# Mobile Application-Integrated Self-Learning Module to Enhance Grade 11 Learners' Conceptual Understanding and Motivation in Stoichiometry

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## ABSTRACT

This study developed and evaluated a mobile application–integrated Self-Learning Module (SLM), grounded in the ADDIE instructional design model and the 5E learning framework, to enhance Grade 11 learners' conceptual understanding and motivation in Stoichiometry. Specifically, it identified the least-mastered Chemistry competency, developed and validated the instructional module, determined its effects on learners' conceptual understanding and motivation, assessed its acceptability and usability, and examined the relationship between conceptual understanding and motivation.

A quasi-experimental one-group pretest–posttest design, complemented by qualitative thematic analysis, was employed. A needs assessment involving 153 Grade 11 learners from three public senior high schools in Iligan City, Philippines, identified stoichiometry as a priority area for intervention, with the highest least-mastered rates observed in determining percentage composition (66.0%) and expressing solution concentrations quantitatively (64.1%). The validated module was subsequently implemented among 90 Grade 11 learners from a separate public senior high school in the same city. Data were gathered through the needs assessment test, a 40-item conceptual understanding test administered as pretest and posttest, an adapted motivation questionnaire, an acceptability and usability survey, and semi-structured interviews.

Expert evaluation confirmed high content and instructional validity of the developed module, with parameter mean ratings ranging from 3.33 to 4.00 (Valid to Highly Valid). Following implementation, learners' conceptual understanding improved significantly, with mean scores rising from 15.98 (39.95%) at pretest to 19.30 (48.25%) at posttest (paired-sample t-test, $p<0.001$). Motivation likewise increased significantly, from an overall mean of 2.32 (Partially Motivated) to 2.75 (Motivated) ($p<0.001$), with gains recorded across all five motivational dimensions assessed. A statistically significant but low positive correlation was found between conceptual understanding and motivation ($r = 0.2558$, $p = 0.0150$), indicating that motivation contributed to, but was not the sole determinant of, learning gains. Learners rated the module acceptable and usable, and thematic analysis of open-ended responses showed that its interactive features, guided problem-solving activities, and mobile accessibility improved engagement, confidence, and conceptual understanding, although a few learners noted device- and connectivity-related constraints during use.

These findings suggest that the mobile application–integrated SLM is a promising technology-enhanced instructional tool for improving conceptual understanding and motivation in Stoichiometry. However, because the one-group pretest–posttest design did not include a comparison or control group, the observed gains cannot be attributed to the intervention alone; factors such as maturation, repeated testing, or concurrent classroom instruction may also have contributed. The study therefore recommends future research employing quasi-experimental or experimental designs with control groups, larger and more diverse samples, and extended intervention periods to strengthen causal inference and further validate the effectiveness of mobile-assisted self-learning modules across science education contexts.

**Keywords:** conceptual understanding, mobile application integration, motivation, perception, self-learning module, stoichiometry

# INTRODUCTION

Chemistry constitutes a fundamental domain of science education because it cultivates scientific literacy, analytical reasoning, and quantitative problem-solving competencies essential for understanding chemical phenomena. Among its core concepts, stoichiometry serves as the conceptual bridge between chemical reactions and mathematical reasoning, requiring learners to integrate symbolic, particulate, and quantitative representations. Despite its centrality in chemistry instruction, stoichiometry continues to present substantial learning challenges because it demands simultaneous mastery of abstract concepts, proportional reasoning, and mathematical computation (Salame et al., 2026). Consequently, learners frequently develop misconceptions that impede meaningful conceptual understanding and successful problem solving.

The persistent difficulty in chemistry learning is reflected in both national and international educational assessments. Results from the Programme for International Student Assessment (PISA) consistently demonstrate that Filipino learners perform below the global average in science literacy, highlighting persistent deficiencies in higher-order scientific reasoning and conceptual application (Chi, 2023). Within the Philippine K–12 curriculum, learners are expected to solve quantitative problems involving chemical reactions using the mole concept and balanced chemical equations. However, empirical evidence identifies stoichiometry as one of the least-mastered competencies, primarily because learners struggle to establish meaningful relationships among chemical equations, mole conversions, and proportional reasoning (Llaneras et al., 2026)

Recent developments in educational technology have demonstrated the pedagogical value of mobile learning applications for promoting conceptual understanding through interactive visualization, simulation-based instruction, immediate feedback, and learner autonomy (Laumann et al., 2025; Adebayo et al., 2024). Likewise, chemistry-specific mobile applications facilitate the comprehension of abstract concepts by providing dynamic representations that enhance cognitive engagement and knowledge construction (Wang & Chen, 2020). Concurrently, self-learning modules (SLMs) have become integral instructional resources within flexible, blended, and independent learning environments because they promote self-paced learning and learner autonomy (Pokhrel & Chhetri, 2021). Nevertheless, previous investigations have reported that many existing SLMs exhibit limited interactivity, insufficient instructional scaffolding, and inadequate alignment with learners' conceptual needs, thereby restricting their effectiveness in promoting meaningful learning (Rico & Mendoza, 2021).

Despite the documented effectiveness of both mobile learning applications and self-learning modules, research integrating these instructional innovations remains limited, particularly in addressing least-mastered competencies in chemistry. Most existing studies evaluate these interventions independently rather than as complementary instructional resources capable of enhancing conceptual understanding and learner motivation simultaneously. Addressing this gap, the present study developed and implemented a mobile application–integrated self-learning module grounded in the ADDIE instructional design model and the 5E learning framework to improve Grade 11 learners' conceptual understanding of stoichiometry. Specifically, the study sought to identify the least-mastered competency in Chemistry, develop and validate the instructional module, determine its effects on learners' conceptual understanding and motivation, evaluate its acceptability and usability, and examine the relationship between conceptual understanding and motivation. The findings are expected to contribute empirical evidence supporting technology-enhanced, learner-centered instructional practices that advance the quality of chemistry education.

# METHODOLOGY

This investigation employed a mixed-methods research design using a one-group pretest–posttest approach complemented by qualitative thematic analysis to determine the effectiveness of a mobile application–integrated self-learning module (SLM) in enhancing learners' conceptual understanding and motivation in Stoichiometry. The study involved different groups of Grade 11 and Grade 12 learners across its developmental and implementation phases. A needs assessment involving 153 Grade 11 learners from three selected public senior high schools in Iligan City was conducted to identify the least-mastered competency in Chemistry. The intervention was subsequently implemented among 90 Grade 11 learners from a selected public senior high school. Separate groups of Grade 11 and Grade 12 learners participated in pilot testing to establish the clarity, validity, and reliability of the instructional materials and research instruments before the full-scale implementation.

Data were gathered using researcher-developed and adapted instruments subjected to expert validation before implementation. These included: (1) a needs assessment test to determine the least-mastered Chemistry competency; (2) a conceptual understanding test administered during the pretest and posttest phases; (3) an adapted motivation questionnaire measuring intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation; and (4) an acceptability and usability questionnaire evaluating learners' perceptions of the developed instructional material. Researcher-developed instruments underwent pilot testing to establish internal consistency, reliability, and item clarity.

The instructional intervention was developed using the ADDIE instructional design model, encompassing the analysis, design, development, implementation, and evaluation phases. During the analysis phase, a needs assessment identified stoichiometry as the least-mastered competency. Guided by these findings, a mobile application–integrated self-learning module structured around the 5E instructional model was designed and developed. The module subsequently underwent expert validation, pilot testing, and revision before classroom implementation. During implementation, participants completed the conceptual understanding pretest and motivation questionnaire before engaging with the intervention for one week. Upon completion, learners answered the posttest, post-intervention motivation questionnaire, and the acceptability and usability survey. Open-ended responses were likewise collected to capture learners' experiences with the instructional material.

Quantitative data were analyzed using descriptive statistics, particularly the arithmetic mean, to describe learners' performance and motivation levels. Paired-sample t-tests were employed to determine statistically significant differences between pretest and posttest conceptual understanding and motivation scores, while Pearson product–moment correlation analysis examined the relationship between conceptual understanding and motivation. Statistical significance was established at $\alpha = 0.05$. Qualitative responses were analyzed using Braun and Clarke's six-phase thematic analysis, involving familiarization, initial coding, theme generation, theme review, theme definition, and report development to identify recurring patterns that characterized learners' perceptions of the module's acceptability, usability, and instructional effectiveness.

## RESULTS

### A. Least Mastered Competencies in Chemistry

The table (Table 1) presents the five least-mastered Chemistry competencies among Grade 11 learners based on the needs assessment. The highest percentage of non-mastery (66.0%) was observed in determining the percentage composition of a compound from its chemical formula and vice versa, followed by expressing solution concentrations quantitatively (64.1%). Other competencies with substantial learning deficiencies included determining empirical and molecular relationships (58.8%), explaining the pressure–volume relationship of gases (51.6%), and applying factors affecting reaction rates to practical situations (49.0%). These findings indicate that learners experience considerable difficulty in competencies requiring the integration of conceptual understanding, mathematical reasoning, and problem-solving skills.

**Table 1.** Top 5 Least-Mastered Competencies in Chemistry

| Rank | Competency | Percentage of Learners (Not Mastered) |
|---|---|---|
| 1 | Determine the percentage composition of a compound given its chemical formula and vice versa. | 66.0% |
| 2 | Express concentrations of solutions quantitatively by preparing different concentrations of mixtures according to uses and availability of materials. | 64.1% |
| 3 | Determine the percentage composition of a compound given its chemical formula and vice versa. | 58.8% |
| 4 | Investigate the relationship between volume and pressure at constant temperature of a gas. | 51.6% |
| 5 | Explain how the factors affecting rates of chemical reactions are applied in food preservation and materials production, control of fire, pollution, and corrosion. | 49.0% |

The prevalence of these learning gaps suggests that conventional instructional approaches may be insufficient to facilitate deep conceptual learning. Consequently, there is a need for innovative, learner-centered instructional interventions that incorporate interactive and technology-enhanced strategies. These results also justify prioritizing the development of a mobile application–integrated self-learning module targeting the identified least-mastered competencies to improve conceptual understanding, engagement, and overall academic achievement in Chemistry.

**B. Development of the Mobile Application-Integrated Self-Learning Module**

The experts' evaluation indicates that the developed Stoichiometry Self-Learning Module (SLM) with Mobile Application Integration possesses a high level of instructional quality across the dimensions of usability, acceptability, effectiveness, and content accuracy. Most indicators obtained a mean rating of 3.67 (Highly Valid), while Accessibility of Features, Classroom Applicability, and Alignment with the Chemistry Curriculum each received the highest mean rating of 4.00 (Highly Valid). Although Clarity of Instructions obtained a slightly lower mean of 3.33 (Valid), it nevertheless met the established standard for instructional acceptability, suggesting only minor revisions to improve comprehensibility.

**Table 2**. Experts' Rating on the Stoichiometry SLM with Mobile Application Integration

| Item Number | Parameters | Mean Rating | Descriptive Rating |
|---|---|---|---|
| **Usability** | | | |
| 1 | Ease of Navigation | 3.67 | Highly Valid |
| 2 | Clarity of Instructions | 3.33 | Valid |
| 3 | Accessibility of Features | 4.00 | Highly Valid |
| 4 | User Control and Flexibility | 3.67 | Highly Valid |
| 5 | Ease of Learning the System | 3.67 | Highly Valid |
| **Acceptability** | | | |
| 1 | Relevance to Chemistry Learning | 3.67 | Highly Valid |
| 2 | Suitability for Students | 3.67 | Highly Valid |
| 3 | Teacher Acceptance | 3.67 | Highly Valid |
| 4 | Student Interest | 3.67 | Highly Valid |
| 5 | Classroom Applicability | 4.00 | Highly Valid |
| **Effectiveness** | | | |
| 1 | Improvement of Conceptual Understanding | 3.67 | Highly Valid |
| 2 | Development of Problem-Solving Skills | 3.67 | Highly Valid |
| 3 | Practice Opportunities | 3.67 | Highly Valid |
| 4 | Immediate Feedback | 3.67 | Highly Valid |
| 5 | Learning Reinforcement | 3.67 | Highly Valid |
| **Content Accuracy** | | | |
| 1 | Accuracy of Chemical Concepts | 3.67 | Highly Valid |
| 2 | Correctness of calculations | 3.67 | Highly Valid |
| 3 | Alignment with the Chemistry Curriculum | 4.00 | Highly Valid |

These findings demonstrate that the developed instructional material is pedagogically sound, curriculum-aligned, and suitable for classroom implementation. The consistently high ratings indicate that the module effectively integrates mobile technology with structured learning activities, enabling learners to navigate content easily, engage in guided problem-solving, receive immediate feedback, and reinforce conceptual understanding. Furthermore, its strong alignment with curriculum standards ensures that the identified least-mastered competencies in stoichiometry are addressed systematically and meaningfully.

The results imply that the mobile application–integrated SLM has substantial potential to bridge existing learning gaps in Chemistry by providing an interactive, learner-centered, and technology-enhanced instructional resource. Consequently, its adoption may improve conceptual understanding, strengthen problem-solving skills, increase

learner motivation and engagement, and ultimately contribute to improved academic performance in Stoichiometry and other quantitative Chemistry topics.

### C. Effectiveness of the Mobile Application Integrated Self-Learning Module

The data (Table 3) indicate that Grade 11 learners demonstrated an improvement in their conceptual understanding of Stoichiometry following exposure to the mobile application–integrated Self-Learning Module (SLM). The mean pretest score increased from 15.98 (39.95%) to a posttest mean score of 19.30 (48.25%), representing an increase of 3.32 points or 8.30 percentage points.

**Table 3.** Pretest and Posttest Mean Scores in Conceptual Understanding of Grade 11 Learners

| | **Pretest** | **%** | **Posttest** | **%** | **p-value** | **Interpretation** |
|---|---|---|---|---|---|---|
| **Mean Score** | 15.98 | 39.95 | 19.30 | 48.25 | $p<0.001$ | Statistically Significant |

The p-value of $p<0.001$ confirms that the observed improvement is statistically significant, indicating that the increase in learners' conceptual understanding was unlikely due to chance and can be attributed to the instructional intervention. Although posttest performance remained below the mastery level, the results demonstrate meaningful learning gains over the intervention period. These findings imply that the developed mobile application–integrated SLM effectively addressed learners' conceptual difficulties by providing structured instructional support and interactive learning experiences. However, the relatively low posttest mean suggests that additional instructional reinforcement, extended intervention duration, and continuous practice opportunities are necessary to achieve mastery and promote deeper conceptual understanding of Stoichiometry.

**Table 4.** Level of Motivation of Grade 11 Learners

| | **Pre-Intervention** | **Description** | **Post-Intervention** | **Description** | **p-value** | **Interpretation** |
|---|---|---|---|---|---|---|
| Intrinsic Motivation | 2.45 | Partially Motivated | 2.86 | Motivated | - | - |
| Career Motivation | 2.39 | Partially Motivated | 2.77 | Motivated | - | - |
| Self-Determination | 2.28 | Partially Motivated | 2.71 | Motivated | - | - |
| Self-Efficacy | 2.23 | Partially Motivated | 2.67 | Motivated | - | - |
| Grade Motivation | 2.26 | Partially Motivated | 2.72 | Motivated | - | - |
| **Mean Score** | 2.32 | Partially Motivated | 2.74 | Motivated | $p<0.001$ | Statistically Significant |

The findings indicate that the motivation of Grade 11 learners significantly improved after using the mobile application–integrated Self-Learning Module (SLM). The overall mean motivation score increased from 2.32 (Partially Motivated) during the pre-intervention to 2.74 (Motivated) after the intervention. All motivational dimensions—intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation-showed positive increases. Moreover, the p-value ($p<0.001$) indicates that the improvement was statistically significant. These results imply that the developed SLM effectively enhanced learners' motivation by providing engaging, interactive, and learner-centered learning experiences, thereby fostering greater confidence, persistence, and willingness to learn Stoichiometry.

Learners perceived the instructional module as acceptable and usable in terms of design, content organization, and ease of implementation as shown in Table 5. Qualitative responses identified step-by-step problem-solving procedures, guided worked examples, and mobile application integration as the features that most supported learning.

**Table 5.** Mean Acceptability and Usability Scores of the Stoichiometry SLM with Mobile Application Integration per Learners' Perception

| Mean Acceptability Score | Interpretation | Mean Usability Score | Interpretation |
|---|---|---|---|
| 3.2758 | Acceptable | 3.3230 | Usable |

The correlation analysis (Table 6) reveals a statistically significant but low positive relationship between Grade 11 learners' conceptual understanding and motivation after exposure to the mobile application–integrated Self-Learning Module (SLM).

**Table 6.** Correlation between Conceptual Understanding and Motivation Level of Grade 11 Learners

| Variables | r-value | p-value | Interpretation |
|---|---|---|---|
| Conceptual Understanding (Posttest Score)<br>Motivation Level (Mean Motivation Score) | 0.2558 | 0.0150 | Significant but Low Positive Correlation |

The computed Pearson correlation coefficient (r = 0.2558) indicates a weak positive association, while the p-value (0.0150), which is below the 0.05 level of significance, confirms that the relationship is statistically significant. This finding suggests that learners with higher levels of motivation tended to demonstrate better conceptual understanding of Stoichiometry, although the strength of this relationship was relatively modest. Therefore, motivation contributes to learners' conceptual learning but is not the sole determinant of academic performance.

The results imply that enhancing learners' motivation through technology-enhanced instructional materials can positively influence conceptual understanding by increasing engagement, persistence, and active participation in learning activities. However, the weak correlation also indicates that other factors, such as prior knowledge, mathematical ability, cognitive readiness, instructional quality, and learning strategies, likely contribute substantially to conceptual understanding. Consequently, improving learners' achievement in Stoichiometry requires a multifaceted instructional approach that combines motivational support with explicit conceptual instruction, guided problem-solving, continuous formative assessment, and differentiated learning experiences.

## DISCUSSION

The present investigation provides empirical evidence that stoichiometry remains one of the most challenging competencies in senior high school Chemistry. The needs assessment revealed that 66.0% of the learners failed to master the competency on determining the percentage composition of a compound, while 64.1% experienced difficulty in expressing solution concentrations quantitatively. Additional learning gaps were identified in determining empirical and molecular relationships (58.8%), investigating the pressure–volume relationship of gases (51.6%), and explaining the application of reaction rates (49.0%). These findings indicate that learners encounter persistent difficulties in competencies requiring the integration of conceptual understanding, mathematical reasoning, proportional thinking, and symbolic representation. Such results corroborate previous investigations demonstrating that stoichiometry is inherently difficult because learners must simultaneously coordinate abstract chemical concepts with quantitative problem-solving processes (Salden et al., 2024; Sepe, 2023). Consequently, the identified deficiencies provided a compelling rationale for developing an instructional intervention specifically designed to address these least-mastered competencies.

To respond to these instructional needs, a mobile application–integrated Self-Learning Module (SLM) was developed using the ADDIE instructional design model and the 5E learning framework. Expert evaluation demonstrated that the developed instructional material possessed a high degree of instructional quality. Most evaluation indicators obtained a mean rating of 3.67 (Highly Valid), whereas Accessibility of Features, Classroom Applicability, and Alignment with the Chemistry Curriculum each received the highest rating of 4.00 (Highly Valid). Although Clarity of Instructions obtained a relatively lower rating of 3.33 (Valid), the score still exceeded the acceptable standard for instructional materials and suggests only minor revisions to enhance comprehensibility. Collectively, these findings indicate that the module is pedagogically sound, curriculum-aligned, technologically appropriate, and suitable for classroom implementation. The integration of mobile

applications, guided worked examples, scaffolded problem-solving activities, and immediate feedback mechanisms likely enhanced learners' engagement while reducing the cognitive demands associated with complex stoichiometric computations. These findings support previous studies emphasizing that technology-enhanced instructional environments facilitate conceptual understanding through visualization, interactivity, and timely instructional feedback (Laumann et al., 2025; Adebayo et al., 2024; Wang & Chen, 2020).

The effectiveness of the developed instructional intervention was further demonstrated by the significant improvement in learners' conceptual understanding following implementation. The mean conceptual understanding score increased from 15.98 (39.95%) during the pretest to 19.30 (48.25%) in the posttest, representing an improvement of 3.32 points or 8.30 percentage points. The computed p-value (<0.001) confirms that this improvement was statistically significant and unlikely to have occurred by chance. Although the posttest mean remained below the mastery threshold, the observed gains indicate that the intervention effectively reduced learners' conceptual difficulties within the one-week implementation period. The relatively modest posttest performance likewise suggests that conceptual change in stoichiometry requires sustained instructional reinforcement and repeated opportunities for guided practice. These findings are consistent with constructivist learning theory, which posits that conceptual understanding develops progressively through active engagement, meaningful experiences, and continuous refinement of existing knowledge structures. The systematic sequencing of learning activities provided by the 5E instructional model appears to have supported learners in constructing more coherent conceptual frameworks while minimizing common misconceptions associated with stoichiometric reasoning.

Beyond cognitive achievement, the intervention also produced substantial improvements in learners' motivation toward Chemistry. The overall motivation score increased from 2.324 (Partially Motivated) before the intervention to 2.745 (Motivated) after the intervention, with a highly significant p-value of 0.000005654. Improvements were consistently observed across all motivational dimensions, including intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation. These findings suggest that the integration of mobile technology transformed the learning environment into a more engaging, interactive, and learner-centered experience that fostered greater autonomy and confidence. Mobile-assisted learning environments provide learners with immediate feedback, flexible access to instructional resources, and opportunities for independent exploration, all of which are recognized contributors to increased academic motivation. Accordingly, the present findings reinforce previous research indicating that technology-enhanced learning environments promote sustained learner engagement and improve motivational outcomes in science education (Laumann et al., 2025; Wang & Chen, 2020).

Learners' positive perceptions further strengthen the evidence supporting the instructional value of the developed module. Expert validation established that the instructional material was highly acceptable and usable, while qualitative responses revealed that learners particularly appreciated the module's step-by-step problem-solving procedures, guided examples, interactive mobile features, and immediate feedback. These instructional characteristics enabled learners to visualize abstract chemical processes more effectively, reduce procedural errors, and maintain engagement throughout the learning activities. Such findings suggest that integrating mobile learning technologies within self-learning modules provides an effective mechanism for addressing persistent learning difficulties in Chemistry while simultaneously promoting learner independence and active knowledge construction.

The correlation analysis likewise demonstrated a statistically significant but low positive relationship between conceptual understanding and motivation ($r = 0.2558$, $p = 0.0150$). Although the magnitude of the relationship was relatively weak, the statistically significant correlation indicates that learners with higher levels of motivation generally achieved better conceptual understanding. This finding suggests that motivation functions as one contributing factor in conceptual learning rather than as its sole determinant. Other variables, including prior knowledge, mathematical competence, cognitive readiness, instructional quality, and learning strategies, likely exert substantial influence on learners' conceptual performance. Consequently, instructional interventions should simultaneously address both cognitive and affective domains to maximize learning outcomes. Enhancing learner motivation through engaging instructional materials should therefore complement, rather than replace, explicit conceptual instruction and scaffolded problem-solving experiences.

The one-group pretest–posttest design precludes definitive causal inference because no comparison group was included. Likewise, the relatively brief intervention period may have limited the extent of conceptual gains achieved by learners. Differences in learners' access to mobile devices, levels of digital literacy, and prior academic preparation may also have influenced learning outcomes. Future investigations should employ quasi-experimental or experimental research designs with larger and more diverse participant samples, longer intervention periods, and longitudinal assessments to determine the sustainability of learning gains and establish stronger causal evidence regarding the effectiveness of the intervention.

Overall, the findings demonstrate that the mobile application–integrated Self-Learning Module constitutes an effective technology-enhanced instructional innovation for improving both conceptual understanding and learner motivation in Stoichiometry. By systematically addressing identified learning gaps through scaffolded instruction, interactive learning experiences, and mobile-assisted activities, the intervention contributes to more meaningful and learner-centered Chemistry instruction. These findings advance the growing body of evidence supporting digital instructional innovations in science education and align with Sustainable Development Goal 4 (Quality Education) by promoting inclusive, equitable, and high-quality learning opportunities through evidence-based educational technologies.

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