)	**Least mastered**
Describe some simple reactions of organic compounds: combustion of organic fuels, addition, condensation, and saponification of fats.	17 18	26 26	26 (58%)	19 19	19 (42%)	**Not mastered**
Describe the formation and structure of polymers	19	26	26 (58%)	19	19 (42%)	**Not mastered**
Give examples of polymers	21	27	27 (60%)	18	18 (40%)	**Not mastered**

Explain the properties of some polymers in terms of their structure	20	26	26 (58%)	19	19 (42%)	**Not mastered**
Describe some biomolecules: proteins, nucleic acids, lipids, and carbohydrates	22 24 27 29	28 28 26 17	25 (56%)	17 17 19 28	20 (44%)	**Not mastered**
Describe the structure of proteins, nucleic acids, lipids, and carbohydrates, and relate them to their function	23 25 26 28 30	27 30 23 30 28	28 (62%)	18 15 22 15 17	17 (38%)	**Not mastered**
Mean Percentage Score					45%	**Not mastered**

Legend: Not mastered (50 % below), Least mastered (51 - 74%), Nearly Mastered (75 - 79%), Mastered (80 - 100*%)*

Table 7 shows that many students exhibited low mastery of organic chemistry competencies, with several competencies below 50% correct response rate. Only a few areas, such as listing the general characteristics of organic compounds (53%) and identifying examples of compounds with different functional groups (53%), were categorized as "least mastered." Although these scores are slightly higher, significant gaps in understanding remain, particularly in identifying and applying foundational concepts in organic chemistry.

Competencies like describing structural isomerism (51%) and describing the bonding in ethane, ethene, and ethyne (49%), showed minor improvement but still did not reach mastery levels. Areas requiring attention include describing biomolecules (44%) and their structures and functions (38%), as well as understanding the formation and properties of polymers (42%). Students particularly struggled with describing simple reactions of organic compounds (42%) and recognizing the unique properties of carbon (44%). These results underscore the need for targeted instructional interventions that emphasize hands-on activities and conceptual clarity to address knowledge gaps and improve comprehension of both theoretical and practical aspects of organic chemistry.

CONCLUSION AND RECOMMENDATION

The findings reveal that the mastery level of Grade 11 STEM learners in organic chemistry competencies is relatively low, with several competencies in the "not mastered" category and a few in the "least mastered" category. Students faced challenges particularly with competencies related to the special nature of carbon, functional groups, simple reactions of organic compounds, polymer and its properties, and biomolecules, indicating significant gaps in both foundational knowledge and applied understanding. This lack of mastery underscores the need for improved teaching strategies, focused interventions, and instructional materials tailored to address these deficiencies. The results emphasize the importance of reinforcing critical concepts in organic chemistry to better equip students for advanced studies and practical applications in STEM fields. To address the identified gaps in mastery, the researchers suggest that teachers may implement strategic interventions such as differentiated instruction, the use of computer-aided instruction, interactive laboratory activities, game-based intervention and the like to enhance conceptual understanding and retention. Developing targeted assessment tools and remedial programs focused on these weak areas can also provide personalized support to learners. Additionally, incorporating collaborative learning strategies such as game-based learning and leveraging technology through simulations and educational apps, can foster engagement and deeper comprehension among students. For long-term improvement, curriculum designers should consider integrating organic chemistry topics more progressively, ensuring a balance between theoretical and practical aspects, to build a strong foundation for students' success in STEM careers.

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