Bridging Learning Gaps in General Chemistry: Diagnostic Insights into Mastery and Self-Efficacy

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ABSTRACT

This study aimed to develop a validated, standardized assessment tool to identify the least mastered competencies in the topic of Solutions in General Chemistry and to examine the self-efficacy of Grade 12 learners across multiple academic strands, including STEM, ABM, HUMSS, ICT, and TVL. Employing a quantitative research design with qualitative support, the study collected quantitative data through the researcher-developed assessment instrument and qualitative data via an open-ended self-efficacy questionnaire, which was analyzed thematically. The assessment tool underwent expert validation, readability testing, pilot testing, item analysis, and reliability evaluation. From an initial 50-item test, 37 items were retained in the final version, which demonstrated good reliability (Cronbach's α = 0.804). Results indicated that learners' overall mastery was generally low, with most students scoring below 50% of the total score. All five learning areas—solubility rules, factors affecting solubility, concentration units, colligative properties, and colloids and emulsions—were classified as least mastered or not mastered, with the lowest performance observed in factors affecting solubility and concentration units. Qualitative findings revealed that self-efficacy was highly variable and influenced by topic difficulty, clarity of instruction, and available learning support. Mathematical complexity, abstract concepts, and cognitive load negatively affected confidence, whereas persistence, self-regulated learning strategies, peer collaboration, and supportive teaching practices enhanced learners' self-efficacy. Overall, the study highlights significant cognitive and affective challenges in General Chemistry and underscores the value of diagnostic assessments and innovative, learner-centered instructional approaches. Future research may investigate the efficacy of strategies such as chemistry-based games, simulations, tactile learning, and collaborative activities to improve mastery and self-efficacy.

Key Words: Chemistry Competencies, Mastery Level, Self-efficacy, Solutions

INTRODUCTION

Chemistry education plays a central role in cultivating learners' scientific literacy, analytical reasoning, and problem-solving abilities—skills critical for success in the twenty-first century. General Chemistry, a core component of the Senior High School curriculum, provides foundational knowledge for further studies in science-related disciplines and prepares learners for the application of scientific principles in real-world contexts. Despite its significance, research consistently indicates that learners perceive chemistry as a difficult subject due to its abstract concepts, symbolic representations, and the integration of quantitative problem-solving (Cooper & Klymkowsky, 2020; Taber, 2022). These challenges often contribute to low academic achievement, reduced confidence, and diminished interest in the subject.

Among General Chemistry topics, solutions present particular difficulties for learners. Mastery in this domain requires integration across multiple representations—macroscopic, submicroscopic, and symbolic—as well as competence in mathematical reasoning. Empirical studies have demonstrated persistent challenges among learners in understanding solubility behavior, concentration units, and colligative properties, as well as applying these concepts to problem-solving and real-life situations (Towns, Raker, & Becker, 2020; Cooper, Underwood, & Hilley, 2021). These conceptual deficits highlight the need for systematic assessment of learners' mastery levels in solution-related topics.

Accurate and reliable assessment is essential for identifying learning gaps and informing instructional planning. Contemporary research emphasizes the importance of rigorous validation procedures, including item analysis, reliability testing, and alignment with curricular competencies, to ensure that assessment instruments effectively measure intended learning outcomes (Brookhart, 2020; DeVellis, 2021). Without validated instruments, educational decisions may be based on incomplete or inaccurate information, limiting the capacity to address learners' individual needs.

In addition to cognitive skills, affective factors such as self-efficacy significantly influence chemistry learning. Learners with higher self-efficacy exhibit increased motivation, persistence, and effective learning strategies, whereas those with low self-efficacy are more prone to anxiety, cognitive overload, and avoidance behaviors (Bandura, 2020; Schunk & DiBenedetto, 2020; Honicke, Broadbent, & Fuller-Tyszkiewicz, 2022).

In the Philippine context, learners in Senior High School STEM and non-STEM strands exhibit diverse academic backgrounds and variable proficiency in science and mathematics. Local research has reported that many learners demonstrate low to moderate mastery of key chemistry competencies, particularly in conceptually complex and mathematically demanding topics (Poblete et al., 2025). These studies underscore persistent difficulties in applying chemistry concepts to problem-solving scenarios, reflecting gaps in both conceptual understanding and procedural skills.

To address these challenges, the present study developed and validated a standardized assessment tool focusing on solutions in General Chemistry and examined learners' self-efficacy in learning the subject. The findings provide empirical evidence to support instructional planning, curriculum refinement, and the adoption of learner-centered strategies aimed at enhancing both conceptual mastery and affective competence in chemistry education.

METHODOLOGY

This study employed a quantitative research design complemented by qualitative data to investigate Grade 12 learners' mastery of solutions-related competencies in General Chemistry and their self-efficacy in learning the topic. The mixed-methods approach facilitated a comprehensive understanding of learners' cognitive performance and affective experiences.

Participants. Participants included Grade 12 learners across multiple academic strands: Science, Technology, Engineering, and Mathematics (STEM); Accountancy, Business, and Management (ABM); Humanities and Social Sciences (HUMSS); Information and Communication Technology (ICT); and Technical-Vocational-Livelihood (TVL). Inclusion of learners from diverse strands ensured broad representation of academic backgrounds.

A total of 150 learners participated in the pilot testing of the initial 50-item assessment tool, adhering to a recommended 3:1 ratio of participants to items for reliable item analysis. These pilot participants were not included in the main study to prevent test familiarity. During the final administration, a 37-item standardized and validated assessment tool was completed by 111 Grade 12 learners, sufficient to ensure reliable measurement of mastery levels across solution-related competencies.

Research Instruments. Two primary instruments were used. First is the Diagnostic Assessment Tool – A researcher-developed, standardized assessment aligned with Senior High School Most Essential Learning Competencies (MELCs) covering key topics in solutions, including solubility rules, concentration units, factors affecting solubility, colligative properties, and colloids and emulsions. Version 2 of the tool underwent rigorous validation by three content and pedagogy experts, evaluating content validity, clarity, difficulty, quality of distractors, alignment with learning objectives, and format consistency. Readability testing ensured accessibility for Senior High School learners. Second is the Self-Efficacy Questionnaire – an open-ended qualitative instrument administered to 20 learners to capture perceptions of competence, strategies for overcoming difficulties, teacher support, and transfer of learning in General Chemistry. Responses were analyzed thematically to contextualize quantitative results and provide deeper insights into learners' affective experiences.

Data Collection and Analysis. Quantitative data from the diagnostic assessment were analyzed to determine learners' overall mastery levels, performance per content area, and least mastered competencies. Qualitative data from the self-efficacy questionnaire were subjected to thematic analysis, identifying recurring patterns, influences on learner confidence, and factors affecting performance. Integration of quantitative and qualitative findings facilitated a holistic interpretation of learners' cognitive and affective profiles in General Chemistry.

Table 1: Mean Rating Descriptor on the Assessment Tool Validation

Scale/Range	Decision	Description
1-1.19	REJECT	Not acceptable. Revamp the test items.
2.0-2.9	MODIFY	Acceptable, but requires slight revision.
3.0-4.0	ACCEPT	Acceptable, no modification needed.

Statistical Tools. Appropriate statistical techniques were employed to analyze the data collected in this study. The mean ($\bar{x}$) was calculated to summarize the evaluations provided by content and pedagogy experts during the validation of each assessment item. This measure facilitated informed decisions regarding the retention, revision, or removal of specific test items based on predetermined decision ranges.

To evaluate the readability of the assessment instrument, both the SMOG (Simple Measure of Gobbledygook) Index and the Flesch-Kincaid Grade Level were utilized. The SMOG Index estimates the reading level necessary to comprehend a text by analyzing sentence length and the frequency of polysyllabic words, thereby assessing textual complexity and ensuring accessibility for the target learners. Complementarily, the Flesch-Kincaid Grade Level translates text difficulty into a corresponding U.S. school grade level, providing an estimate of the formal education required to understand the content. These readability measures ensured that the assessment tool was appropriate for Senior High School learners' literacy levels.

Following pilot testing, item analysis was conducted to evaluate the quality of individual items and the assessment as a whole. The analysis employed difficulty and discrimination indices to identify items that were ambiguous, confusing, or misaligned with intended learning outcomes. Based on these metrics, items were either retained, revised, or discarded, enhancing the validity and reliability of the instrument. Additionally, percentages (%) were used to describe and interpret the distribution of learner responses across test items and mastery levels, providing a clear overview of performance patterns and areas requiring instructional focus.

Table 2: Difficulty and Discrimination Indices Scale

Range/Scale	Difficulty Index	Discrimination Index
0.86 and above	Very Easy	To be Discarded
0.71-0.85	Easy	To be Revised
0.30-0.70	Moderate	To be Retained
0.15-0.29	Difficult	To be Revised
0.14 and below	Very Difficult	To be Discarded
Adopted from Hopkins and Antes		

Table 3: DepEd Mastery Level Standard Scale

Mastery Level	Standard Scale
Mastered	80% - 100%

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Nearly Mastered	60%-79%
Least Mastered	40%-59%
Not Mastered	0-39%

Table 4: Interpretation of the Learners' Individual Performance in the Assessment

Percentage	**Remarks**
90%-100%	Passed
85%-89%	Passed
80%-84%	Passed
75%-79%	Passed
Below 75%	Failed

Adopted from DepEd Order No. 8 s, 2015

Ethical Considerations. This study strictly adhered to established ethical standards in educational research. Formal permission was obtained from the appropriate school authorities, and informed consent was secured from all participants. Learners were fully apprised of the study's objectives, procedures, and their right to withdraw at any time without academic or personal consequences. Participant confidentiality and anonymity were maintained through the assignment of alphanumeric codes, and all collected data were securely stored and utilized solely for academic and research purposes. The research posed no physical, psychological, or academic risk to participants. In acknowledgment of their time and contribution, appropriate tokens of appreciation were provided to participating learners, teachers, and school administrators.

3. RESULTS AND DISCUSSION

3.1 Standardized Assessment Tool

Following pilot testing, the assessment instrument underwent comprehensive item analysis to evaluate the effectiveness of each question in measuring the intended competencies. Reliability analysis was also conducted to ensure the consistency and dependability of results across diverse learner groups. Based on the outcomes of the item analysis, thirteen (13) items were discarded, seventeen (17) were revised, and twenty (20) items were retained for their effectiveness in assessing targeted competencies. The finalized instrument, comprising 37 refined items, was subsequently administered in the main study to determine the mastery levels of Grade 12 learners across multiple academic strands in the Solutions unit of General Chemistry. This standardized tool provided a valid and reliable measure of learner proficiency, facilitating the identification of least mastered competencies and informing targeted instructional strategies.

Table 5: Summary of the Item Analysis

Item No.	**Difficulty Index**	**Interpretation**	**Discrimination Index**	**Remarks**
1	0.79333	Easy	0.14634	Revise
2	0.19333	Difficult	0.19512	Revise
3	0.32667	Moderate	0.41463	Retain
4	0.38000	Moderate	-0.09756	Discard
5	0.62667	Moderate	0.41463	Retain
6	0.29333	Difficult	0.19512	Revise
7	0.29333	Difficult	0.51220	Retain

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8	0.36000	Moderate	0.46341	Retain
9	0.31333	Moderate	0.36585	Retain
10	0.33333	Moderate	0.43902	Retain
11	0.32000	Moderate	0.63415	Retain
12	0.27333	Difficult	-0.21951	Discard
13	0.64000	Moderate	0.63415	Retain
14	0.21333	Moderate	0.21951	Revise
15	0.42000	Moderate	0.73171	Revise
16	0.74000	Easy	0.56098	Retain
17	0.20667	Difficult	0.09756	Discard
18	0.69333	Moderate	0.26829	Revise
19	0.15333	Difficult	0.24390	Revise
20	0.34000	Moderate	0.02439	Discard
21	0.24000	Moderate	0.12195	Discard
22	0.50667	Moderate	0.46341	Retain
23	0.24000	Difficult	0.31707	Retain
24	0.28667	Difficult	0.19512	Revise
25	0.29333	Difficult	0.46341	Retain
26	0.31333	Moderate	0.39024	Retain
27	0.26000	Difficult	0.17073	Revise
28	0.22000	Difficult	-0.24390	Discard
29	0.32667	Moderate	0.21951	Revise
30	0.32000	Moderate	0.09756	Discard
31	0.64000	Moderate	0.41463	Retain
32	0.52000	Moderate	0.56098	Retain
33	0.12000	Very Difficult	-0.09756	Discard
34	0.16667	Difficult	-0.07317	Discard
35	0.18667	Difficult	0.41463	Retain
36	0.15333	Difficult	-0.02439	Discard
37	0.61333	Moderate	0.19512	Revise
38	0.55333	Moderate	0.51220	Retain
39	0.46667	Moderate	0.36585	Retain
40	0.40667	Moderate	0.19512	Revise
41	0.13333	Very Difficult	0.26829	Revise
42	0.26667	Difficult	0.29268	Revise
43	0.16000	Difficult	0.12195	Discard
44	0.27333	Difficult	0.19512	Revise
45	0.37333	Moderate	0.09756	Discard
46	0.44667	Moderate	0.82927	Revise
47	0.08000	Very Difficult	-0.07317	Discard
48	0.30667	Moderate	0.41463	Retain
49	0.32000	Moderate	0.39024	Retain
50	0.38000	Moderate	0.56098	Retain
Interpretation: ≥0.86 (Very Easy, Discard) 0.71-0.85 (Easy, Revise) 0.30-0.70 (Moderate, Retain) 0.15-0.29 (Difficult, Revise) ≤0.14 (Very Difficult, Discard)				

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Reliability of the Assessment Tool. The reliability of the assessment instrument was evaluated through Cronbach's alpha coefficient during both pilot testing and actual implementation. As shown in Table 6, the pilot test produced a Cronbach's alpha of 0.748, indicating an acceptable level of internal consistency. This result suggests that the items within the pilot version of the assessment were moderately consistent in measuring learners' conceptual understanding of the topic, reflecting satisfactory reliability for educational assessments.

During the main implementation, the standardized 37-item tool demonstrated an improved Cronbach's alpha of 0.804 (Table 7), representing a good level of reliability. This finding indicates that the items were highly consistent in assessing learners' comprehension of solution-related concepts in General Chemistry. The strong internal consistency supports the dependability of the instrument and confirms that it can reliably produce stable results across diverse learner groups. Moreover, the high reliability coefficient demonstrates the tool's suitability for accurately measuring student performance, identifying least mastered competencies, and informing instructional planning and targeted interventions.

Table 6: Reliability Test Result Statistics (Pilot Testing)

	Mean	**SD**	**Cronbach's α**
scale	0.35	0.123	0.748
Reliability Interpretation: α ≥0.9 (Excellent) α=0.8-0.89 (Good) α=0.70-0.79 (Acceptable) α=0.60-0.69 (Questionable) α=0.50-0.59 (Poor) α<0.50 (Unacceptable)			

Table 7: Reliability Test Result Statistics (Actual Implementation)

	Mean	**SD**	**Cronbach's α**
scale	0.474	0.17	0.804
Reliability Interpretation: α ≥0.9 (Excellent) α=0.8-0.89 (Good) α=0.70-0.79 (Acceptable) α=0.60-0.69 (Questionable) α=0.50-0.59 (Poor) α<0.50 (Unacceptable)			

3.2 Learners' Performance in the Standardized Assessment Tool

The finalized 37-item standardized assessment was administered to a total of one hundred eleven (111) Grade 12 learners enrolled in multiple academic strands at a public senior high school in Misamis Occidental, Philippines. The instrument was designed to evaluate students' mastery of solution-related competencies in General Chemistry, including solubility rules, concentration units, colligative properties, and related quantitative and conceptual skills. Data collected from this administration provided a comprehensive overview of learners' performance, enabling the identification of overall mastery levels, specific least mastered competencies, and patterns in conceptual understanding across diverse learner groups.

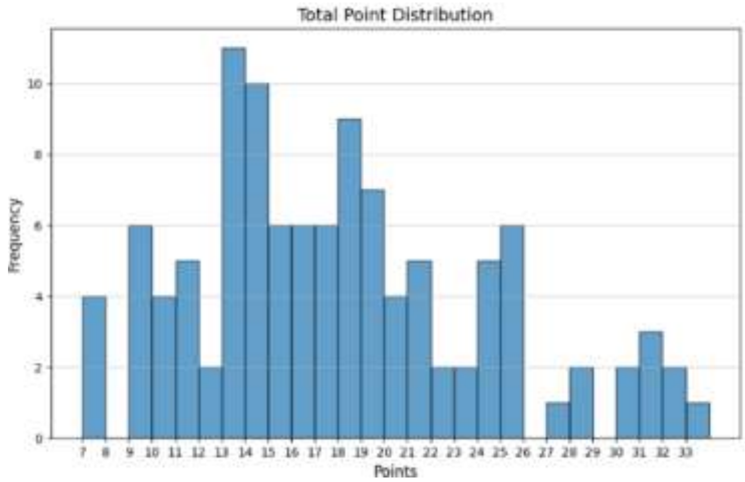

Figure 1: Total Points Distribution

3.3 Distribution of Learners' Scores in the Standardized Assessment

Figure 1 depicts the distribution of scores obtained by the 111 Grade 12 learners on the 37-item standardized assessment. The x-axis represents the score ranges, while the y-axis reflects the number of learners within each range. Scores spanned from a minimum of 7 to a maximum of 33, with a median score of 17. The distribution demonstrates a left-skewed pattern, indicating that a substantial proportion of learners scored toward the lower end of the scale. Notably, the highest frequency of scores was concentrated between 13 and 14 points, corresponding to less than 50% of the total possible score, which reflects pervasive difficulties in mastering solution-related competencies in General Chemistry.

Table 8 further presents the individual percentage scores of learners alongside their corresponding performance interpretations. Analysis of these data reveals that only 10 out of 111 learners (9%) achieved a passing score of 75% or higher. The majority of learners scored below the proficiency threshold, highlighting widespread conceptual and procedural challenges in the targeted chemistry topics. This finding underscores the need for targeted instructional interventions and enhanced support to address the observed learning gaps.

Table 8: Individual Performance of the Learners in the Standardized Assessment Tool

Student ID No.	Score	Percentage	Interpretation
L1	22	59%	Failed
L2	11	30%	Failed
L3	33	89%	Passed
L4	21	57%	Failed
L5	14	38%	Failed
L6	12	32%	Failed
L7	25	68%	Failed
L8	18	49%	Failed
L9	17	46%	Failed
L10	15	41%	Failed
L11	13	35%	Failed
L12	11	30%	Failed
L13	16	43%	Failed
L14	10	27%	Failed
L15	21	57%	Failed
L16	13	35%	Failed
L17	13	35%	Failed
L18	7	19%	Failed
L19	9	24%	Failed
L20	16	43%	Failed
L21	18	49%	Failed
L22	18	49%	Failed
L23	16	43%	Failed
L24	18	49%	Failed
L25	13	35%	Failed
L26	18	49%	Failed
L27	18	49%	Failed

L28	17	46%	Failed
L29	16	43%	Failed
L30	18	49%	Failed
L31	12	32%	Failed
L32	16	43%	Failed
L33	9	24%	Failed
L34	14	38%	Failed
L35	9	24%	Failed
L36	16	43%	Failed
L37	14	38%	Failed
L38	17	46%	Failed
L39	11	30%	Failed
L40	13	35%	Failed
L41	13	35%	Failed
L42	17	46%	Failed
L43	14	38%	Failed
L44	7	19%	Failed
L45	19	51%	Failed
L46	7	19%	Failed
L47	19	51%	Failed
L48	19	51%	Failed
L49	11	30%	Failed
L50	9	24%	Failed
L51	13	35%	Failed
L52	32	86%	Passed
L53	31	84%	Passed
L54	24	65%	Failed
L55	23	62%	Failed
L56	15	41%	Failed
L57	15	41%	Failed
L58	18	49%	Failed
L59	20	54%	Failed
L60	11	30%	Failed
L61	9	24%	Failed
L62	21	57%	Failed
L63	10	27%	Failed
L64	20	54%	Failed
L65	21	57%	Failed
L66	14	38%	Failed
L67	10	27%	Failed
L68	14	38%	Failed
L69	30	81%	Passed
L70	31	84%	Passed

L71	24	65%	Failed
L72	24	65%	Failed
L73	14	38%	Failed
L74	15	41%	Failed
L75	18	49%	Failed
L76	25	68%	Failed
L77	14	38%	Failed
L78	7	19%	Failed
L79	22	59%	Failed
L80	9	24%	Failed
L81	24	65%	Failed
L82	20	54%	Failed
L83	14	38%	Failed
L84	10	27%	Failed
L85	13	35%	Failed
L86	32	86%	Passed
L87	30	81%	Passed
L88	25	68%	Failed
L89	27	73%	Failed
L90	15	41%	Failed
L91	19	51%	Failed
L92	17	46%	Failed
L93	23	62%	Failed
L94	17	46%	Failed
L95	13	35%	Failed
L96	20	54%	Failed
L97	14	38%	Failed
L98	24	65%	Failed
L99	25	68%	Failed
L100	13	35%	Failed
L101	13	35%	Failed
L102	19	51%	Failed
L103	25	68%	Failed
L104	28	76%	Passed
L105	25	68%	Failed
L106	28	76%	Passed
L107	15	41%	Failed
L108	19	51%	Failed
L109	21	57%	Failed
L110	19	51%	Failed
L111	31	84%	Passed
Overall	**17.52252**	**47%**	**Failed**
Interpretation: 75%-100% - Passed Below 75% - Failed			

3.4 Mastery Level of Grade 12 Learners in General Chemistry (Solutions)

This section examines the mastery levels of Grade 12 learners in General Chemistry, with a specific focus on the topic of Solutions. Evaluating learners' mastery provides critical insights into both their strengths and areas of difficulty, serving as a foundation for targeted instructional interventions aimed at enhancing conceptual understanding and overall academic performance. Table 9 and Figure 2 summarize the percentage mastery results for each assessed competency within the Solutions topic, offering a clear depiction of learner proficiency and identifying specific areas that require remediation.

Table 9: Mastery Level of the Grade 12 Learners in Solutions

Learning Competency/Topic	Item No.	No. of Correct Responses	No. of Incorrect Responses	Percentage	Mastery Level	Mean Percent	Mastery Level
Solubility Rules	1	91	20	81.98%	Mastered	47.35%	Least Mastered
	4	62	49	55.86%	Least Mastered		
	5	53	58	47.75%	Least Mastered		
	6	49	62	44.14%	Least Mastered		
	19	40	71	36.04%	Not Mastered		
	20	45	66	40.54%	Least Mastered		
	25	57	54	51.35%	Least Mastered		
	31	35	76	31.53%	Not Mastered		
	32	41	70	36.94%	Not Mastered		
Factors Affecting the Solubility of a Substance	2	42	69	37.84%	Not Mastered	35.14%	Not Mastered
	7	40	71	36.04%	Not Mastered		
	8	37	74	33.33%	Not Mastered		
	33	37	74	33.33%	Not Mastered		
Different Ways in Expressing Concentration of Solutions	9	53	58	47.75%	Least Mastered	46.25%	Least Mastered
	10	39	72	35.14%	Not Mastered		
	11	75	36	67.57%	Nearly Mastered		
	12	46	65	41.44%	Least Mastered		
	13	49	62	44.14%	Least Mastered		
	16	43	68	38.74%	Not Mastered		
	21	41	70	36.94%	Not Mastered		
	26	36	75	32.43%	Not Mastered		
	27	73	38	65.77%	Nearly Mastered		
	28	62	49	55.86%	Least Mastered		
	34	60	51	54.05%	Least Mastered		
	35	39	72	35.14%	Not Mastered		
The Effect of Concentration on the Colligative Properties of Solutions	3	61	50	54.95%	Least Mastered	55.60%	Least Mastered
	14	88	23	79.28%	Nearly Mastered		
	15	77	34	69.37%	Nearly Mastered		
	29	38	73	34.23%	Not Mastered		
	30	58	53	52.25%	Least Mastered		

	22	67	44	60.36%	Nearly Mastered		
	36	43	68	38.74%	Not Mastered		
Colloids and Emulsion	17	60	51	54.05%	Least Mastered	48.29%	Least Mastered
	18	42	69	37.84%	Not Mastered		
	23	42	69	37.84%	Not Mastered		
	24	80	31	72.07%	Nearly Mastered		
	37	44	67	39.64%	Not Mastered		
Interpretation: Mastered (80%-100%) Nearly Mastered (60%-79%) Least Mastered (40%-59%) Not Mastered (≤39%)							

In Table 9, analysis of learner performance across the Solutions topic revealed significant variability in mastery levels among different subtopics. Under Solubility Rules, Item 1 demonstrated the highest level of mastery, with 81.89% of learners responding correctly, indicating a solid understanding of fundamental solubility principles. In contrast, several items—such as Item 5 (47.75%) and Item 31 (31.53%)—were categorized as least mastered and not mastered, respectively, highlighting persistent difficulties with specific solubility concepts. Overall, the mastery level for Solubility Rules was 47.35%, classified as least mastered, underscoring the need for targeted instructional reinforcement.

Regarding factors affecting solubility, all items yielded mastery levels below 39%, placing them in the not mastered category. The low percentage of correct responses suggests considerable gaps in understanding the influence of variables such as temperature and pressure on solubility. The overall mastery for this subtopic was 35.14%, indicating a clear need for in-depth discussion and clarification.

In concentration units, Items 11 (67.57%) and 27 (65.77%) were nearly mastered, reflecting that learners could correctly apply concentration concepts in more straightforward contexts. However, the remaining items were classified as least mastered or not mastered, demonstrating difficulty in expressing solution concentration in diverse formats, including molarity and molality. The overall mastery level for concentration units was 46.25%, classified as least mastered.

Learners' performance on colligative properties was mixed. Items 14 (79.28%), 15 (69.37%), and 22 (60.36%) were nearly mastered, suggesting a partial conceptual understanding among students. Yet, other items fell within the least mastered or not mastered range, resulting in an overall mastery of 55.60%, categorized as least mastered. This finding highlights the need for focused instruction to reinforce comprehension of colligative properties.

For colloids and emulsions, all items were within the not mastered to least mastered range, with correct response rates ranging from 37.84% to 72.07%. The overall mastery level was 48.29%, indicating substantial gaps in understanding, particularly in distinguishing colloids, suspensions, and emulsions, as well as applying these concepts to real-world contexts.

The observed mastery patterns suggest that innovative instructional strategies are warranted to address both cognitive and affective challenges in chemistry learning. Approaches such as game-based learning, collaborative activities, and technology-integrated instruction can foster active engagement, interaction, and enjoyment while maintaining academic rigor (Sailer & Homner, 2020; Dichev & Dicheva, 2023). These methods also support the development of essential 21st-century skills, including critical thinking, communication, collaboration, creativity, and digital literacy, which are increasingly emphasized in contemporary science education frameworks (OECD, 2021; Dede, 2022).

Figure 2 presents the distribution of learners' mastery levels across five key content areas under the General Chemistry topic of Solutions. Overall, the chart reveals consistently low mastery across all competencies, indicating widespread conceptual and procedural difficulties among the learners.

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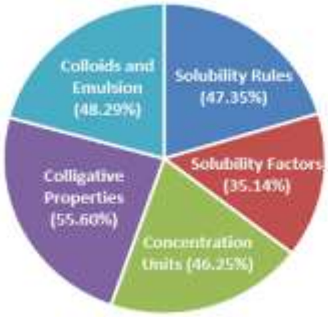

Figure 2: Summary of Mastery Level in Solutions

Among the five domains, Colligative Properties registered the highest mastery level at 55.60%. Although this area performed relatively better than the others, it still falls within the least mastered classification, suggesting that learners possess only partial understanding of concepts such as vapor pressure lowering, boiling point elevation, freezing point depression, and osmotic pressure. This pattern implies that while some foundational ideas are grasped, deeper conceptual integration and problem-solving proficiency remain limited.

The mastery levels for Colloids and Emulsion (48.29%), Solubility Rules (47.35%), and Concentration Units (46.25%) are closely clustered and all fall below the 50% threshold. These results indicate that learners struggle with both conceptual distinctions (e.g., colloids vs. suspensions, soluble vs. insoluble compounds) and quantitative representation s (e.g., molarity, molality, and percent concentration). The near-uniformity of these low percentages suggests systemic challenges in linking symbolic representations, mathematical reasoning, and conceptual understanding.

The lowest mastery level was observed in Factors Affecting Solubility, which obtained only 35.14%. This area is categorized as not mastered and represents the most critical learning gap. The result indicates significant difficulty in understanding how variables such as temperature, pressure, and the nature of solute and solvent influence solubility. The abstract and multi-variable nature of these concepts likely contributes to learners' poor performance, particularly when instruction emphasizes memorization rather than conceptual explanation.

Taken together, the pie chart highlights that none of the solution-related competencies reached a satisfactory level of mastery. The findings point to the need for targeted instructional interventions, particularly for conceptually abstract and mathematically demanding topics. Diagnostic use of these results can guide teachers in prioritizing remediation efforts, strengthening conceptual scaffolding, and employing learner-centered strategies—such as visualizations, simulations, and contextualized problem-solving—to improve mastery and deepen understanding in General Chemistry.

3.5 Mastery Levels of Grade 12 Learners across Strands

Table 10 presents the mastery levels of Grade 12 learners across the STEM, ABM, HUMSS, ICT, and TVL strands in the topic of Solutions, as measured through mean percentage scores and corresponding mastery level.

Table 10: Mastery Levels of Grade 12 Learners in STEM, ABM, HUMSS, ICT, and TVL Strands in Solutions

Learning Competency /Topic	**STEM**		**ABM**		**HUMSS**		**ICT**		**TVL**	
	Mean Percentage	Mastery Level	Mean Percentage	Mastery Level	Mean Percentage	Mastery Level	Mean Percentage	Mastery Level	Mean Percentage	Mastery Level
Solubility Rules	59.85%	Least Mastered	46.67%	Least Mastered	41.88%	Least Mastered	40.35%	Least Mastered	33.78%	Not Mastered
Factors Affecting the	46.02%	Least Mastered	30.00%	Not Mastered	32.69%	Not Mastered	28.95%	Not Mastered	24.00%	Not Mastered

Solubility of a Substance										
Different Ways in Expressing Concentration of Solutions	57.01%	Least Mastered	44.17%	Least Mastered	40.38%	Least Mastered	48.25%	Least Mastered	29.67%	Not Mastered
The Effect of Concentration on the Colligative Properties of Solutions	64.29%	Nearly Mastered	58.57%	Least Mastered	56.04%	Least Mastered	50.38%	Least Mastered	42.86%	Least Mastered
Colloids and Emulsion	55.91%	Least Mastered	44.00%	Least Mastered	47.69%	Least Mastered	51.58%	Least Mastered	34.40%	Not Mastered
Interpretation: Mastered (80%-100%) Nearly Mastered (60%-79%) Least Mastered (40%-59%) Not Mastered (≤39%)										

The results indicate that learners across all strands generally demonstrate low to marginal mastery of the competencies under the Solutions topic, with no strand reaching the "Mastered" level (80%–100%) in any of the listed competencies. In terms of Solubility Rules, STEM learners obtained the highest mean percentage (59.85%), followed by ABM (46.67%), HUMSS (41.88%), ICT (40.35%), and TVL (33.78%). Despite STEM learners performing relatively better, their level remained at Least Mastered, while TVL learners fell under Not Mastered, suggesting considerable difficulty in understanding and applying solubility rules, particularly among non-STEM strands. For Factors Affecting the Solubility of a Substance, all strands showed weak performance. STEM learners again achieved the highest mean percentage (46.02%), classified as Least Mastered, whereas ABM, HUMSS, ICT, and TVL learners were all categorized as Not Mastered, with mean percentages ranging from 24.00% to 32.69%. This finding implies that learners struggle with conceptual factors such as temperature, pressure, and nature of solute and solvent, which require higher-order conceptual understanding.

On the other hand, the competency on Different Ways in Expressing Concentration of Solutions revealed similar trends. STEM (57.01%), ABM (44.17%), HUMSS (40.38%), and ICT (48.25%) learners were all classified as Least Mastered, while TVL learners (29.67%) remained Not Mastered. This suggests that mathematical representations of concentration (such as molarity, molality, percent concentration) pose challenges, especially for learners with limited exposure to quantitative problem-solving. However, relatively better performance was observed in The Effect of Concentration on the Colligative Properties of Solutions, particularly among STEM learners, who attained a mean percentage of 64.29%, classified as Nearly Mastered. Nevertheless, ABM, HUMSS, ICT, and TVL learners were still within the Least Mastered category. This indicates that while STEM learners show emerging understanding of abstract relationships between concentration and properties such as boiling point elevation and freezing point depression, mastery remains insufficient across strands. Lastly, for Colloids and Emulsion, STEM (55.91%), ABM (44.00%), HUMSS (47.69%), and ICT (51.58%) learners were classified as Least Mastered, whereas TVL learners (34.40%) were in Not Mastered classification. The results suggest persistent misconceptions or limited retention in the colloids and emulsion. In summary, the findings highlight a consistent pattern wherein STEM learners outperform other strands, yet still fall short of full mastery in most competencies. Non-STEM strands, particularly TVL, demonstrate significantly lower mastery levels, indicating a need for differentiated instruction, contextualized examples, and enhanced remediation strategies. These results underscore the necessity of targeted pedagogical interventions in the Solutions topic to address strand-specific learning gaps and improve overall chemistry learning and achievement.

3.6 Differences in the Mastery Levels among Grade 12 Learners across Strands

To determine the appropriate statistical test for comparing mastery levels among different strands, the data was first checked for normality using the Shapiro-Wilk test. This was performed to check if the mastery levels for each strand followed a normal distribution. This is a critical assumption for the validity of parametric tests like the Analysis of Variance (ANOVA).

Table 11: Normality Test using Shapiro-Wilk

	STEM	ABM	HUMSS	ICT	TVL
N	44	10	13	19	25
Shapiro-Wilk W	0.978	0.879	0.935	0.972	0.97
Shapiro-Wilk p	0.542	0.128	0.391	0.824	0.643
sig. at p <0.05					

As shown in Table 11, the p-values for all strands: STEM (p = 0.542), ABM (p = 0.128), HUMSS (p = 0.391), ICT (p = 0.824), and TVL (p = 0.643), were greater than the 0.05 significance level. This confirms that the mastery scores for all five (5) strands are normally distributed, justifying the use of an Analysis of Variance (ANOVA) to determine if there were statistically significant differences in the mastery levels across the five (5) different strands. Table 12 below revealed a highly significant effect of the strands on test scores, F (4, 106) = 12.2, p < 0.001. Since the p-value is less than the alpha level of 0.05, it indicates that the mastery levels are not equal across all strands. Thus, the results showed a statistically significant difference among strands. However, the ANOVA itself does not specify which stands differ from one another, therefore, requiring a Tukey Post-Hoc analysis.

Table 12: Mastery Levels among Strands using ANOVA

	Sum of Squares	df	Mean Square	F	p
Strand	1374	4	343.5	12.2	<0.001
Residuals	2980	106	28.1		
sig. at p <0.05					

Table 13: Mastery Level Comparison among Strands using Tukey Post-Hoc Test

Comparison							
Strand		**Strand**	**Mean Difference**	**SE**	**df**	**t**	**p_{tukey}**
STEM	-	**ABM**	4.364	1.86	106	2.349	0.138
	-	**HUMSS**	5.133	1.67	106	3.067	0.023
	-	**ICT**	4.679	1.46	106	3.215	0.015
	-	**TVL**	9.084	1.33	106	6.841	<.001
ABM	-	**HUMSS**	0.769	2.23	106	0.345	0.997
	-	**ICT**	0.316	2.07	106	0.152	1
	-	**TVL**	4.72	1.98	106	2.379	0.129
HUMSS	-	**ICT**	-0.453	1.91	106	-0.238	0.999
	-	**TVL**	3.951	1.81	106	2.179	0.196
ICT	-	**TVL**	4.404	1.61	106	2.729	0.056
sig. at p <0.05							

Table 14: Summary Comparison among Strands

Comparison	Mean Difference	Significance (p)	Interpretation
STEM vs. TVL	9.084	< .001	Highly Significant Difference
STEM vs. HUMSS	5.133	0.023	Significant Difference
STEM vs. ICT	4.679	0.015	Significant Difference
STEM vs. ABM	4.364	0.138	No Significant Difference
ICT vs. TVL	4.404	0.056	Borderline, but Not Significant

sig. at $p < 0.05$

As shown in Table 13 and 14, the Tukey Post-Hoc reveals that the STEM strand is the primary driver of this statistical significance. Leaners in STEM achieved significantly higher mastery levels compared to HUMSS, ICT, and TVL. The largest gap was observed between STEM and TVL, with a mean difference of 9.084. Interestingly, while the ABM strand trended higher than the TVL, ICT, and HUMSS, these differences were not statistically significant ($p > 0.05$). This is likely influenced by the smaller sample size (N=10) of the ABM group compared to STEM (N=44), which reduces the statistical power to detect smaller differences. Furthermore, the lack of significant differences between HUMSS, ICT, and TVL suggests that mastery levels among these three (3) strands are relatively comparable. These results suggest that additional academic support or curriculum review may be beneficial for the HUMSS, ICT, and TVL strands to narrow the mastery gap with the STEM group.

The findings align with the Academic Selectivity model of Custodio et al. (2021) regarding STEM performance. It posits that the STEM strand often attracts students with higher pre-existing competencies in Science and Mathematics, and the STEM specifically emphasizes investigative and analytical thinking, which sharpens general test-taking strategies and mastery of core academic concepts. Whereas the lack of significance in the ABM strand is best understood through Cohen's (1988) principles of statistical power, wherein power is heavily influenced by sample size (N). As the sample size decreases, the margin of error increases, making it much harder to reach the $p < 0.05$ threshold. Therefore, if the ABM has larger sample size, the mean difference would likely have reached statistical significance. On the other hand, the observed parity among HUMSS, ICT, and TVL supports the curricular convergence theories of Sarmiento and Orale (2016). They argue that while the Senior High School (SHS) program is diversified by strands, the Core Subjects remain standardized across all tracks. And because students in HUMSS, ICT, and TVL often share similar instructional hours and pedagogical approaches for these core competencies, their academic mastery levels tend to converge. This indicates that, statistically, there is almost no difference between these strands, supporting the idea that non-STEM students achieve a uniform level of mastery in the current educational setup.

3.7 Self-Efficacy of Learners in General Chemistry

This section presents learners' perceptions of their competence and confidence in learning General Chemistry. Twenty (20) Grade 12 learners across multiple academic strands completed a self-efficacy open-ended questionnaire designed to assess perceived ability, responses to difficulty, learning strategies, teacher support, and the transfer of knowledge to novel problems. The qualitative data were thematically analyzed to identify recurring patterns and insights into the cognitive and affective factors influencing learners' engagement and performance in General Chemistry.

Table 15: Learners' Responses to the Self-efficacy Open-ended Questionnaire (Initial Codes to Themes)

Themes	Code and Category Description
Theme 1: Perceived Chemistry Competence	Students' self-evaluation of their ability to understand General Chemistry, ranging from low to high confidence and often dependent on topic, structure, and experience.

Theme 2: Cognitive Load and Learning Barriers	Difficulties encountered in learning chemistry due to abstraction, mathematical demands, instructional pace, and emotional factors.
Theme 3: Persistence and Self-Regulated Learning	Students' ability to persist, manage challenges, and regulate their learning when faced with difficult chemistry concepts or problems.
Theme 4: Learning Strategies and Study Practices	Cognitive and metacognitive strategies used by students to understand concepts and solve chemistry problems.
Theme 5: Use of Learning Resources and Technology	Utilization of digital and supplementary resources to support understanding and problem-solving in chemistry.
Theme 6: Social Support and Collaborative Learning	The role of peer interaction and collaboration in enhancing confidence and understanding in chemistry.
Theme 7: Teacher Influence on Self-Efficacy	Impact of teachers' instructional practices, feedback, pacing, and encouragement on students' confidence in learning chemistry solutions.
Theme 8: Transfer of Learning and Application Confidence	Students' confidence in applying chemistry knowledge to unfamiliar problems and real-life situations.

The qualitative analysis of learners' self-efficacy revealed eight interrelated themes that collectively shape confidence and engagement in General Chemistry.

Theme 1: Perceived Chemistry Competence. Learners exhibited varied levels of self-efficacy. Some reported high confidence, citing improved understanding over time and familiarity with core concepts. Others expressed moderate or low confidence, often contingent upon topic complexity or instructional clarity. Notably, confidence increased when lessons were well-organized, repeated, or linked to practical activities, whereas partial understanding necessitated reliance on external support. These findings indicate that perceived competence is dynamic, influenced by both instructional and experiential factors.

Theme 2: Cognitive Load and Learning Barriers. Respondents consistently identified cognitive and emotional barriers, including difficulties with mathematical computations, formula application, and abstract concepts. Many learners reported feeling overwhelmed by the volume of formulas and the fast pace of instruction, contributing to confusion, reduced confidence, and anxiety. These barriers impeded knowledge transfer and adversely affected problem-solving self-efficacy.

Theme 3: Persistence and Self-Regulated Learning. Despite challenges, many learners demonstrated persistence and self-regulatory behaviors, such as self-review, taking breaks when overwhelmed, and gradually attempting more difficult problems. Students who engaged in sustained practice and strategic learning reported higher confidence in their ability to solve chemistry problems over time.

Theme 4: Learning Strategies and Study Practices. Learners employed a variety of strategies to enhance comprehension, including problem-solving exercises, note-taking, highlighting, and visual representations. While rote memorization and last-minute study were common, deeper approaches—such as integrated learning and self-generated practice—correlated with higher perceived effectiveness and increased confidence, emphasizing the critical role of strategic study behaviors in fostering self-efficacy.

Theme 5: Use of Supplementary Resources and Technology. Participants highlighted the value of technology, including online tutorials, recorded lectures, and interactive quizzes, in reinforcing understanding. Technology allowed learners to control the pace of study and revisit challenging concepts, which enhanced confidence and comprehension.

Theme 6: Social Interaction. Collaborative learning, peer support, and group discussions were consistently cited as beneficial. Learners reported increased confidence when explaining concepts to classmates or engaging in cooperative problem-solving, demonstrating the importance of social interaction in reducing anxiety and strengthening self-efficacy in cognitively demanding subjects.

Theme 7: Teacher-Related Factors. Clear explanations, structured pacing, stepwise guidance, and constructive feedback were reported to enhance learners' confidence. Encouragement and positive reinforcement fostered engagement, while rapid instruction or inadequate feedback negatively impacted self-efficacy, highlighting the teacher's critical role in shaping learner confidence.

Theme 8: Transfer of Knowledge to Novel Situations. Learners' confidence in applying chemistry concepts to unfamiliar problems was conditional. Confidence was higher when problems mirrored classroom examples or when guidance was available. Repeated practice and conceptual understanding improved independent application, yet hesitation persisted in novel contexts, indicating a need for greater scaffolding and exposure to diverse problem types.

Collectively, these findings demonstrate that self-efficacy in General Chemistry is influenced by multiple instructional, cognitive, and social factors (Usher et al., 2020; Ferrell, Phillips, & Barbera, 2021). Learners with weak foundational knowledge exhibited lower motivation and engagement, while those with better conceptual understanding displayed higher persistence and self-confidence (Poblete et al., 2025). These results underscore the reciprocal relationship between academic performance and affective factors in chemistry learning.

CONCLUSION AND RECOMMENDATION

The study concludes that the developed assessment tool for the Solutions topic in General Chemistry is a valid and reliable instrument for measuring learner mastery. Grade 12 learners across various strands exhibited generally low mastery of conceptually and mathematically demanding competencies, particularly factors affecting solubility and concentration units.

Learners' self-efficacy was found to be flexible and strongly influenced by instructional practices, learning strategies, peer and teacher support, and opportunities for higher-order thinking. Limited exposure to real-world applications and complex problem-solving contributed to low confidence and superficial understanding.

Based on these findings, the study recommends:

1. Diagnostic Use of the Assessment Tool: Employ the tool to guide learner-centered, differentiated instruction and to identify least mastered competencies for targeted remediation.
2. Innovative Instructional Strategies: Integrate active and interactive methods, including game-based learning, problem-based activities, simulations, and collaborative tasks, to reduce anxiety, enhance motivation, and promote 21st-century skills.
3. Supportive Educational Environment: Ensure sufficient instructional time, technological resources, and professional development for teachers to implement effective, learner-focused strategies.
4. Future Research: Investigate the effectiveness of specific innovative instructional approaches on learner mastery, self-efficacy, engagement, and the development of higher-order thinking and 21st-century skills in chemistry education.

These recommendations emphasize the need for a holistic approach that integrates cognitive, affective, and social dimensions to improve both academic performance and learner confidence in General Chemistry.

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