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Research Article

Enhancing Independent Learning and Conceptual Understanding of Integration in Higher Education Mathematics with Photomath

Onesme Niyibizi[1,2], **Jean Nepomuscene Singirankabo**[3]

[1]Ph.D. Candidate in Mathematics Education, College of Education, University of Rwanda, Kigali, Rwanda
[2]Department of Sciences of the Faculty of Education, Institut Catholique de Kabgayi, Muhanga, Rwanda
[3]Department of Mathematics Education, Ecole des Sciences Byimana, Ruhango, Rwanda

Abstract
This study investigated the potential of the Photomath application to promote self-directed learning and integrated conceptual understanding among first-year pre-service mathematics teachers studying at a private higher learning institution during the 2024–2025 academic year. Fastened in a quantitative quasi-experimental survey design, the study targeted 46 purposively selected students pursuing mathematics-related subject combinations. Data were collected using a validated Likert-scale questionnaire designed to capture students' attitudes, learning autonomy, and levels of conceptual understanding. The instrument demonstrated acceptable internal consistency, with reliability coefficients ranging between 0.76 and 0.84. Statistical analysis using Multivariate Analysis of Variance (MANOVA) revealed statistically significant effects of Photomath usage on students' attitudes toward mathematics, their conceptual understanding, and their capacity for independent learning. The findings indicated that the app positively influenced learners' motivation and engagement by providing immediate feedback and step-by-step solution pathways. These features enabled students to follow logical problem-solving processes, thereby supporting deeper engagement with mathematical procedures and concepts. Participants further reported that Photomath facilitated the integration of mathematical ideas through its visual representations, symbolic explanations, and structured guidance. Such affordances supported self-directed learning by allowing learners to verify solutions independently, revisit explanations, and regulate their own pace of learning. While a minority of respondents expressed concerns regarding potential overreliance on the application and the risk of superficial understanding when used uncritically, the overall perceptions remained strongly positive. In conclusion, the study demonstrates that Photomath functions not only as a computational tool but also as a pedagogical aid that supports learner-centered instructional approaches. When used thoughtfully, the application has the potential to enhance conceptual understanding, foster autonomy, and complement formal mathematics instruction in higher education contexts.

Keywords: Conceptual Understanding, Independent Learning, Integration, Photomath

Correspondence
Onesme Niyibizi
niyibizionesme12@gmail.com

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1. INTRODUCTION

Mathematics, particularly the integration concepts, is a subject hard to understand for the majority of first-year pre-service teachers seeking higher education. Independent learning ability mastery and deep conceptual understanding are keys to performing within this subject. In higher education mathematics, these two competencies are essential because learners are expected to engage with abstract ideas, construct meaning autonomously, and transfer theoretical knowledge to problem-solving contexts. However, many students struggle with integration due to its highly procedural nature, abstract symbolism, and the cognitive demand required to connect calculus concepts to real-world applications. These challenges often lead to surface learning, reliance on rote memorization, and limited retention of core principles.

Furthermore, pedagogical approaches in many mathematics classrooms tend to emphasize procedural fluency over conceptual reasoning, leaving a gap in learners' ability to interpret, generalize, and apply integration concepts independently. Online learning platforms such as the Photomath application have been possible instruments to help students overcome challenging mathematical problems independently. This study explored the effects of Photomath on independent learning, concept comprehension, and student disposition among first-year pre-service teachers. It was important to understand these effects as a method of integrating effective online methods into teacher training curricula aimed at enhancing mathematics teaching.

Therefore, this study aims to address the following research questions:

1. How does the use of Photomath affect first-year pre-service teachers' independent learning abilities, including accessibility, autonomy, and motivation?
2. What is the influence of Photomath on students' conceptual understanding of integration, particularly regarding step-by-step explanations, visualization, and knowledge transfer?
3. What are the perceptions and attitudes of first-year pre-service teachers toward Photomath in terms of satisfaction, technology acceptance, and concerns about its limitations?

1.1. Literature Review

Independent learning has become a focal issue in mathematics education, and mobile apps have been discovered more and more as facilitators of independent learning (Zhang et al., 2025). Fairman et al. (2025) confirmed that mobile learning apps substantially increase students' control and self-pacing of learning in calculus courses. Similarly, Monib et al. (2025) observed that university students who utilized digital math tools gained confidence and were motivated to work independently. The findings are aligned with constructivist principles that encourage autonomy of the learner and active engagement. However, Vieriu and Petrea (2025) were concerned about overreliance on technology and advocated for balanced use.

Conceptual mathematical knowledge is reinforced as learners engage with materials that provide step-by-step procedures and graphical illustrations (Elhilal, 2025). Tang et al. (2025) demonstrated how mobile apps that provide detailed procedural steps facilitate increased cognitive processing and reduced rote memorization. Rao et al. (2025) also emphasized how visualization facilitates learners' comprehension of abstract mathematical integration. While Elmahdi et al. (2025) cautioned that automated solutions might mask conceptual weaknesses, emerging evidence shows that properly designed apps promote meaningful knowledge transfer and retention, dispelling these concerns.

Student attitudes toward educational technology are a central element of successful integration and learning outcomes (Başgül & Coştu, 2025). Putri (2025) reported that students like mobile learning devices due to their accessibility and engagement potential, despite being aware of limitations such as risks of dependency and shallow understanding. Al-Adwan et al. (2025) also confirmed that perceived usefulness outweighs concerns, enabling ongoing technology adoption in classes. On the contrary, Abuzar (2025) believed that most students overlook the disadvantages of edtech, and users' awareness and critical use are required.

2. METHODS

2.1. Design

Quantitative research design with a quasi-experimental survey method was used in this study to examine the effect of Photomath on independent learning and conceptual understanding of integration of the first-year pre-service teachers at the private higher learning institution during the 2024–2025 academic year. The research was guided by three major objectives: (1) to explore the ways in which Photomath facilitates independent learning; (2) to find out its effect on conceptual understanding of integration; and (3) to explore students' attitudes and perceptions towards using Photomath as an electronic learning tool.

Photomath was purposefully selected as the intervention tool because it integrates advanced AI-driven step-by-step problem solving with visual and interactive feedback, making it distinct from other digital applications or traditional pen-and-paper methods. Unlike general-purpose tools such as GeoGebra or Symbolab, Photomath provides instant, scaffolded explanations that promote conceptual engagement rather than rote computation. Its self-paced and visual feedback features support autonomy and metacognitive reflection, enabling learners to independently verify, explore, and internalize mathematical concepts. Furthermore, its widespread accessibility via smartphones enhances learning beyond classroom settings, thus raising continuous, self-directed learning, a key component of independent learning and conceptual understanding.

2.2. Participants

The target population was all first-year pre-service mathematics-related combination students enrolled in the 2024–2025 academic year. Purposive sampling was employed in order to choose 46 participants to ensure that they would represent both Mathematics and Computer Sciences with Education and Mathematics and Geography with Education combinations. The general section of the questionnaire was employed to collect demographic details, including gender, age, and prior familiarity with Photomath.

2.3. Data Collection Tool

A guided questionnaire was used as the primary data collection tool, divided into two parts: Part A: Collected demographic information (e.g., gender, age, academic composition, and Photomath familiarity) and Part B: Measured participants' attitudes towards items under three thematic objectives using a 4-point Likert scale (1 = Strongly Disagree to 4 = Strongly Agree). The constructs were: Part B1: Accessibility, autonomy, and motivation during independent learning. Part B2: Conceptual understanding through step-by-step explanation, visualization, and deep learning. Part B3: Perceptions of usefulness, use, and limitations of Photomath.

The questionnaire was developed by the authors based on the study's conceptual framework and literature on technology-enhanced learning and self-directed learning, rather than adapted from existing validated instruments. The tool comprised 25 items in total: 5 in Part A and 20 in Part B. Example items included "Photomath helps me understand mathematical concepts independently" and "Using Photomath motivates me to complete math-related tasks." Participants were informed that completing the questionnaire would take approximately 10–12 minutes. The scoring involved summing responses for each construct, with higher aggregate scores reflecting more positive attitudes toward Photomath use in learning mathematics.

The pool of items was reviewed by experts in educational technology and mathematics education to ensure content validity. Pilot testing was conducted with a few pre-service teachers who were not involved in the main study, and the items showed good internal consistency, with Cronbach's alpha between 0.76 and 0.84 for different constructs.

The participants completed the questionnaire upon experiencing the Photomath application during their activity of answering integration problems for a duration of three weeks of teaching. Ethical principles, including informed consent and data confidentiality, were strictly maintained.

2.4. Data Analysis

Data for statistical significance between the application of Photomath and the dependent variables under each objective were tested using Multivariate Analysis of Variance (MANOVA) in SPSS. Demographic data were analyzed using descriptive statistics (percentages and frequencies). MANOVA was appropriate because multiple interdependent dependent variables under each objective were present, and effect sizes were measured using Partial Eta Squared (η^2) values.

3. RESULTS AND DISCUSSION

3.1. Demographic Information

The demographic details in Table 1 reveal equal gender distribution (50% male and 50% female), suggesting that both sexes were equally targeted by the intervention and by the utilization of Photomath. The majority of participants (73.9%) aged 18–22 years fall within the age range typical of first-year university students. This group is also likely to be more technology-literate and accepting of mobile learning technologies, possibly evidencing the high take-up of Photomath (67.4% for new users).

Table 1. Demographic Information of Participants (N = 46)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	23	50.0%
	Female	23	50.0%
Age	Less than 18 years	4	8.7%
	18–22 years	34	73.9%
	Above 22 years	8	17.4%
Combination	Maths & Computer Sciences with Education	28	60.9%
	Maths & Geography with Education	18	39.1%
First time using Photomath	Yes	31	67.4%
	No	15	32.6%

The balanced gender and academic pairing distribution (Math & Computer Sciences 60.9%, Math & Geography 39.1%) reduces bias and aids in generalizing the results. Having two-thirds of participants be new to Photomath offers a distinct view of the application's effect on first-time users without pre-existing bias or exposure. These groups enhance the study's validity through diverse but relevant participant backgrounds.

These findings are in agreement with Glaser (2025), who reported parallel age-grading interest in educational technologies among Middle Eastern undergraduate students. Mekheimer (2025) also proved that young university students tend to use educational applications positively, in contrast to their older peers. In contrast to Gondwe (2025), however, who reported male predominance in the utilization of digital mathematics aids in sub-Saharan Africa, this study identifies no gender-based disparity in exposure to or utilization of Photomath.

The implications of this profile are that first-year pre-service teachers, especially digital natives, can be effective users and champions of mobile mathematics apps if they are trained appropriately. Institutions can use this profile to develop training programs and digital interventions for the same cohorts of students in higher education environments. Finally, the demographic profile is in support of the credibility of the findings of the study and reflects a true representation of the target population. Initial exposure to Photomath for most of the subjects also helps to provide a robust platform for determining the real effectiveness of the app in stimulating conceptual understanding and independent learning.

Table 2. Photomath and Independent Learning

Effect	Wilks' Lambda	F (df)	p-value	Partial η^2
Accessibility & Ease of Use (AEUP)	0.722	F(4, 41) = 3.95	0.008	0.278
Autonomy & Self-Directed Learning (ASL)	0.685	F(4, 41) = 4.71	0.003	0.315
Learning Strategies & Motivation (LSM)	0.751	F(4, 41) = 3.39	0.017	0.249

Table 2 illustrates that Photomath is also important in independent learning, with statistically significant MANOVA results for ease of use and accessibility ($p = 0.008$), autonomy and self-directed learning ($p = 0.003$), and learning strategies and motivation ($p = 0.017$). Partial eta-squared values (.249 to.315) indicate a moderate effect size and reveal that Photomath has a considerable positive effect on student independence in integration problem-solving.

These results point to Photomath both as a solver of problems and as an enabler of learning that can facilitate students towards autonomous learning. Participants reported heightened ability to solve problems independently and enhanced self-initiative to learn. This confirms the platform as an enabler of autonomous learning, a core goal of modern mathematics education.

This concurs with Fairman et al. (2025), who enumerated the importance of mathematical apps in enabling independent learning in calculus courses. Monib et al. (2025) also set out that the university students who used mathematical apps were more confident academically and independent. Nevertheless, the current study differs from Vieriu and Petrea (2025), who cautioned that such tools would promote over-dependence rather than independence, a concern less evident here since autonomy scores were significantly high.

The significance of the research lies in its validation that Photomath is more than just a basic calculator, serving as a guided learning system where learner-centered learning is promoted, which aligns with constructivist learning theories. It is especially important in resource-constrained institutions where teacher assistance is patchy or non-existent.

Thus, these results support the integration of Photomath into learning platforms emphasizing independent, student-driven learning, and suggest that institutions teach students not only to use the tool but also when and why to use it to enhance learning.

Table 3. Conceptual Understanding of Integration

Effect	Wilks' Lambda	F (df)	p-value	Partial η^2
Step-by-step Explanations & Conceptual Clarity (SECC)	0.693	F(4, 41) = 4.55	0.04	0.308
Visualization and Interpretation (VIIC)	0.761	F(4, 41) = 3.25	0.021	0.241
Deep Learning and Knowledge Transfer (DLKT)	0.708	F(4, 41) = 4.12	0.007	0.292

The results in Table 3 indicate that Photomath has a substantial impact on conceptual integration understanding. Statistically significant impacts were found in step-by-step explanation and conceptual clarity ($p = 0.004$), visualization and interpretation ($p = 0.021$), and deep learning and knowledge transfer ($p = 0.007$). The respective effect sizes (partial $\eta^2 = 0.241$ to 0.308) suggest Photomath's significant contribution to a deeper mathematical understanding.

The openness of Photomath's step-by-step breakdown of integration techniques can potentially deter students from memorization and encourage them to focus on understanding mathematical processes. The tool's graphical elements and symbolic representation appear to reinforce visual learning and integrate with real-world applications, thus enabling the development of transferable knowledge.

This supports the earlier findings of Tang et al. (2025), who demonstrated that step-by-step mobile tools enable higher engagement and cognitive processing in mathematics. Rao et al. (2025) also determined that visualization tools in mobile apps enhance the ability of students to read mathematical functions. Elmahdi et al. (2025), however, questioned the conceptual depth these tools allow, proposing that automated solutions can mask deeper misunderstandings. However, in this study, both knowledge transfer and retention (DLKT) were impacted considerably, reflecting real conceptual gains.

The contribution of the study lies in empirically validating that such mobile applications as Photomath do not merely facilitate procedural repetition but also foster meaningful learning of abstract mathematical concepts. This fills a gap in the literature that is prone to highlighting the motivational effects of technology while overlooking its cognitive contribution.

With these findings, teachers are advised to seek to couple Photomath with instructional strategies that prompt conceptual thinking, in a way that step-by-step guidance is complemented with metacognitive questioning.

Table 4. Perceptions and Attitudes toward Photomath

Effect	Wilks' Lambda	F (df)	p-value	Partial η^2
User Satisfaction and Usefulness (USPU)	0.698	F(4, 41) = 4.38	0.005	0.302
Technology Acceptance and Engagement (TAE)	0.748	F(4, 41) = 3.45	0.015	0.253
Limitations and Concerns (LC)	0.773	F(4, 41) = 3.01	0.028	0.227

The findings in Table 4 show that students have positive attitudes towards Photomath as an e-learning tool. Statistically significant results were found in user satisfaction and perceived usefulness ($p = 0.005$), technology acceptance and engagement ($p = 0.015$), and limitations and concerns ($p = 0.028$) with moderate effect sizes ($\eta^2 = 0.227$ to 0.302). These results suggest that while students are inclined to value the benefits of Photomath generally, they are also interested in its potential limitations.

Students appreciated Photomath's efficiency, accessibility, and learning engagement influence. Meanwhile, they worried about over-reliance on the tool and a lack of detailed conceptual explanation in some cases. This balanced perspective is a sign of a mature user group that is able to critically evaluate digital learning tools.

This aligns with Putri (2025), where it was found that students embrace mobile learning technologies but also express concerns about academic integrity and comprehension. Al-Adwan et al. (2025) found the same patterns among Korean students, where perceived usefulness would trump technological limitations. In contrast, Abuzar (2025) argued that the majority of students do not value the limitations of edtech tools compared with the cautious optimism found in this study.

The most important contribution of this study is the equilibrium in understanding student attitudes, identifying weaknesses and strengths of mobile learning apps in mathematics. These can inform future app design, along with institutional policy for guiding appropriate use.

Teachers and policymakers need to address these attitudes by disseminating Photomath as a complementary learning aid with the advancement of critical thinking, reflection, and responsible use in mathematics education.

4. CONCLUSION

The results of this study show that first-year pre-service teachers' independent learning and conceptual grasp of integration are greatly improved by the Photomath application. The results of the MANOVA revealed statistically significant effects in every domain that was studied, including motivation, autonomy, accessibility, ease of use, step-by-step conceptual clarity, and integration concept visualization. Participants also reported high levels of engagement and satisfaction with Photomath, despite some reservations about its shallow explanations and over-reliance. These findings highlight the educational benefits of incorporating digital resources such as Photomath into higher education settings in order to promote mathematical independence and deeper learning. To prevent dependency and guarantee conceptual mastery, teacher education programs should think about formally integrating Photomath into teaching practices while also offering advice on how to use it in moderation alongside more conventional teaching techniques.

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Data Availability Statement. All data can be obtained from the corresponding author.

Conflicts of Interest. The author declares no conflicts of interest.

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