

Learning Companion-Based Self-Learning Module (LCSLM) For Stoichiometry Instruction

Julyza A. Sayre., Douglas A. Salazar

Mindanao State University University - Iligan Institute of Technology

DOI: <https://doi.org/10.47772/IJRISS.2026.100801142>

Received: 16 August 2026; Accepted: 21 August 2026; Published: 25 September 2026

ABSTRACT

Stoichiometry remains one of the most challenging topics in secondary chemistry education due to its high cognitive load and integration of abstract mathematical and chemical concepts. This study evaluated the design, development, and instructional efficacy of a Learning Companion-Based Self-Learning Module (LCSLM) featuring an animated pedagogical agent named "Jul". Jul provides six instructional functions: conceptual explanations, procedural rule guidance, worked-example accounting, contextualized real-world bridging, metacognitive self-check prompts, and affective support. Expert evaluation ($N = 3$) confirmed high module acceptability ($M = 3.9$) across content, instructional design, usability, and pedagogical alignment. A single-group pretest-posttest pilot implementation was conducted with Grade 11 secondary students ($N = 21$). A non-parametric evaluation demonstrated a statistically significant improvement in stoichiometry achievement scores from pre-assessment ($Mdn = 5.00$) to post-assessment ($Mdn = 12.00$), as confirmed by a Wilcoxon Signed-Rank test ($W = 184$, $p < 0.001$, $r_{rb} = .593$). Learners also evaluated the module favorably, with an overall mean of 3.49, interpreted as Highly Acceptable. The findings suggest that the LCSLM demonstrates promising instructional quality, usability, and potential to support learners' conceptual understanding and self-directed engagement in stoichiometry. Further research involving larger samples and more rigorous experimental designs is warranted to establish its effectiveness.

Keywords: Educational Design Research, learning companion, self-learning module, stoichiometry, General Chemistry, instructional material, pedagogical agent

INTRODUCTION

Chemistry is often perceived by learners as one of the most challenging branches of science due to its dual reliance on abstract conceptual frameworks and mathematical problem-solving (Bantiling et al., 2025). Mastery of topics within this discipline requires students to seamlessly transition between macroscopic observations, sub-microscopic particles, and mathematical representations (Rahmawati et al., 2022). When students struggle to bridge the gap between conceptual understanding and numeric calculations, academic anxiety and failure rates frequently follow (Jastillana et al., 2025).

Among the major concepts in Chemistry, stoichiometry is widely recognized as one of the most challenging topics in Chemistry education due to its abstract nature, mathematical demands, and requirement for multi-step problem-solving skills (Salame et al., 2026). Learners are expected to interpret balanced chemical equations, apply mole relationships, and perform conversions involving mass, moles, and particles. However, many students struggle to develop mastery in these competencies because stoichiometric calculations require both conceptual understanding and procedural fluency (Lao-lao et al., 2026). Difficulties in balancing equations, identifying mole ratios, and organizing solution steps often result in misconceptions and low achievement in Chemistry (Alvaro, 2020).

Learners often demonstrate insufficient independent problem-solving skills due to the lack of structured guidance during practice activities. Many learning materials provide either fully worked examples or independent exercises with minimal intermediate support. Consequently, students may struggle to transition from guided instruction to independent application of concepts (Sweller et al., 2019). Educational theories on

scaffolding emphasize the importance of gradual release of responsibility, where learners first observe modeled examples, then engage in guided practice before independently solving problems (Munshi et al., 2022). In the context of stoichiometry, the absence of step-by-step instructional support may hinder students from developing confidence and mastery in solving quantitative Chemistry problems (Verangel, 2022).

Because scaffolding requires continuous instructional guidance, researchers have explored various instructional design strategies that provide learners with ongoing support throughout learning activities. One emerging approach is the incorporation of learning companions that accompany learners during instruction. Recent instructional design research has explored the use of learning companions, recurring instructional characters that provide guidance, prompts, encouragement, and scaffolding throughout the learning process (Hu et al., 2025; Schroeder et al., 2024). Rather than serving merely as a decorative element, the learning companion functions as a guide by providing explanations, prompts, encouragement, and instructional support that help learners navigate lessons and learning activities (Jansone, 2026, Schroeder et al., 2024). By fostering a sense of guidance and interaction, learning companions have been recognized for their potential to enhance learner engagement, motivation, and confidence, particularly in self-directed learning environments (Hu et al., 2025). Despite these potential benefits, the application of learning companions has been largely concentrated in digital learning environments including intelligent tutoring systems, educational software, virtual learning environments, and AI-assisted educational platforms, with limited attention given to their integration into printed or self-learning instructional materials. (Pérez-Marín, 2021; Schroeder et al., 2025). Comparatively, studies examining how learning companion principles can be systematically embedded in printed or self-learning instructional materials remain scarce, suggesting an opportunity for further instructional design research.

On the other hand, self-learning modules remain one of the primary instructional resources used in many educational settings, particularly where independent learning is emphasized. However, these materials are often presented in a highly textual and procedural manner, which may reduce learner engagement, motivation, and perceived instructional support (Cena et al., 2025). While various strategies have been employed to improve the design of self-learning materials, the deliberate integration of a continuous learning companion that guides learners throughout the learning process, from lesson introduction and concept development to guided practice, reflection, and encouragement, remains underexplored. Since self-learning modules require learners to study independently, the absence of continuous instructional guidance may limit opportunities for scaffolding compared with teacher-led instruction.

To address this gap, the present study develops a learning companion-based self-learning module for General Chemistry. The module incorporates a recurring learning companion that accompanies learners throughout the instructional sequence by providing explanations, motivational prompts, learning guidance, reflective questions, and transition cues designed to support independent learning. By extending the learning companion concept beyond digital platforms into a structured printed learning material, this study seeks to contribute an alternative instructional design approach that promotes learner engagement, confidence, and meaningful learning while remaining practical for classroom and self-directed learning contexts.

METHODOLOGY

This study employed an Educational Design Research (EDR) approach to develop and preliminarily evaluate a Learning Companion-Based Self-Learning Module (LCSLM) for stoichiometry instruction. EDR was selected to provide a systematic process for designing, developing, evaluating, and refining the instructional material through iterative stages. The development process comprised six stages: needs analysis, design, development, expert evaluation, revision, and pilot testing and evaluation. The expert evaluation provided evidence on the instructional quality of the developed material and informed its refinement, while the pilot implementation provided preliminary evidence of learners' performance and perceptions following their use of the LCSLM.

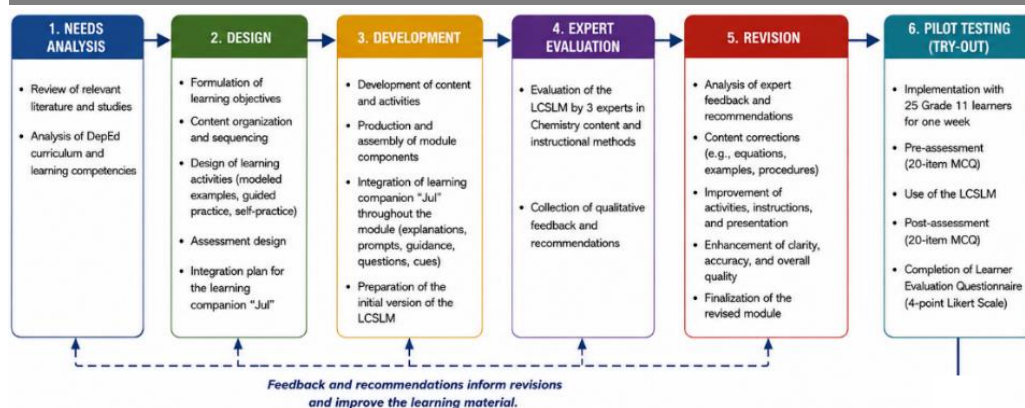


Figure 1. Development Process of the Learning Companion-Based Self-Learning Module

A. Participants of the Study

The study involved two groups of participants: expert evaluators and Grade 11 learners. The expert evaluation panel consisted of three ($N = 3$) specialists in Chemistry Education, each possessing advanced doctoral-level training in Science Education with a specialization in Chemistry and a minimum of 5 years of professional experience in chemistry instruction and instructional material development. These criteria were considered to ensure that the evaluators possessed appropriate subject-matter and pedagogical expertise to assess the quality and instructional appropriateness of the developed LCSLM.

The second group initially comprised 25 Grade 11 learners enrolled in General Chemistry from one intact section of a secondary school in Iligan City, Philippines. Four learners were unable to complete the post-assessment; consequently, 21 learners completed the pre-assessment, one-week pilot implementation, and post-assessment and were included in the analysis of pre- and post-assessment results. The learners who completed the pilot implementation also participated in the learner evaluation of the LCSLM.

B. Development of the Learning Companion-Based Self-Learning Material

The development of the LCSLM followed six sequential stages.

Needs Analysis. The development process began with a needs analysis involving a review of relevant literature and studies, the Department of Education curriculum and learning competencies, and appropriate instructional references for General Chemistry. The findings informed the identification and organization of the content, learning objectives, instructional activities, and assessment tasks to be incorporated into the module.

Design. Based on the identified instructional needs, the structure and instructional sequence of the module were planned. The module was designed to provide progressive support through modeled examples, guided practice, and independent practice, consistent with principles of instructional scaffolding and gradual release of responsibility.

Development. The initial version of the module was developed around the integration of a recurring learning companion, *Jul*. Rather than functioning solely as a visual or decorative element, *Jul* was incorporated as an instructional companion who provides explanations, motivational prompts, learning guidance, reflective questions, transition cues, and support during learning activities. These features were embedded throughout the instructional sequence to support learners as they progressed from conceptual development to guided and independent practice.

Expert Evaluation. The initial version of the LCSLM was evaluated by three experts specializing in Chemistry content and instructional methods. The experts assessed the material using the Expert Evaluation Sheet and provided qualitative comments and recommendations concerning its content, instructional design, presentation, and overall quality. The initial 20-item multiple-choice test and learner evaluation questionnaire were subjected

to expert review; following item analysis, five items were removed from the multiple-choice test, resulting in a final 15-item test.

Revision. The quantitative ratings and qualitative recommendations obtained from the expert evaluation were used to revise the module. Revisions included corrections to selected chemical equations and worked examples, improvements in solution procedures and visual organization, and consideration of curriculum alignment.

Pilot Testing and Evaluation. Following revision, the LCSLM was implemented with the target learners for one week. Learners completed a pre-assessment before using the module and a post-assessment after the implementation period. They also completed the learner evaluation questionnaire to provide feedback regarding their experience with the developed material.

C. Instruments

Three primary instruments were used to collect quantitative and qualitative data.

Expert Evaluation Sheet. An Expert Evaluation Sheet using a four-point Likert scale was used to assess the instructional quality of the developed LCSLM in terms of attainment of objectives, accuracy of content, originality, clarity, and appeal. The instrument also included open-ended items through which experts provided comments and recommendations for improving the material.

15-Item Multiple-Choice Test. A researcher-made multiple-choice test was developed to measure learners' conceptual understanding of stoichiometry before and after the implementation of the LCSLM. The initial test consisted of 20 items and was reviewed by three experts in Chemistry instruction to establish evidence of content validity. An item analysis was conducted to examine the difficulty and discrimination of the test items.

Table 1. Item Analysis of Initial 20-item Multiple Choice Test

Item	Difficulty Index	Discrimination Index	Decision
1	0.75	0.5	Retain
2	0.5	0.33	Retain
3	0.92	0.17	Reject
4	0.5	0.67	Retain
5	0.17	0	Reject
6	0.67	0.33	Retain
7	0.67	0	Reject
8	0.58	0.5	Retain
9	0.75	0.17	Revise
10	0.5	0	Reject
11	0.25	0.17	Revise
12	0.17	0	Reject
13	0.58	0.17	Revise

14	0.33	0.67	Retain
15	0.58	0.83	Retain
16	0.25	0.5	Revise
17	0.67	0.67	Retain
18	0.67	0.67	Retain
19	0.58	0.83	Retain
20	0.42	0.5	Retain

The item analysis showed that 15 of the 20 items demonstrated acceptable to good item characteristics, while five items (Items 3, 5, 7, 10, and 12) exhibited poor discrimination indices, ranging from 0.00 to 0.17. Items 5 and 12 were also relatively difficult (0.17), whereas Item 3 was very easy (0.92). These items were therefore removed from the initial test. The remaining 15 items were retained for the final version of the test, providing a more appropriate set of items for assessing learners' conceptual understanding of stoichiometry. The internal consistency of the revised assessment was then examined using the Kuder–Richardson Formula 20 (KR-20), which yielded a coefficient of 0.74.

Learner Evaluation Questionnaire. A researcher-made learner evaluation questionnaire using a four-point Likert scale was administered following the pilot implementation. The questionnaire was reviewed by the same expert panel for clarity, relevance, and appropriateness of the items prior to administration.

The internal consistency of the six dimensions was examined using Cronbach's alpha. The coefficients ranged from 0.865 to 0.937, indicating good to excellent internal consistency across the six dimensions. Specifically, the coefficients were 0.894 for Content Clarity and Accuracy, 0.865 for Learning Companion-Based Self-Learning Module, 0.865 for Guided and Self-Practice Activities, 0.937 for Confidence and Learning Development, 0.879 for Design and Organization, and 0.903 for Appropriateness of the Learning Material.

D. Data Gathering Procedure and Analysis

Following the completion of the expert evaluation and revision of the LCSLM, the revised material was implemented with the participating learners for one week. A pre-assessment was administered before learners used the module, followed by the implementation of the LCSLM. After the implementation period, learners completed the post-assessment and learner evaluation questionnaire.

Prior to data collection, permission to conduct the study was obtained from the appropriate school authorities. The participants were informed of the purpose and procedures of the study, and the required consent and assent procedures were completed. Participation was voluntary, and the confidentiality of the participants' responses and assessment results was maintained throughout the study.

Table 2. Descriptive interpretation for Expert Evaluation

Scale Range	Descriptive Interpretation
3.25 – 4.00	Excellent
2.50 – 3.24	Good
1.75 – 2.49	Fair
1.00 – 1.74	Needs Improvement

Table 3. Descriptive Interpretation for Learner Evaluation

Mean Range	Descriptive Interpretation
3.25 – 4.00	Highly Acceptable
2.50 – 3.24	Acceptable
1.75 – 2.49	Moderately Acceptable
1.00 – 1.74	Not Acceptable

Quantitative data from the expert evaluation and learner evaluation questionnaire were analyzed using descriptive statistics. Means were computed for each criterion and dimension to determine the level of evaluation of the developed material based on the four-point Likert scale. The numerical ratings and their corresponding descriptive interpretations are presented below.

The qualitative responses from the open-ended items in the expert evaluation were analyzed using content analysis. Responses were reviewed, grouped according to recurring ideas, and organized into themes representing the strengths and areas for refinement identified by the evaluators.

For the paired pre-assessment and post-assessment scores of the 21 learners who completed both assessments, the Wilcoxon Signed-Rank Test was used to determine whether a statistically significant difference existed in learners' performance before and after the use of the LCSLM. The rank-biserial correlation was also computed to determine the magnitude of the observed difference. The level of significance was set at $\alpha = .05$, and statistical analyses were conducted using jamovi.

The readability of the developed LCSLM was assessed using the Fry Readability Graph. Samples were obtained from the first, middle, and last portions of the material. For each sample, the number of sentences and syllables within a 100-word passage was determined. The resulting values were used with the Fry Readability Graph to estimate the corresponding grade-level readability of the material.

RESULTS AND DISCUSSION

This section presents the findings obtained from the evaluation of the developed Learning Companion-Based Self-Learning Module (LCSLM) for stoichiometry instruction. The results cover expert evaluation, readability analysis, preliminary assessment of learners' academic performance, and learner evaluation of the developed material.

A. Expert Evaluation Results of the Developed LCSLM

Expert evaluation was conducted to assess the instructional quality of the developed LCSLM in terms of attainment of objectives, accuracy of content, originality, clarity, and appeal. Quantitative ratings were complemented by qualitative feedback from the expert evaluators to identify the strengths of the material and areas requiring refinement. The results are presented in Table 4.

Table 4. Summary of Expert Evaluation Results of the Developed LCSLM

Criteria	Mean	Descriptive Interpretation
Attainment of Objectives	3.87	Excellent
Accuracy of Content	3.47	Excellent
Originality	4.00	Excellent

Clarity	3.87	Excellent
Appeal	4.00	Excellent
Overall Mean	3.68	Excellent

As shown in Table 4, the developed LCSLM obtained an overall mean of 3.68, interpreted as Excellent. Originality and Appeal received the highest ratings ($M = 4.00$), followed by Attainment of Objectives and Clarity ($M = 3.87$). The perfect ratings for Originality and Appeal validate the novel integration of a recurring learning companion within a printed self-learning material, corroborating instructional design research by Schroeder et al. (2024) and Hu et al. (2025), which highlights that persona-guided elements significantly enhance material engagement and aesthetic appeal. Furthermore, the strong scores for Attainment of Objectives and Clarity ($M = 3.87$) confirm that providing explicit instructional cues and structured learning paths ensures clear pedagogical direction during independent study, directly addressing concerns raised by Cena et al. (2025) regarding the lack of instructional guidance in traditional self-learning modules. Although Accuracy of Content received the lowest mean ($M = 3.47$), it remained comfortably within the Excellent category, with qualitative expert feedback informing specific conceptual refinements prior to pilot implementation.

Qualitative Feedback from Expert Evaluators

The open-ended responses of the expert evaluators were analyzed to identify recurring strengths and recommendations for improving the developed LCSLM. Five major themes emerged: (1) strong instructional design and organization, (2) learner-centered design and guided learning support, (3) alignment of learning activities and assessment, (4) technical revisions, and (5) presentation and curriculum alignment. The themes and representative responses are presented in Table 5.

Table 5. Themes Identified from Expert Evaluators' Open-Ended Responses

Theme	Description	Representative Response
<i>Strong Instructional Design and Organization</i>	Experts recognized the logical sequencing of lessons, effective scaffolding, and organization of learning activities that progressively develop learners' understanding of stoichiometry.	<i>"The activities are well-structured and move logically from basic balancing to harder word problems."</i>
<i>Learner-Centered Design and Guided Learning Support</i>	Experts highlighted the learner-centered design of the module, particularly the consistent use of Jul, contextualized examples, and organized guidance to support independent and self-paced learning.	<i>"The character 'Jul' serves as a consistent guide throughout the module."</i>
<i>Alignment of Learning Activities and Assessment</i>	The learning activities and assessments were considered appropriately aligned with the intended learning objectives and progression of stoichiometric skills.	<i>"The activities and assessments are correctly aligned to the objectives of the module."</i>
<i>Technical Revisions</i>	Experts identified selected chemical equations, worked examples, and solution procedures that required correction or further review.	<i>"The chemical equations inside the lesson contain technical errors that must be fixed."</i>
<i>Presentation and Curriculum Alignment</i>	Experts recommended improvements in the visual organization of activities and continued alignment with current curriculum standards.	<i>"The writer may consider inserting boxes, color, and proper spacing to distinguish activities."</i>

Overall, the qualitative feedback complemented the quantitative evaluation by affirming the module's instructional structure, scaffolded stoichiometry progression, and the narrative integration of "Jul" as an effective

companion for self-paced learning. Crucially, expert suggestions provided actionable targets for refinement, specifically correcting chemical equations, improving layout spacing, and fine-tuning curriculum alignment. Minor technical revisions suggested by the panel, including formatting corrections for subscript alignment in chemical formulas such as H_2O and Fe_2O_3 , were addressed prior to student deployment.

B. Readability of The LCSLM

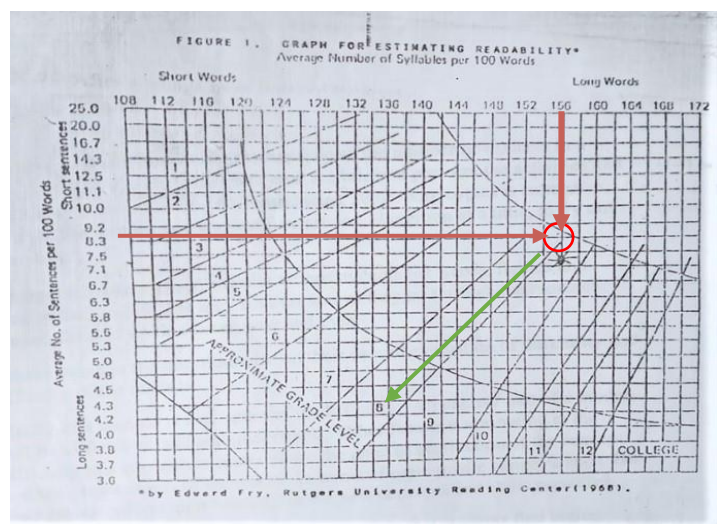
The textual readability of the LCSLM was evaluated using the Fry Readability Graph to determine whether the reading difficulty was appropriate for the target Grade 11 learners. Sample passages of 100 words were selected from the initial, middle, and final sections of the material to compute the average number of sentences and syllables.

Table 6. Number of Sentences and Syllables Per Hundred Words.

	<i>No. of Sentences</i>	<i>No. of Syllables</i>
<i>First page</i>	7	141
<i>Middle Page</i>	8	156
<i>Last Page</i>	10	171
<i>Average</i>	8.3	156

Plotting these average values (8.3 sentences and 156 syllables) on the Fry Readability Graph yielded an estimated reading level corresponding to Grade 8 (Figure 2).

Figure 2. Graph for Estimating Readability



Although the LCSLM is designed for Grade 11 General Chemistry, a Grade 8 reading level is advantageous for self-learning materials. Because the module is intended for self-paced study with limited real-time teacher guidance, accessible sentence structure prevents language from becoming an unnecessary barrier. Minimizing linguistic demands allows self-directed learners to dedicate greater cognitive resources to the core mathematical and conceptual demands of stoichiometry.

Crucially, while the Fry formula establishes the accessibility of the textual content, it measures structural readability rather than conceptual appropriateness. The underlying chemical concepts (e.g., mole ratios) remain aligned with Senior High School standards despite the accessible sentence structure. Nevertheless, evaluating readability formulas alone cannot capture how students mentally process the material, future research should

combine textual readability metrics with direct measures of learner comprehension and cognitive load during module engagement.

Following readability verification, the refined LCSLM was subjected to pilot implementation to evaluate its preliminary impact on student performance. The results of the pre- and post-implementation assessments are presented in the next section.

C. Learners' Conceptual Understanding Before and After the Use of the LCSLM

Following expert evaluation, revision, and readability assessment, the LCSLM underwent pilot implementation using a single-group pre-assessment–post-assessment design over a one-week period. Learners' conceptual understanding was evaluated by comparing their pre-assessment and post-assessment performance. Due to the small sample size and non-normal distribution, a non-parametric Wilcoxon Signed-Rank Test was conducted using jamovi to examine performance differences. The results are presented in Table 7.

Table 7. Pre- and Post-Assessment Results of Learners

	N	Median	<i>Q1</i>	<i>Q3</i>	Mean	<i>SD</i>	<i>W</i> (Wilcoxon)	<i>p</i>	Effect Size (<i>rrb</i>)
Pre	21	7	5.00	10.00	7.71	3.18	184	<.001	0.593
Post	21	13	11.50	14.50	12.86	1.82			

Descriptive analysis showed a clear upward shift in central tendency and a narrowing score dispersion, with median scores increasing from 7.00 (*Q1* = 5.00, *Q3* = 10.00) to 13.00 (*Q1* = 11.50, *Q3* = 14.50). The post-test lower quartile threshold (*Q1* = 11.50) exceeded the pre-test upper quartile threshold (*Q3* = 10.00), indicating that lower-performing students made gains that surpassed the baseline scores of the top-performing pre-test tier. Furthermore, the non-overlap of interquartile ranges demonstrates consistent learning gains across all baseline performance levels.

A Wilcoxon signed-rank test revealed a statistically significant improvement in student performance following exposure to the LCSLM (*W* = 184.00, *p* = .001). Median scores increased from 7.00 on the pre-assessment to 13.00 on the post-assessment. These performance gains corroborate the instructional design frameworks surrounding learning companions and continuous scaffolding. Specifically, the observed score gains substantiate the assertion by Schroeder et al. (2024) that embedding a recurring learning companion provides critical prompts, explanations, and instructional support throughout the learning process. While learning companions have been predominantly restricted to digital environments, the large effect size (*rrb* = 0.593) indicates that adapting these principles into printed, self-learning modules can potentially support independent mastery. However, this effect size should be interpreted cautiously given the single-group design and small pilot sample (*N* = 21).

D. Learners' Evaluation of the LCSLM

Following the pilot implementation, learners evaluated the developed LCSLM across six dimensions: Content Clarity and Accuracy, “Jul” as a Learning Companion, Guided and Self-Practice Activities, Confidence and Learning Development, Design and Organization, and Appropriateness of the Learning Material. The results are summarized in Table 8.

Table 8. Summary of Learners' Evaluation of the Developed Learning Companion-Based Self-Learning Module

Criteria	Mean	Descriptive Interpretation
Content Clarity and Accuracy	3.53	Highly Acceptable

“Jul” as a Learning Companion	3.44	Highly Acceptable
Guided and Self-Practice Activities	3.56	Highly Acceptable
Confidence and Learning Development	3.37	Highly Acceptable
Design and Organization	3.52	Highly Acceptable
Appropriateness of the Learning Material	3.50	Highly Acceptable
Overall Mean	3.49	Highly Acceptable

As shown in Table 8, the LCSLM obtained an overall mean of 3.49 corresponding to a descriptive interpretation of Highly Acceptable. Among the six dimensions, Guided and Self-Practice Activities received the highest rating ($M = 3.56$), followed by Content Clarity and Accuracy ($M = 3.53$) and Design and Organization ($M = 3.52$). The high acceptance of guided practice activities corroborates prior research emphasizing that step-by-step instructional scaffolding and structured problem-solving tasks significantly enhance student engagement during independent study (Cena et al., 2025).

Furthermore, the favorable rating for “Jul” as a Learning Companion ($M = 3.44$) indicates that learners responded positively to the integration of a recurring instructional character within a printed module. This aligns with findings by Schroeder et al. (2024) and Hu et al. (2025), demonstrating that instructional companions provide effective support, guidance, and encouragement. Although Confidence and Learning Development yielded the lowest mean ($M = 3.37$), it remained comfortably within the Highly Acceptable threshold. This slightly lower score reflects the inherent cognitive demands of mastering quantitative stoichiometry, while still confirming that the module fostered self-perceived competence and learner agency during self-directed study.

CONCLUSION

The findings suggest that a learning companion can function as more than a visual feature within a self-learning material; it can serve as a consistent source of instructional guidance and scaffolding throughout the learning sequence. By integrating *Jul* into a printed self-learning module, this study demonstrates the potential of extending the learning companion concept beyond predominantly digital learning environments and into non-digital instructional materials.

The favorable expert and learner evaluations, together with the improvement observed during the pilot implementation, indicate that learning companion-based design is a promising approach for making self-learning materials more guided, supportive, and learner-centered. In particular, the consistent presence of *Jul* provides a means of embedding explanations, prompts, encouragement, and guided practice within a material that learners can use independently. Thus, the study contributes an alternative way of addressing the limited continuous instructional support often associated with self-learning materials.

However, these findings remain preliminary given the small, single-group pilot implementation. Further research involving larger samples, longer implementation periods, and comparison groups is needed to establish the effectiveness of learning companion-based materials and to determine how their specific instructional functions influence learners' learning outcomes and experiences.

ACKNOWLEDGEMENT

The researchers sincerely acknowledge the support and assistance of *Mindanao State University–Iligan Institute of Technology* (MSU-IIT) and the *Department of Science and Mathematics Education* for providing the academic environment and institutional support necessary for the completion of this study. Special appreciation is extended to the professor who provided guidance, valuable insights, and encouragement throughout the conduct and completion of the research. The researchers also acknowledge the learners, teachers, and expert evaluators who generously contributed their time and participation to the study. Their contributions were

instrumental to the development and preliminary evaluation of the Learning Companion-Based Self-Learning Module.

REFERENCES

1. Alvaro, E. A. (2020). Enhancing the solving-skills on stoichiometry through collaborative and problem-based package among senior high school students. E-Saliksik: DepEd Research Portal. https://e-saliksik.deped.gov.ph/wp-content/uploads/2022/03/I_2020_Alvaro_Enhancing-the-Solving-Skills-on-Stoichiometry-through-Collaborative-and-Problem-Based-Package-among-Senior-High-School-Students.pdf
2. Bantiling, N. S., Bongcales, L. R. C., Ellore, C. T. D., Galope, C. D., Haquias, P. A. L., Hermoso, C. S. L., Ribo, P. K. A. S., Tabaculde, J. D., Taborada, J., & Bacang, M. A. B. R. (2025). Understanding the struggles of STEM 12 students in their academic competence. *International Journal of Academic Multidisciplinary Research*, 9(5), 510–517. <http://ijeais.org/wp-content/uploads/2025/5/IJAMR250565.pdf>
3. Cena, J. F., Diez, M. B., Flores, M. R., Noquiao, H. P. P., & Quinco-Cadosales, M. N. (2025). Interactive Self-Learning Modules (ISLMs) in sustaining student engagement and learning outcomes: A meta-synthesis. *International Journal of Advanced Multidisciplinary Research and Studies*, 5(4), 1457–1468. <https://doi.org/10.62225/2583049X.2025.5.4.4782>
4. Hu, YH., Yu, HY. & Hsieh, CL (2025). Can pedagogical Agent-Based scaffolding boost information Problem-Solving in One-on-One collaborative learning with a virtual learning companion? *Educ Inf Technol* **30**, 25853–25880. <https://doi.org/10.1007/s10639-025-13784-2>
5. Jansone, A., & Cīrule, Z. A. (2026). Artificial Intelligence-Based Pedagogical Agent in an E-Learning Environment. *Computers*, 15(7), 401. <https://doi.org/10.3390/computers15070401>
6. Jastillana, R.M., Pacionela, R., Salem, D., Camarista, G. (2025). Mathematics Anxiety and Types and Frequency of Errors in Algebraic Problem-solving among Grade 12 STEM Students. 12(8), <https://doi.org/10.51244/IJRSI.2025.120800221>.
7. Lao-Lao, M. R. R., Nabua, E. B., Clamohoy, D. M., Luzica, S. A. (2026). Fragmented Conceptual Understanding and Quantitative Challenges in Stoichiometry and Chemical Reactions among Grade 12 Students. *International Journal of Research and Innovation in Social Science*, 9(12), <https://doi.org/10.47772/IJRISS.2025.91200271>.
8. Lazaro, C. B. D. G. (2026). Strengthening problem-solving skills in balancing chemical equations through scaffolding framework. *International Journal for Multidisciplinary Research*, 8(4). <https://doi.org/10.36948/ijfmr.2026.v08i04.85601>
9. Munshi, A., Biswas, G., Baker, R., Ocumpaugh, J., Hutt, S., & Paquette, L. (2023). Analysing adaptive scaffolds that help students develop self-regulated learning behaviours. *Journal of Computer Assisted Learning*, 39(2), 351–368. <https://doi.org/10.1111/jcal.12761>
10. Pérez-Marín, D. (2021). A Review of the Practical Applications of Pedagogic Conversational Agents to Be Used in School and University Classrooms. *Digital*, 1(1), 18–33. <https://doi.org/10.3390/digital1010002>
11. Rahmawati, Y., Zulhipri, Hartanto, O., Falani, I., & Iriyadi, D. (2022). Students' conceptual understanding in chemistry learning using PhET interactive simulations. *Journal of Technology and Science Education*, 12(2), 303–326. <https://doi.org/10.3926/jotse.1597>
12. Salame, I. I., Kanishka, H., & Ishak, A. (2026). Examining challenges and difficulties students face in learning about stoichiometry in general chemistry courses. *Interdisciplinary Journal of Environmental and Science Education*, 22(1), e2604. <https://doi.org/10.29333/ijese/17701>
13. Schroeder, N. L., Davis, R. O., & Yang, E. (2025). Designing and Learning With Pedagogical Agents: An Umbrella Review. *Journal of Educational Computing Research*, 62(8). <https://doi.org/10.1177/07356331241288476>
14. Sweller, J., van Merriënboer, J.J.G. & Paas, F. Cognitive Architecture and Instructional Design: 20 Years Later. *Educ Psychol Rev* **31**, 261–292 (2019). <https://doi.org/10.1007/s10648-019-09465-5>