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Exploring the impact of device ownership, usage patterns, and technology proficiency on mobile learning among higher education students: a multi-faceted study

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Abstract. This study explores the impact of device ownership, frequency of use, and technology proficiency on integrating mobile technologies (IMT) in learning by students in higher education institutions (HEIs) in Ghana. The objective is to understand how these factors are influenced by demographic variables such as age, gender, and program of study. Using Partial Least Squares Structural Equation Modeling (PLS-SEM), data were collected from 457 students selected with a disproportionate stratified sampling technique across multiple HEIs offering STEM programs to analyse these relationships. The results demonstrated that technology proficiency significantly enhances the integration of mobile technologies into learning. It was noted that device ownership alone was insufficient to improve technology proficiency; frequent and effective usage was more essential. Additionally, gender and program of study moderated the effects of device ownership and frequency of use on technology proficiency. These findings highlight the importance of promoting effective usage patterns and advancing technology proficiency to integrate mobile technologies in educational settings better. It is recommended that HEIs focus on providing training programs to staff to integrate more learning activities that promote frequent use of mobile technologies in academic activities to enhance students' technology proficiency.

Keywords: mobile technologies, higher education institutions, technology proficiency, device ownership, frequency of use, demographic moderators, STEM programs, integration of mobile learning

1. Introduction

The integration of mobile technologies into educational settings has increasingly become a focal point for research within higher education. As digital devices become more ubiquitous, understanding how these tools affect learning outcomes is crucial. This study aims to explore the multi-faceted dimensions of mobile learning by examining three critical factors: device ownership, usage patterns, and technology proficiency among students in higher education institutions.

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Device ownership is posited as a fundamental enabler of mobile learning, providing the necessary hardware for accessing digital educational resources. Prior studies have shown that ownership alone does not guarantee effective learning; rather, how students use these devices critically affects their learning outcomes [2, 4, 11, 35, 42]. Frequency and patterns of usage, which range from passive content consumption to interactive and collaborative learning, play a significant role in determining the educational benefits of mobile technology [26, 41].

Moreover, technology proficiency, or the ability to effectively utilise digital tools, has been identified as a significant predictor of successful technology integration in education [38]. Students with higher levels of digital literacy are more likely to leverage mobile technologies in ways that enhance their learning experiences. This study also considers the moderating effects of demographic factors such as age, gender, and program of study. Research suggests that these variables can influence how students adopt and utilise technology in learning environments [4, 37]. By incorporating these moderating factors, the study aims to provide a comprehensive analysis of the factors influencing mobile learning adoption and usage among higher education students.

The objective of this research is not only to delineate the relationships between device ownership, usage patterns, and technological proficiency but also to understand how these relationships are affected by student demographics. This approach reflects a growing recognition of the complex, interconnected nature of factors that contribute to effective mobile learning. Research has shown that students in higher education are using mobile technologies extensively, with smartphones being the most commonly used device [5, 40, 44]. Other studies have also demonstrated that the use of mobile technologies can have a positive impact on student engagement, participation, and learning outcomes [57]. For instance, the use of mobile devices can allow students to access course materials and resources anytime, anywhere, which can facilitate their learning and help them stay connected with their peers and instructors [62].

Despite the pervasive adoption of mobile technologies in higher education, significant gaps remain in our understanding of how these tools are integrated into students' learning processes. While device ownership is widespread, the extent to which it translates into effective educational use is not uniformly positive. This indicates that mere access to technology does not guarantee enhanced learning outcomes. Furthermore, variability in usage patterns and technology proficiency among students suggests that certain factors influence these differences. It is, therefore, pertinent to conduct further research to determine the impact of device ownership, usage patterns, and technology on mobile learning among higher education institution (HEI) students. Additionally, demographic variables such as age, gender, and program of study may further modulate these effects. However, the literature currently offers limited insights into how these moderating factors interact with technology use in educational contexts. This gap hinders the development of targeted, effective educational strategies and technologies that accommodate diverse student needs and capitalise on the potential of mobile learning.

This study aims to systematically explore the impact of device ownership, frequency of use, and technological capability on the integration of mobile technologies in learning among higher education students. It specifically focuses on the moderating roles of age, gender, and program of study. By elucidating these dynamics, the research seeks to contribute to a more nuanced understanding of mobile learning and to inform the design of more inclusive and effective educational technologies.

1.1. Purpose of the study

The purpose of this study was to explore how device ownership, usage patterns, and technology proficiency impacted the integration of mobile technologies in learning among higher education students in Ghana. Specifically, it aimed to investigate how these factors influenced students' learning processes and outcomes. Additionally, this research examined the moderating roles of demographic variables such as age, gender, and program of study. By elucidating these dynamics, the study sought to contribute to a more detailed understanding of mobile learning and to inform the design of more inclusive and effective educational technologies.

1.2. Research question

1. How do device ownership, frequency of use, and technology proficiency influence the integration of mobile technologies in learning among students at higher education institutions, and how are these relationships moderated by age, gender, and program of study?

1.3. Research hypothesis

H1: Technology proficiency mediates the relationship between device ownership and the integration of mobile technologies.

H2: Technology proficiency mediates the relationship between frequency of use and the integration of mobile technologies.

H3: The relationship between device ownership and technology proficiency is moderated by age, gender and program of study.

H4: The relationship between frequency of use and technology proficiency is moderated by age, gender and program of study.

H5: Technology proficiency positively influences the integration of mobile technologies.

2. Literature review

The integration of mobile devices into higher education has become increasingly prevalent, with students and instructors alike recognising the potential benefits of leveraging these devices for learning. However, despite widespread ownership, there remains a significant gap between the potential and actual use of mobile technology in academic settings. This literature review explores the impact of device ownership, usage patterns, and technology proficiency on mobile learning among higher education students. The review synthesises current research findings to provide a comprehensive understanding of these factors, their influence on educational outcomes and their implications for future research and practice.

Device ownership is a foundational aspect of mobile learning. Studies have consistently shown that mobile device ownership is high among higher education students. A 2015 EDUCAUSE report found that 86% of undergraduates owned a smartphone, with nearly half owning a tablet [5]. Similarly, a follow-up report in 2023 indicated that nearly 100% of students owned smartphones [50].

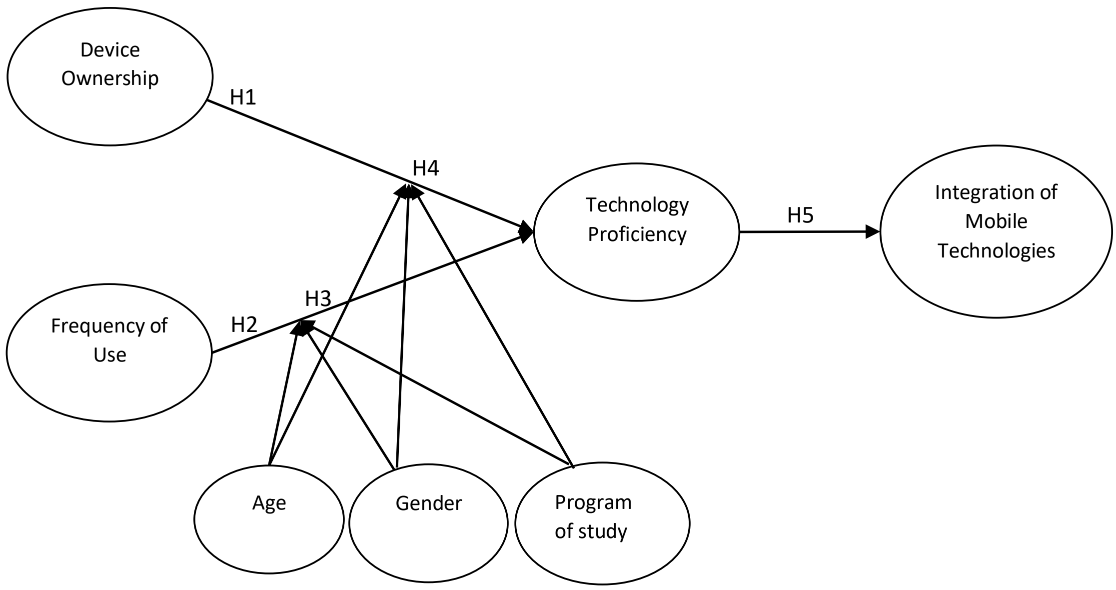

Figure 1: Conceptual model.

Furthermore, device ownership influences students' motivation and engagement. Several studies indicate that students who own mobile devices exhibit higher levels of motivation and engagement in their studies, as well as improved academic performance [19, 25]. These devices provide students with the flexibility to learn at their own pace and convenience, which enhances their overall learning experience. However, the study also notes that merely owning a device is not sufficient enough; how students use the device plays a crucial role in determining its impact on learning outcomes.

Despite the widespread ownership of mobile devices, usage patterns vary significantly. A 2012 survey at the University of Central Florida found that while 83% of students owned smartphones, only 50% reported using them daily for schoolwork [5]. The way students use their mobile devices significantly affects their learning experiences and outcomes. Kim, Mims and Holmes [32] found that students who frequently used their mobile devices for academic purposes tended to develop better digital literacy skills and achieved higher academic performance. Crompton et al. [9] also opined that students with their own devices were more likely to engage in learning activities outside traditional classroom settings. This engagement includes accessing course materials, participating in discussions with peers and instructors, and completing assignments [14, 16, 36].

However, not all usage patterns are beneficial. Studies have shown that non-academic use of mobile devices, such as social media and general gaming, could lead to distractions and decreased academic performance [29]. However, gamification for learning is a way of making more complex concepts fun and easier to comprehend and has been found to increase student motivation and engagement, leading to better learning outcomes [18, 22, 43, 52, 53]. It is, therefore, essential to promote productive mobile device usage patterns among students by integrating mobile learning activities into the curriculum to guide students toward more meaningful use of their devices [10].

2.1. Mediating factor

Technology proficiency is a critical determinant of successful mobile learning. Many students lack the necessary technical skills to use mobile devices effectively for learning purposes [31, 49]. Davies and West [12] argue that students with higher levels of technology proficiency are better equipped to navigate and integrate mobile learning applications effectively. Proficient students can leverage advanced features of educational technologies, engage in collaborative learning environments, and troubleshoot technical issues more efficiently.

Developing technology proficiency requires targeted training and support. Several studies have highlighted the positive impact of training programs on students' ability to use mobile technologies for learning [51, 55]. The researchers highlighted that students need to be exposed to and be familiar with technologies in order to compete in the world marketplace, and they need to be able to integrate the same in dynamic social environments. Moreover, technology proficiency is linked to students' self-efficacy in using mobile devices. Zimmerman and Kulikowich [63] found that students with higher self-efficacy are more likely to explore and utilise mobile learning tools effectively. This relationship underscores the need for educational institutions to provide ongoing support and resources to enhance students' technology proficiency and self-efficacy.

Several models and frameworks have been developed to assess and enhance technology proficiency, particularly in educational contexts. These aim to evaluate how individuals interact with technology, focusing on different levels of skill acquisition and integration. Some prominent ones include the International Society for Technology in Education (ISTE) Standards, the Technological Pedagogical Content Knowledge (TPACK) framework, and the Substitution Augmentation Modification Redefinition (SAMR) model [28, 34, 47]. Each of these emphasises the integration of technology in education, assessing users' ability to engage with and utilise digital tools effectively.

However, for this study, the Digital Competence Framework for Citizens (DigComp) is the most suitable model. DigComp offers a comprehensive framework that encompasses five critical areas of technology proficiency, namely information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving [48]. These areas align directly with the skills required for effective mobile learning. By focusing on a range of competencies, DigComp not only assesses basic technological abilities but also evaluates higher-order skills like content creation, collaboration, and digital safety [61]. All these are crucial for mobile learning environments.

Given this study's focus on device ownership, usage patterns, and technology proficiency, DigComp provides a nuanced understanding of how students use mobile devices in learning contexts. Its broad, adaptable framework is particularly valuable for evaluating students' different skill levels, making it the best fit for assessing their readiness and capability to leverage mobile technologies in their educational experiences.

2.2. Moderating factors

Demographic variables such as age, gender, and program of study can moderate the effects of device ownership, frequency of use, and technology proficiency on mobile learning [58]. Warschauer et al. [59] found that these demographic factors influence students' attitudes toward technology and their comfort levels in using mobile devices for learning. Some researchers found out that younger students and those enrolled in technology-intensive programs were generally more adept at using mobile learning tools [54, 60].

Understanding these moderating factors is crucial for designing inclusive mobile learning strategies. According to a study by Han and Shin [23], tailored interventions that consider demographic differences could enhance the effectiveness of mobile learning initiatives. This approach ensures that all students, regardless of their background, can benefit from the integration of mobile technologies into their education.

The integration of mobile technologies into higher education is profoundly influenced by device ownership, frequency of use, and technology proficiency. These factors collectively shape students' learning experiences and outcomes. To maximise the benefits of mobile learning, educational institutions must ensure equitable access to devices, promote effective usage patterns, and enhance students' technology proficiency through continuous support and training. Additionally, considering demographic variables could help create more inclusive and effective mobile learning environments. By addressing these key areas, higher education institutions can leverage mobile technologies to improve student engagement and learning outcomes.

3. Methodology

This study used a quantitative methodology and a cross-sectional study design. In order to answer research questions and test hypotheses, the scores from instruments such as questionnaires were statistically evaluated. Data on students' device ownership, frequency of use, technology proficiency, and the integration of mobile technologies were gathered for this study.

3.1. Population

Every person the researcher is interested in is the population of the study [39]. Students enrolled in STEM programmes at Ghana's public and private HEIs made up the study's population. A total of 91 HEIs, made up of 81 private and 10 public, run STEM programmes out of the 138 degree awarding HEIs [17]. The combined population of students in these STEM programmes was approximately 15,000.

3.2. Sample and sampling procedure

The student population numbers for public and private HEIs were skewed in favour of public HEIs in this study. Using a disproportionate stratified random sampling technique, 10 HEIs were chosen from the target population. When elements from each stratum are selected in a way that does not correspond to their proportional representation in the whole population, this is known as disproportionate stratified sampling [8]. Every member of the population does not have an equal chance of being included in the sample when using this strategy [8, 39]. No stratum receives the same sample percentage. A sampling fraction of 70% was allocated to private HEIs and 30% to public HEIs because there are far fewer public HEIs than there are private HEIs in Ghana. As a result, three public and seven private HEIs were chosen. However, the specific 10 HEIs selected for the study were done randomly from their list using Microsoft Office Excel 2019's random function.

Additionally, a random sample of 100 students from each public HEI and 30 from each private HEI was taken to guarantee a proportionate distribution of the sample across the strata. This was because public HEIs had a higher student population and more STEM programs available than private HEIs, which had a smaller student population. As a result, there were 510 students in the sample overall, 300 of whom attended public HEIs and 210 of whom attended private HEIs.

3.3. Instrument

Data from the participants was gathered for the study using a questionnaire instrument and the survey method. There were four sections on the questionnaire, numbered Section A through Section D. Students' demographic information on gender, age range, institution of study, department, and year of study were all gathered in Section A. Section B measured students' device ownership and their frequency of usage of their devices. Section C used a five-point Likert scale, ranging from 1 for no skill to 5 for excellent skill, to test participants' technological proficiency in 26 distinct mobile task execution scenarios. This section contains some items that were modified from Venkatesh and Davis [56].

A four-point Likert scale was used to assess how students integrated mobile devices for learning purposes in Section D, which was adapted from Davis [13], and Venkatesh and Davis [56]. The items were further divided into five constructs, each with a different number of items. To keep the responders from adopting a neutral stance, a forced Likert scale, which has four points, was employed—the first construct, which had five items, assessed the ease of access to learning resources. The second construct, which had three items, was a personalised learning environment. The third was interaction and social learning, which comprised five items and elicited how respondents used mobile technologies to engage. Instant feedback and assessment constructs came next, each with four and two items, respectively.

3.4. Reliability and validity

The quality of a research study is usually measured by determining its reliability and validity. Reliability and validity of scores on instruments lead to meaningful interpretations of data [8]. SmartPLS 4.0 was used to develop a measurement model, which was evaluated to ensure the reliability and validity of the constructs by assessing the Cronbach's alpha, composite reliability (ρ_A and ρ_C), and average variance extracted (AVE) [33]. The values of both criteria should be higher than 0.7 [21].

3.5. Data analysis

Data gathered from the questionnaire was cleaned to remove errors or missing values. The responses from the questionnaire items were coded and analysed using IBM Statistical Package for Social Science (SPSS v. 25). Univariate analysis was used to analyse the demographics, and descriptive statistics like means and frequencies were presented.

Further multivariate analysis was done using Structural Equation Modeling with Partial Least Squares (SEM-PLS), implemented in SmartPLS 4 software. SEM-PLS was chosen due to its suitability for exploratory research and its ability to handle complex models with multiple constructs [21].

4. Results

4.1. Demographics

A total of 457 respondents submitted a completed questionnaire, with a significant majority being male. Specifically, 335 respondents (73.3%) were male, while 122 respondents (26.7%) were female. This distribution is representative of the gender composition within the STEM programmes in Ghana. The age distribution revealed that the respondents were mostly young adults, with 223 representing almost half being between 24-29 years (48.8%). This was followed by the 18-23 age range with 123 respondents (26.9%), the 30-34 age range with 91 respondents (19.9%), and 20 respondents (4.4%) above 35 years. The introduction of the free senior high school programme in Ghana could be a factor in more students enrolling in HEIs than previously.

The distribution of respondents across various programmes of study was as follows: ICT was the most represented programme with 166 respondents (36.3%), followed by Computer Science with 110 respondents (24.1%), Mathematics Education with 90 respondents (19.7%), Science Education with 33 respondents (7.2%), Nursing and Midwifery with 28 respondents (6.1%), Engineering with 21 respondents (4.6%), and Home Economics Education with 9 respondents (2.0%). For their level of study, level 100 students constituted 16.8% (n=77) of the total sample, level 200 students represented 33.7% (n=154), level 300 students accounted for the largest group with 37% (n=169), and level 400 students made up 12.5% (n=57).

4.2. Measurement model assessment

The measurement model for the study was constructed based on the conceptual framework, which was derived from hypotheses H1 to H9 as depicted in figure 2. The measurement model defines the relationship between the constructs and their corresponding indicators. In order to assess the measurement model, reliability, convergent, and discriminant validities should be confirmed as shown in table 1 [21]. All factor loadings ranged from 0.707 to 0.961, which are above the threshold value of 0.7 and are considered to be acceptable [7]. A value of 0.5 or greater for the AVE indicates that the construct explains more than half of the variance of its items. For all the constructs, Cronbach's alpha ranged between 0.779 to 0.971, which demonstrated acceptable to excellent internal consistency. Composite reliability values also ranged between 0.843 and 0.976, indicating good reliability.

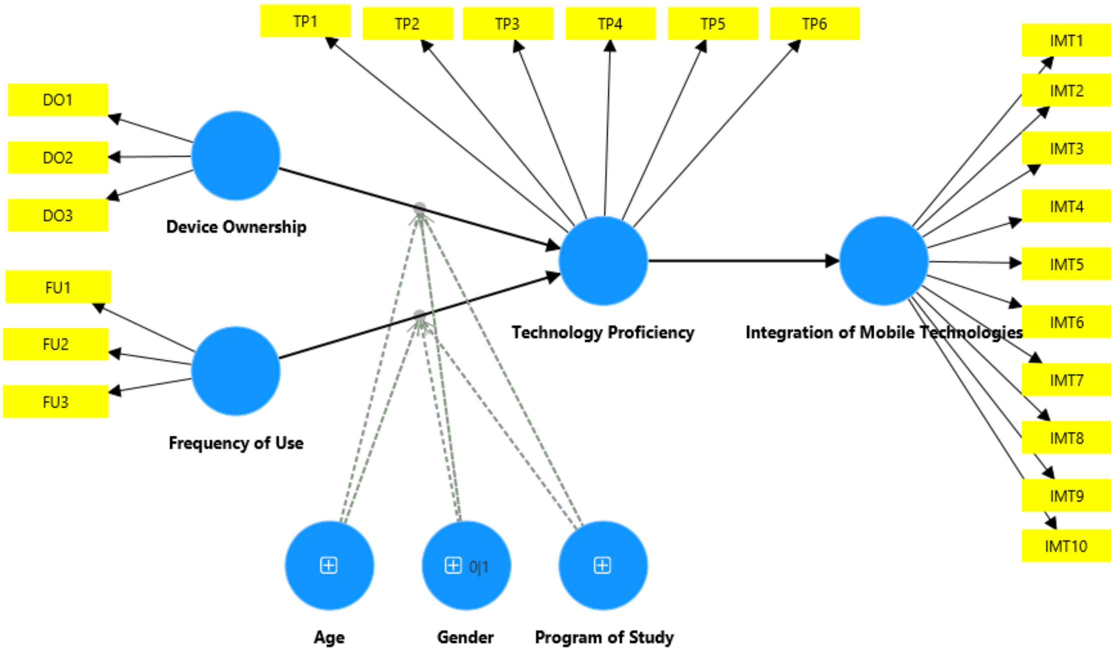

Figure 2: Measurement model for the study.

To confirm discriminant validity, the square root of average variances extracted (AVE) of each variable should be greater than the correlations of that variable with other variables [24]. The Fornell-Larcker criterion results in table 2 show that all constructs have good discriminant validity, as the square root of the AVE for each construct is greater than its correlations with other constructs. This indicates that they are distinct from one another and, therefore, supports the robustness and validity of the measurement model used in the SEM-PLS analysis.

4.3. Structural model assessment

The degree of variance between the model's dependent variables is used to evaluate the explanatory power of the model [15]. The relationships between the constructs were analysed using path coefficients, with significance levels determined via bootstrapping procedures. The R-squared (R^2) values for each endogenous construct were calculated to determine the amount of variance explained by the model. As shown in figure 3, the model has R^2 value of 12.1% for Technology Proficiency and 29.8% for Integration of Mobile Technologies. All indicator loadings are above 0.7, demonstrating that the indicators are well-aligned with their respective constructs. The most significant direct path is from Technology Proficiency to Integration of Mobile Technologies, with a value of 0.546, highlighting the importance of proficiency in technology for integrating mobile technologies. The moderating variables Age, Gender, and Program of Study had varying impacts on the relationship between Frequency of Use and Technology Proficiency.

The hypothesis testing results (table 3) reveal significant insights into the relationships

Table 1
Reliability and validity measures of the model.

Construct	Indicators	Factor loadings	Indicator reliabilities (Loadings^2)	Cronbach's alpha	ρ_A	Composite reliability	Average variance extracted (AVE)
Device Ownership (DO)	DO1	0.707	0.498	0.779	0.950	0.843	0.644
	DO2	0.897	0.805				
	DO3	0.793	0.627				
Frequency of Use (FU)	FU1	0.850	0.503	0.788	0.860	0.864	0.680
	FU2	0.811	0.601				
	FU3	0.812	0.682				
Technology Proficiency (TP)	TP1	0.948	0.899	0.926	0.928	0.938	0.602
	TP2	0.961	0.924				
	TP3	0.946	0.895				
	TP4	0.926	0.857				
	TP5	0.918	0.843				
	TP6	0.906	0.821				
Integration of Mobile Technologies (IMT)	IMT1	0.730	0.533	0.971	0.972	0.976	0.873
	IMT2	0.794	0.630				
	IMT3	0.770	0.593				
	IMT4	0.798	0.637				
	IMT5	0.838	0.702				
	IMT6	0.817	0.667				
	IMT7	0.773	0.598				
	IMT8	0.769	0.591				
	IMT9	0.741	0.549				
	IMT10	0.719	0.517				

between device ownership, frequency of use, technology proficiency, and the integration of mobile technologies. Hypotheses H1 and H3a indicate that neither device ownership nor its interaction with age significantly affects technology proficiency, as reflected by their path coefficients (0.019 and -0.020) and high p-values (0.724 and 0.648). Conversely, hypothesis H2 shows that frequency of use significantly impacts technology proficiency, with a strong path coefficient of 0.307 and a p-value of 0.000. Additionally, the interaction between device ownership and gender (H3b) and between device ownership and program of study (H3c) significantly affects technology proficiency, as evidenced by their path coefficients (0.381 and 0.138) and low p-values (0.003 and 0.023), respectively.

Furthermore, the interaction between frequency of use and age (H4a) and the interaction between frequency of use and gender (H4b) do not significantly influence technology proficiency, as indicated by their path coefficients (0.023 and -0.109) and high p-values (0.693 and 0.381). However, the interaction between frequency of use and program of study (H4c) significantly affects technology proficiency, with a path coefficient of 0.176 and a p-value of 0.020. Lastly, hypothesis H5 confirms that technology proficiency significantly influences the integration of

Table 2
Fornell-Larcker criterion results.

	Age	Device Ownership	Frequency of Use	Integration of Mobile Technologies	Program of Study	Technology Proficiency	Gender
Age	1.000						
Device Ownership	0.163	0.803					
Frequency of Use	0.081	0.161	0.825				
Integration of Mobile Technologies	0.137	0.168	0.147	0.776			
Program of Study	-0.010	0.020	-0.645	-0.054	1.000		
Technology Proficiency	0.090	0.165	0.146	0.546	-0.025	0.934	
Gender	-0.266	-0.145	-0.036	-0.154	-0.006	-0.179	1.000

Table 3
Hypotheses test results.

Hypothesis	Path	Path coefficient	p-value
H1	DO → TP	0.019	0.724
H2	FU → TP	0.307	0.000
H3a	DO x Age → TP	-0.020	0.648
H3b	DO x Gender → TP	0.381	0.003
H3c	DO x Program of Study → TP	0.138	0.023
H4a	FU x Age → TP	0.023	0.693
H4b	FU x Gender → TP	-0.109	0.381
H4c	FU x Program of Study → TP	0.176	0.020
H5	TP → IMT	0.546	0.000

mobile technologies, with a robust path coefficient of 0.546 and a p-value of 0.000. These findings underscore the importance of frequency of use and certain moderating factors (gender and program of study) in enhancing technology proficiency, which in turn facilitates the integration of mobile technologies in educational contexts.

5. Discussion

The PLS-SEM analysis provided critical insights into the reliability and validity of the constructs and the structural relationships between them. The constructs of Device Ownership, Frequency of Use, Technology Proficiency and Integration of Mobile Technologies demonstrated good reliability and validity, as indicated by Cronbach's alpha, composite reliability, and AVE values. The robustness of the proposed model was confirmed through significant path coefficients

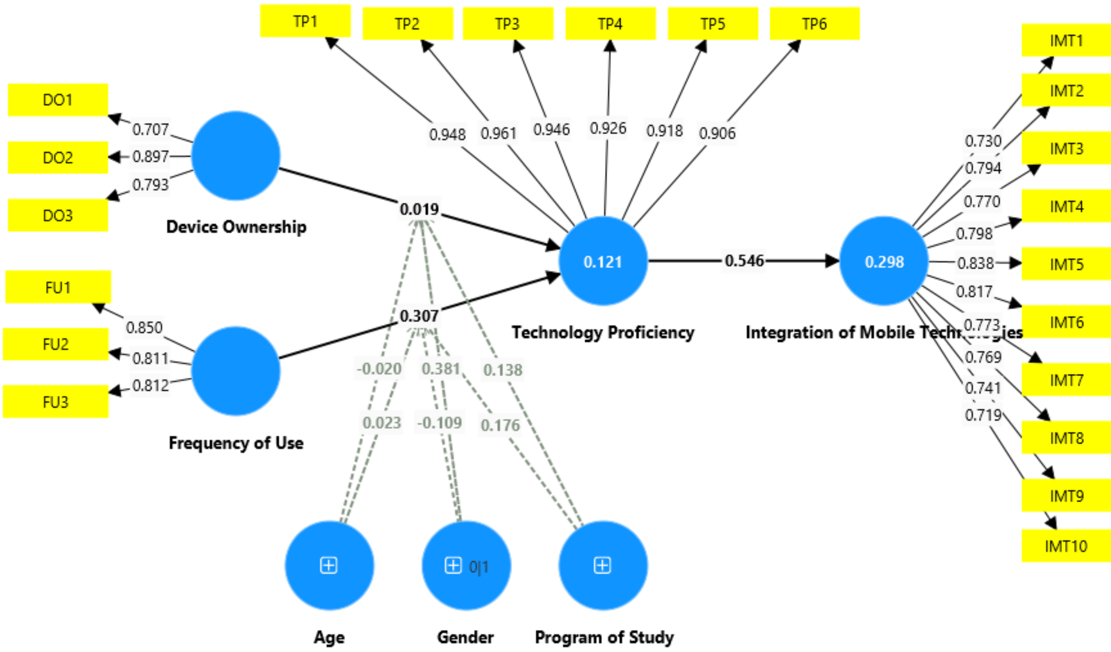

Figure 3: Structural model for the study.

and substantial explained variance. Employing PLS-SEM enabled this study to effectively model the complex relationships between various factors influencing the integration of mobile technologies in HEIs, providing a comprehensive understanding of the underlying moderating and mediating dynamics.

The results indicate that device ownership had a weak direct effect on technology proficiency. Hence, device ownership alone did not guarantee technology proficiency. However, the increased frequency of mobile device use significantly influenced technology proficiency. This suggests that using mobile devices frequently for the right purposes improved technology proficiency as consistent with Gulatee and Combes [20]. With regards to the moderating variables, age had no significant effect on both device ownership and frequency of use to impact technology proficiency. This means that participants' age did not influence whether they owned devices or how often they used them in a way that impacted their technology proficiency. This result aligns with similar conclusions drawn in the studies by Al-Emran et al. [3], Hwang et al. [27], Junco, Merson and Salter [30]. In those studies, age was also not found to play a pivotal role in determining technology adoption, usage frequency, or proficiency levels, suggesting that technological proficiency has become increasingly common across age groups. This may reflect the widespread adoption and ubiquity of mobile devices, rendering age less of a barrier to technology ownership or use than in the past.

In contrast to age, gender had a moderately significant positive effect on device ownership. This means that gender influenced whether participants owned devices, with certain gender groups more likely to own smartphones or similar technologies. However, gender did not significantly affect the frequency of use of these devices, meaning that although gender influences ownership, it does not necessarily predict how often individuals use the technology once they have it. These findings align with the work of Aderogba-Oti [1], Al-Emran et al. [3], Hwang et al. [27], Junco, Merson and Salter [30], Pratama and Scarlatos [46], all of whom reported that while gender may impact technology ownership, it does not always lead to differences in usage frequency. Aderogba-Oti [1] particularly explored gender differences in smartphone ownership and usage, noting that gender plays a role in device acquisition but not necessarily in day-to-day use patterns. Similarly, Pratama and Scarlatos [46] found that while boys and girls might differ in the rates of smartphone ownership, both genders tended to use the devices in similar ways once they had them.

The program of study significantly influenced both device ownership and frequency of use, impacting students' technology proficiency. This suggests that academic programmes shape how students acquire and use technology, likely due to differing technological demands across disciplines. Students in more tech-intensive programmes may be more inclined to own and use devices frequently compared to those in less tech-focused programmes. This finding highlights the role that educational context plays in shaping students' interaction with mobile technologies.

Moreover, the study revealed a strong direct effect of technology proficiency on the integration of mobile technologies in learning. Students with higher proficiency are better able to integrate mobile devices and tools into their educational activities. This supports the conclusions of Byungura et al. [6] and Pinto and Leite [45], who emphasised the importance of improving digital competencies for better technology integration. Thus, enhancing students' technology skills across programs would likely result in more effective use of mobile technologies in education, ultimately improving learning outcomes.

6. Conclusion

The findings from the PLS-SEM analysis underscore the intricate dynamics between device ownership, frequency of use, technology proficiency, and the integration of mobile technologies in higher education institutions (HEIs). While device ownership alone does not directly translate into technology proficiency, frequent use of mobile devices significantly enhances it, highlighting the importance of active engagement with technology. The study also reveals nuanced roles of moderating variables: gender and program of study significantly influence the relationship between device ownership, frequency of use, and technology proficiency, whereas age does not exert a significant moderating effect.

The robust structural model, validated by significant path coefficients and substantial explained variance, provides a comprehensive framework for understanding these relationships. This study contributes to the growing body of literature on technology integration in education, emphasising the need to focus on practical usage and tailored interventions based on demographic factors to enhance technology proficiency. Consequently, enhancing students' technology proficiency is crucial for the effective integration of mobile technologies in their learning processes, aligning with prior research by Byungura et al. [6] and Pinto and Leite [45]. These insights can inform policy and practice in HEIs, guiding strategies to foster technology integration that supports student learning and academic success.

6.1. Areas for future research

The findings of this study open several avenues for future research. First, while this study examined the relationship between device ownership, frequency of use, and technology proficiency, further research could explore the specific types of mobile applications or digital tools that contribute most effectively to improving technology proficiency among students. This would offer more granular insights into how certain technologies influence learning outcomes.

Second, although gender and program of study were shown to have significant moderating effects on device ownership and use, additional research could investigate how other factors, such as socioeconomic status, digital literacy levels, or institutional support (e.g., access to training or IT resources), impact the integration of mobile technologies in educational contexts. Such studies could provide a more comprehensive understanding of the barriers and facilitators to technology integration across diverse student populations.

Finally, given the rapid advancements in mobile technology, future studies could focus on longitudinal research to track changes in technology use and proficiency over time. This could help determine whether the patterns observed in this study hold true as mobile technologies evolve and become even more integral to education, particularly in the context of online and blended learning environments. By identifying long-term trends, researchers can offer valuable insights for educators and policymakers better to support students' technological development and academic success.

7. Declarations

7.1. Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

7.2. Competing interests

The authors declare that they have no competing interests.

7.3. Funding

This research was a requirement for the completion of a doctoral degree by the primary researcher, who received some financial support from the University of South Africa during the course of his study.

7.4. Ethics statement

The research was conducted in full compliance with ethical standards and received ethical clearance from the UNISA School of Science Ethics Review Committee at the University of South Africa (Approval Number: 2022/CSET/SOS/058), ensuring that all participants' rights and confidentiality were respected.

7.5. Authors' contributions

DDE conceived the research topic and objectives, conducted an extensive literature review, performed the data analysis, and drafted the discussion and conclusion sections of the manuscript. HIA provided critical guidance on the research design, offered constructive feedback throughout the study, and ensured rigorous academic standards were met. Additionally, HIA supervised the entire research process, offering support and direction to ensure the study's successful completion. Both authors read and approved the final manuscript.

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