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Mobile learning and digital empowerment in higher education: The mediating role of digital competence and the moderating role of technostress

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ABSTRACT

Mobile learning (M-learning) is an effective educational tool that offers opportunities for quality education in technology-driven classrooms. However, existing research shows a gap in understanding how M-learning, digital competence, and technostress shape students' digital empowerment. This study seeks to bridge this gap by examining the role of M-learning in university students' digital empowerment, considering the mediating effect of digital competence and the moderating effect of technostress. This study employed a quantitative survey design. Data were collected from 410 university students selected from the top ten QS-ranked universities. The Jamovi software was used for data analysis. The results revealed that M-learning was significantly associated with students' digital empowerment. Digital competence partially mediated this relationship. Technostress was found to have an independent association with digital empowerment. However, the interaction between M-learning and technostress did not significantly moderate the relationship. The study provides valuable insights into the role of M-learning in promoting digital empowerment and offers actionable implications for policy and practice in higher education.

KEYWORDS: educational psychology, digital competence, digital empowerment, mobile learning, technostress, quality education, SDG4

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Introduction

Mobile learning (M-learning) has emerged as an essential component in the digital education landscape, providing flexible, student-centered learning opportunities (Kurt, 2023). Despite the growing body of research on M-learning, a gap remains in understanding its role in students' digital empowerment. Digital empowerment is a process by which students gain the skills and confidence to manage and establish digital environments effectively (Amjad & Sheikh, 2026; Parusheva et al., 2025). Furthermore, while digital competence is associated with students' ability to use digital tools, the role of technostress as a psychological barrier has not been sufficiently explored in the context of M-learning. This study addresses this gap by examining how M-learning influences digital empowerment among university students, with digital competence mediating the relationship and technostress moderating it. This is closely linked to Sustainable Development Goal (SDG) 4, aiming for equitable, quality education for all (Grover et al., 2024; Maketo et al., 2023; Okai-Ugbaje et al., 2022).

The research mentions that students' skills and literacy are important for using digital tools (Sillat et al., 2021). Digital competence is the ability to use digital tools effectively and responsibly for retrieving educational sources (Abu-Hilal et al., 2025; Al-Dosari et al., 2026). It is transforming M-learning into a meaningful educational tool (Pan et al., 2024). The literature supports that students who have strong digital competence can use M-learning for retrieving information, sharing ideas, and peer discussion (Dai et al., 2024). However, students lacking such competence may feel stressed, reducing the positive influence of M-learning (Ginting et al., 2024). This is further supported by the argument that prolonged connectivity and the cognitive demands of mobile technologies can generate technostress. It can cause fatigue, anxiety, and reduced productivity (Alotaibi, 2025).

It is also seen that when technology is integrated into any system, it brings its own good and bad with it. For example, students using technological tools report poor mental health. Technostress can affect students' ability and capacity to effectively deal with advanced technology (Almohesh & Altamimi, 2024). The excessive use of M-learning can also lead to technostress (Khlaif et al., 2023). It can hinder the positive outcomes of M-learning by creating psychological and emotional strain (Alshamaila et al., 2023). Technostress undermines the confidence students derive from technology, ultimately eroding their sense of digital empowerment (Feng & Liu, 2024). The interplay between M-learning, digital competence, and technostress requires a deeper investigation to understand how to design a more effective digital learning environment in higher education that empowers and supports students' mental well-being and digital growth.

The twenty-first century is increasingly shaped by technological advancement and digital education. Thus, there has been significant research on the integration of technology in education. In recent years, a vast body of research has examined the use of various tech-driven tools in education (Islamoglu et al., 2021; Karagianni & Drigas, 2023). However, the researcher did not identify any study that explored the role of M-learning in university students' digital empowerment, with the mediating effect of digital competence and the moderating effect of technostress. This study aimed to investigate the role of M-learning, digital competence, and technostress in students' digital empowerment. The study seeks to achieve three research objectives: (1) examining the role of M-learning in university students' digital empowerment, (2) exploring the mediating role of digital competence, and (3) evaluating the moderating effect of technostress. The findings may significantly affect smart learning environments, digital policy, and SDG-aligned educational practices.

Literature Review

M-Learning and Digital Empowerment

In this study, mobile learning refers to students' self-reported academic use of smartphones and other portable digital devices to access, review, share, and engage with learning materials. The construct reflects perceived academic use and affordances rather than objective usage frequency or behavioral intensity. The measure focused on academic activities conducted through mobile devices, including accessing course materials, reading educational resources, using educational applications, communicating with peers, and sharing learning materials. The questionnaire did not measure general recreational technology use. M-learning is a widely studied topic in higher education, considering its broad range of usability and effectiveness. For example, a bibliometric analysis (2008-2020) revealed that M-learning has empowered students through its informal learning mode and flexibility. Furthermore, it imposes no restrictions on students regarding campus or geographic location

(Karakaya & Bozkurt, 2022). Similarly, another study found that the use of M-learning empowers learners to develop social networks and online learning opportunities. (Matzavela & Alepis, 2021).

Similarly, another review study revealed that the use of tablets and smartphones is increasing in education (Maqbool et al., 2025). Importantly, within higher education contexts, digital empowerment is not merely about access to technology but about meaningful engagement with digital tools for academic purposes. Studies focusing on university students emphasize that empowerment emerges when learners can independently navigate digital platforms, critically evaluate information, and actively participate in knowledge construction through mobile technologies. Therefore, the concept of digital empowerment in this study is grounded in student-centered learning environments, where M-learning serves as an enabler of autonomy, collaboration, and self-regulated learning rather than a general technological resource. This has empowered students technologically by enabling them to retrieve relevant educational content, which helps them in their academic journey (Majid et al., 2025). Another recent study on M-learning in the context of higher education revealed that M-learning accelerates university students' learning and empowers them to control their learning with self-paced and personalized study habits (Pérez-Fuentes et al., 2023). Similarly, one study revealed that M-learning helps university students take charge of their learning routines and significantly contributes to their academic success (Amjad et al., 2024a). The above arguments suggest that M-learning is a useful pedagogical technique that empowers students in several ways, ranging from developing social networks to taking charge of their learning habits. Thus, the following directional hypothesis was developed.

H1: Mobile learning significantly predicts and is associated with university students' digital empowerment.

M-Learning, Digital Competence, Digital Empowerment

During the literature review, no study was found on the combination of these three variables: M-learning, digital competence, and digital empowerment. However, considering their close technical associations, several separate studies have found that digital competence is essential for fostering an online learning culture through M-learning (Hidayat-Ur-Rehman, 2024; Pan et al., 2024). A study on M-learning and digital competence was conducted in 15 countries. After collecting data from 427 respondents, the researchers found that digital competence is crucial in theoretical fields and tech-driven inclusive learning environments (Betancourt-Odio et al., 2021). In a study, researchers found that utilizing any technology-driven pedagogical technique requires digital competence to provide a personalized learning environment, and M-learning offers this advantage (Svoboda, 2024). A study on digital competence and empowerment revealed that digital empowerment is achieved through possessing digital literacy, adopting technology, creating digital content, and ensuring safety (Lyu et al., 2025). However, to maintain contextual relevance, the present study interprets these relationships specifically within higher education, where digital competence reflects students' academic use of digital tools for learning, collaboration, and problem-solving in mobile-supported environments. Another study in a higher education context for visually impaired participants revealed that digital competence is associated with participants' empowerment. Considering the above arguments that M-learning is associated with students' digital competence, which relates to their empowerment, the following directional hypothesis was formulated.

H2: Digital competence significantly mediates the relationship between university students' mobile learning and digital empowerment.

M-Learning, Technostress, Digital Empowerment

Previous research has generally examined M-learning, technostress, and digital empowerment separately. In this study, technostress refers to technology-related psychological strain arising from difficulties, demands, or pressures associated with using digital technologies. After collecting data from 692 respondents, a study found that technostress and mobile phone use are closely associated (Khlaif et al., 2023). While some prior studies have examined technostress in K-12 or non-higher education settings, the present study emphasizes evidence from university contexts, where students face unique academic pressures associated with continuous connectivity, digital assignments, and mobile-based learning systems. In higher education, technostress is particularly relevant as it directly influences students' ability to manage academic workloads and engage effectively with M-learning

platforms (Alanazi et al., 2024; Amjad et al., 2024). A study on technostress and digital empowerment revealed that students with higher levels of digital skills felt less perceived technostress (Valta et al., 2024). Thus, it can be argued that digital empowerment helps participants reduce the stress related to technology usage in their academic tasks. However, in contradiction, a study examined technostress and digital empowerment in terms of literacy skills, online engagement, and autonomy. After analyzing the document and interview data, it was revealed that even participants with higher digital skills and empowerment showed stress in a digital environment (Feng & Liu, 2024). A study examining the moderating role of technostress in the relationship between digital learning and facilitating conditions in higher education found that technostress negatively moderates this relationship (Wang et al., 2024). The following directional hypothesis was developed based on the above conflicting results and considering the importance of technostress's moderating role.

> H3: Technostress significantly moderates the relationship between university students' mobile learning and digital empowerment.

Theoretical Background

The current study is guided by an empirically grounded conceptual model rather than a direct application of the Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT is based on four core constructs: performance expectancy, effort expectancy, social influence, and facilitating conditions (Nillos, 2016). These are the key determinants of behavioral intention and usage behavior. In higher education contexts, UTAUT provides a useful guiding framework for understanding how students perceive and adopt digital learning tools, particularly M-learning platforms, by emphasizing both individual expectations and contextual support. Although UTAUT explains technology acceptance and use, its principal constructs were not directly measured in this study.

The proposed model instead focuses on four constructs relevant to students' experiences with mobile-supported learning. Mobile learning represents students' academic engagement with mobile technologies. Digital competence represents their perceived ability to use digital tools effectively. Digital empowerment reflects their perceived confidence and capacity to engage with digital environments. Technostress represents psychological strain associated with technology use. The hypothesized relationships were therefore developed from previous empirical evidence concerning these constructs. The proposed mediation and moderation relationships should be interpreted as empirically derived associations rather than direct predictions of UTAUT.

UTAUT is an effective theory for this study in explaining how digital competence and technostress are boundary conditions in the M-learning and empowerment relationship (Su & Chao, 2022). UTAUT emphasizes user confidence and social-technical support (facilitating conditions) (Singh et al., 2025). This study examines how students' internal capabilities (digital competence) and psychological stress (technostress) interact with M-learning to influence digital empowerment. Based on the UTAUT, the conceptual framework of the current study is presented in Figure 1.

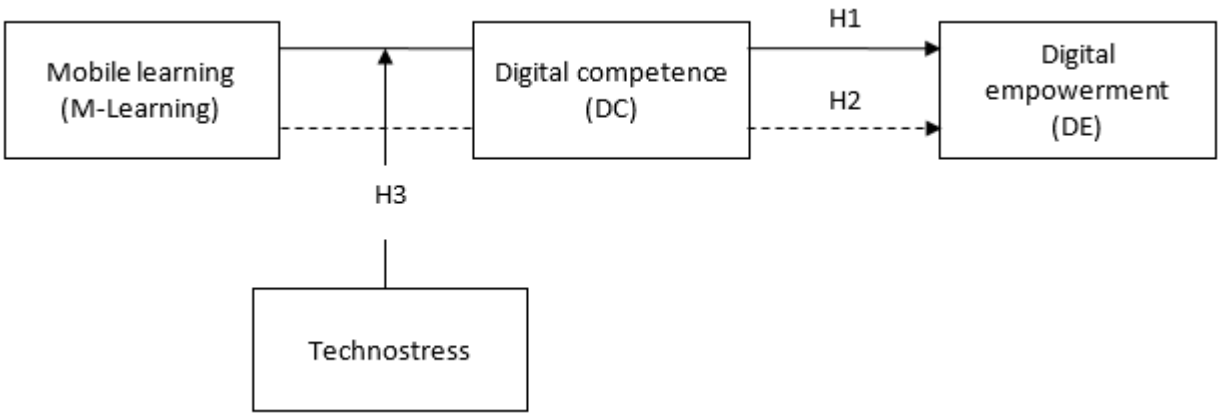


Figure 1. Research Model

Methods

Research Design

The current study was grounded in the positivist paradigm. This paradigm supports quantitative investigation of the relationship between variables (Reed, 2022; Ruffa & Evangelista, 2021). Based on this philosophical support, a quantitative research approach was employed to investigate M-learning's role in university students' digital empowerment, considering the presence of digital competence and technostress. Digital competence is the ability to effectively and responsibly use digital tools and technologies for learning, communication, and collaboration. Technostress is a psychological state resulting from the overuse of technology, which may lead to anxiety, fatigue, and reduced productivity. Digital empowerment is the process through which students gain the confidence and ability to use digital technologies effectively in academic and personal contexts. It is vital to university students' future success in the current tech-driven era. A quantitative research approach was selected for this study because it allows for the examination of relationships between variables through statistical analysis. This approach has the potential to improve the generalization of findings across populations. It also provides measurable and objective results. However, a limitation of this approach is the reliance on self-reported data, which may introduce bias in the results. A survey design was followed to examine the current trends of integrating these technological innovations in higher education. The literature also supports using a survey research design to explore such relationships (Bradfer-Lawrence et al., 2023).

Participants

The participants of the study were university students enrolled in master's and PhD programs in the social and natural sciences at the top ten QS-ranked universities of the country in 2025-26. Inclusion and exclusion criteria were established to recruit the participants. Only students who used smartphones for academic activities such as reading, reviewing, and sharing educational materials were included. Those students who were not using mobile phones for academic purposes were excluded. A sample of 410 university students was selected using a simple random sampling technique. The QS-ranked universities were selected because they have relatively better infrastructure than others. Initially, the respondents were approached and asked about the use of smartphones for academic purposes. Fulfilling the criteria, the students were selected through randomization (lucky draw). Overall, a sample of 450 students was selected. Then, a questionnaire was shared with them using Google Forms through their personal WhatsApp and email. However, 410 of them responded to the questionnaire, comprising the final sample. The response rate was 91.11%. The sampling framework allowed for broad participation, but it introduced potential self-reporting bias, as individuals already engaged in M-learning were more likely to participate. Female participants comprised 52% of the sample, which is almost equal to the national statistics of the gender population. Male participants comprised 48%. A larger proportion of participants (58%) were from public sector universities than from private sector universities (42%). Participants' characteristics are presented in Table 1.

Table 1. Participants' Characteristics

Characteristic	Category	N	Percent
Total sample	University students	410	100%
Gender	Male	197	48%
	Female	213	52%
University sector	Public university students	238	58%
	Private university students	172	42%
Program level	Master's	282	69%
	PhD	128	31%

Instrumentation

An extensive literature review was conducted to identify measures relevant to mobile learning, digital competence, technostress, and digital empowerment among university students. No single existing instrument was considered fully suitable for the present conceptual and contextual requirements. Therefore, a 28-item questionnaire was

developed for the current study. The questionnaire contains four conceptually distinct measures: mobile learning (8 items), digital empowerment (8 items), digital competence (6 items), and technostress (6 items). Each construct was analysed separately because each represents a distinct theoretical domain. Overall, the "Digital Learning Readiness Scale (DLRS)" had four sub-scales. The first part of the DLRS was about consent to participate in the study and about demographic information, including gender, university sector, academic program, and locality. The second part of the DLRS consisted of four subscales, each measured on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The 5-point Likert scale is widely used in social sciences (Zumrawi & Macfadyen, 2023). It provides an adequate balance between response options (Lee & Kim, 2025). An initial pool of 30 items was developed. Then, the face and content validity of the DLRS were ensured using expert opinion and pilot testing. The items were revised based on expert feedback and piloted by students to assess their relevance to the study's objectives and hypotheses, as well as their language, sentence structure, and context within the study. Based on the feedback, two double-barreled items were deleted. Sentence structure was changed for three items. The final DLRS contained 28 items. After pilot testing, the total scale reliability value of Cronbach's alpha was .89. Moreover, the subscale values ranged between .74 and .81, which were above the threshold level of .70 for the acceptance of the tool. A Google Form for the final DLRS was developed. Then, it was shared with participants through WhatsApp and email IDs. After distributing the survey links, they were given two reminders to submit their responses. The data collection was conducted in May and June 2026. The details of four sub-scales, including the number of items, reliability analysis (following final data collection), sample items, and details of the literature review used to develop the items, are presented in Table 2.

Table 2: Digital Learning Readiness Scale

Sr N	Variables	Items	α	CR	AVE	Sample items	Literature review
1	M-learning	8	.78	.78	.53	• Mobile learning allows me to learn anytime and anywhere. • I use educational apps on my mobile to better understand the course content.	(Al-Hunaiyyan et al., 2018; Alshamaila et al., 2023; Karagianni & Drigas, 2023; Naveed et al., 2023; Pérez-Fuentes et al., 2023; Razzaque, 2022)
2	Digital Empowerment	8	.80	.81	.56	• I use digital platforms to express my academic voice and creativity. • I feel empowered to learn beyond classroom boundaries using digital tools.	(Balouei Jamkhaneh et al., 2022; He et al., 2023; Hendl & Jansky, 2022; Lapuz, 2023; Sharma et al., 2022)
3	Digital competence	6	.73	.74	.51	• I can solve basic technical problems while using digital platforms. • I use digital resources to collaborate with peers in learning tasks.	(Gallego Joya et al., 2025; Martzoukou et al., 2020; Pan et al., 2024; Wardhani et al., 2019)
4	Technostress	6	.76	.77	.53	• I find it difficult to balance academic tasks due to excessive use of digital platforms. • I experience stress from being online all the time for academic communication.	(Almohesh & Altamimi, 2024; Feng & Liu, 2024; Khlaif et al., 2023; Torales et al., 2022; Upadhyaya & Vrinda, 2021; Vallone et al., 2023)

The construct and convergent validity of the questionnaire were ensured using confirmatory factor analysis. The KMO (0.86) and Bartlett's test of sphericity ($\chi^2[407] = 3515$, $p < 0.001$) ensured adequate factor loadings. The model fit measures ($RMSEA = 0.05$, $SRMR = 0.06$, $CFI = 0.93$, $TLI = 0.91$) showed good model fitness. All standardized factor loadings ranged between 0.27 and .75 and were statistically significant. All the retained items loaded significantly on their respective latent constructs, supporting the proposed five-factor measurement structure. The factor loadings were sufficiently strong to support the interpretation of the DLRS dimensions as distinct components of sustainability mindset. The composite reliability (CR) values for four constructs ranged between 0.74 and 0.81. The average variance extracted (AVE) values for each of the factors were higher than

0.50. The HTMT values were examined alongside the Pearson correlations to assess the distinctiveness of the constructs. The HTMT values ranged between .62 and .83, indicating that constructs were empirically distant. The standardized factor loadings are presented in Figure 2.

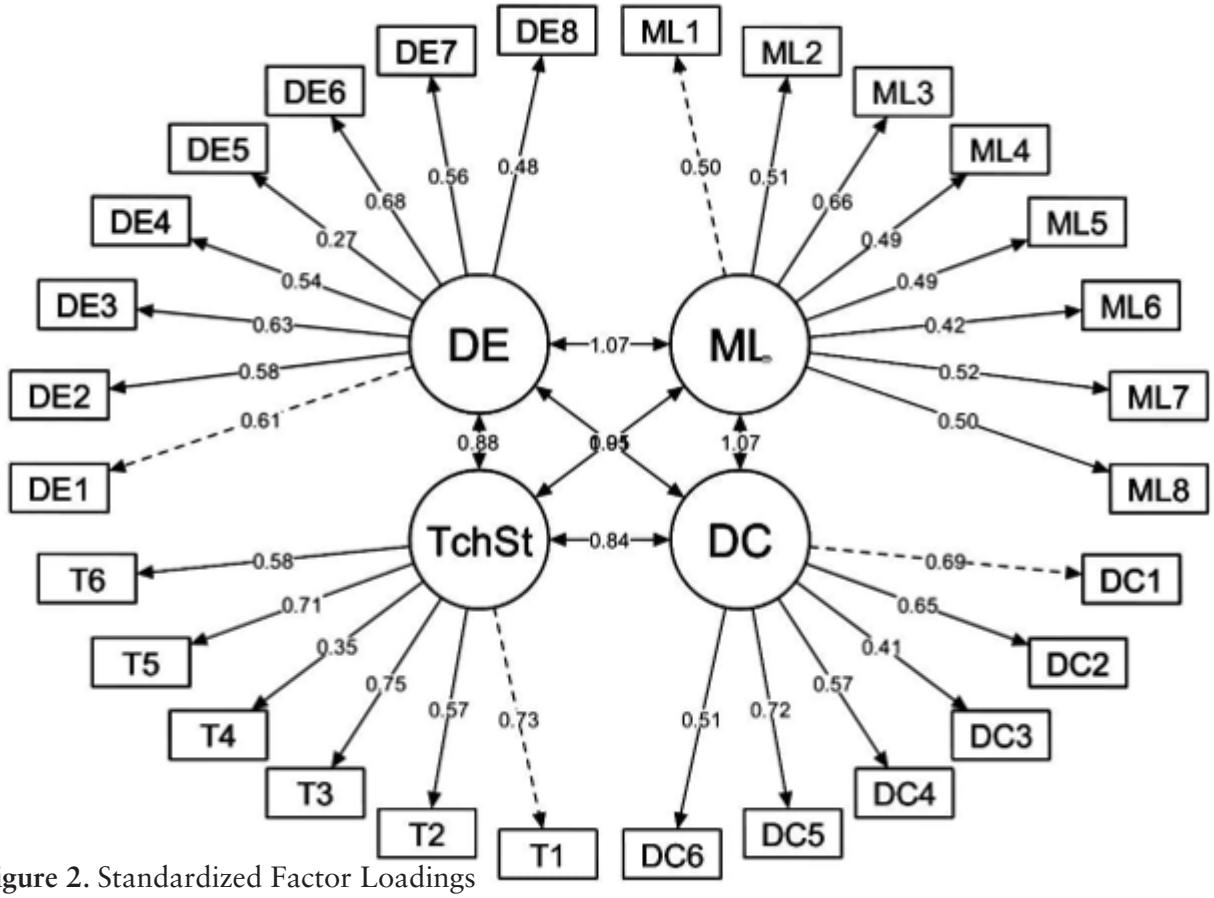


Figure 2. Standardized Factor Loadings

Data Analysis

After collection, the data were imported into an Excel sheet. Then, data screening was carried out. The data analysis was conducted using Jamovi (version 2.7.38). The cleaned data file was used to test the parametric assumptions, including normality and homogeneity of variance, and to identify outliers. Upon meeting the assumptions of parametric statistics, Pearson correlation, simple linear regression, mediation, and moderation analysis techniques were applied to test the study's hypotheses. Given the study's predictive and associational objectives and the nature of the proposed hypotheses, regression-based conditional process analyses were considered methodologically appropriate. Covariance-based structural equation modelling was not employed because the primary objective was to examine hypothesized predictive and associational relationships rather than compare competing latent structural models. Similarly, partial least squares structural equation modelling was not considered necessary because the sample size and theoretical foundation were adequate for testing the proposed direct, indirect, and moderating relationships using regression-based procedures. The hypothesized relationships were examined within a regression-based conditional process framework. Mobile learning was specified as the predictor, digital competence as the mediator, digital empowerment as the outcome, and technostress as the proposed moderator of the relationship between mobile learning and digital empowerment. Direct, indirect, and interaction effects were estimated using regression models. Indirect effects and confidence intervals were estimated using 5,000 bootstrap resamples with 95% confidence intervals. Standardized coefficients were reported with confidence intervals, p-values, and explained variance (R^2). The results are presented in tables and diagrammatic forms. Common method bias (CMB) was considered because the study variables were measured through the same self-report questionnaire at one point in time. Although the researchers anonymized participants' information and no personally identifying information was requested. The questionnaire also used neutral statements, which reduced pressure towards socially desirable responses. However, a separate statistical test of common method variance was not conducted. Therefore, the possibility that the shared measurement method contributed to the observed associations cannot be completely excluded.

Research Ethics

The current study was approved by the Ethics Committee of the School Education Department of the Government of Punjab, vide approval number 001-289719/RC/II/HM, dated 10 April 2026. The ethical approval was aligned with the Declaration of Helsinki. Informed consent was obtained electronically, as the first part of the questionnaire was about consent. By agreeing, they responded to the questionnaire. No personal questions were asked that could reveal their identity. Data were kept confidential and were used for the current study. Data will not be shared with anyone due to ethical reasons. The participants were given the right to withdraw from the data collection. As, the data were collected online, no physical or psychological harm involved.

Results

The data were analyzed to test hypotheses. Pearson correlation was used to test the assumptions of the correlation between the study's variables for applying regression, mediation, and moderation, and the results are presented in Table 3.

Table 3: Correlation Estimates

Variables	M	SD	1	2	3	4
M-learning (ML)	3.64	.57	-			
Digital empowerment (DE)	3.62	.56	.733***	-		
Digital competence (DC)	3.59	.63	.701***	.632***	-	
Technostress (TechStress)	3.67	.64	.684***	.636***	.637***	-

*** $p < .001$

Table 3 provides the relationship between the study's variables. It reveals that M-learning (independent variable) and digital empowerment (dependent variable) have a linear, positive, and strong correlation ($r = .733$, $n = 410$, $p < .001$), providing a strong rationale for simple linear regression. Similarly, the relationship between digital competence (mediator) and digital empowerment (dependent variable) is also linear, positive, and strong ($r = .632$, $n = 410$, $p < .001$), supporting the foundation for mediation analysis. Moreover, the relationship between digital competence and technostress was also found to be linear, positive, and strong ($r = .637$, $n = 410$, $p < .001$). The graphical form of the relationship is presented in Figure 3.

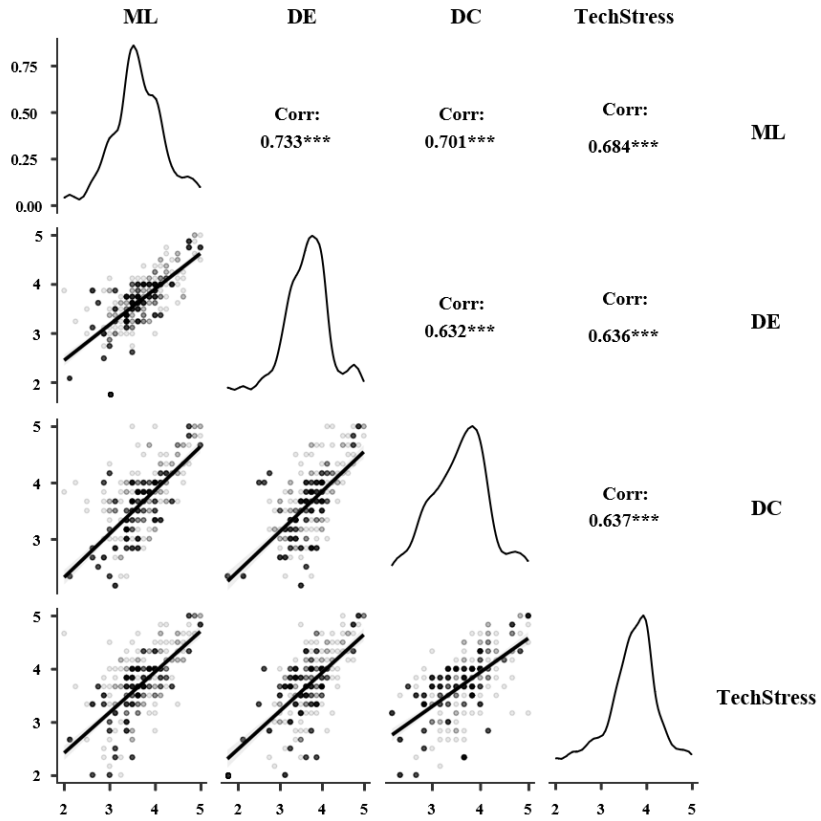


Figure 3: Correlation Plot

The first hypothesis was developed to examine the role of M-learning in university students' digital empowerment. After collecting data, it was analyzed using simple linear regression, and the results are presented in Table 4.

Table 4: Role of M-Learning in Digital Empowerment

Predictor	*B*	*SE*	*t*	*p*
Intercept	1.014	.12	8.30	< .001
M-learning	.722	.03	21.79	< .001

$R = .73$, $R^2 = .54$, $F(1,408) = 475$, $p < .001$.
Dependent variable = Digital Empowerment

Table 4 provides the results for H1. The results indicate that the model was statistically significant and demonstrates a good fit to the data ($F[1, 408] = 475, p < .001$). The overall model explained approximately 54% of the variance in the university students' digital empowerment, as indicated by the coefficient of determination, $R^2 = .54$, with a multiple correlation coefficient of $R = .73$. This suggests that M-learning accounts for a significant proportion of the variance in university students' empowerment. Examining the regression coefficients, the intercept was statistically significant ($B = 1.014$, $SE = .12$, $t = 8.30$, $p < .001$), indicating the expected value of students' digital empowerment when M-learning is zero. M-learning had a positive and statistically significant relationship with the university students' digital empowerment ($B = .722$, $SE = .03$, $t = 21.79$, $p < .001$). This implies that digital empowerment increases by approximately .722 units for each one-unit increase in M-learning, holding other variables constant. Supporting H1, it was found that M-learning is a significant predictor and contributor to the digital empowerment of university students.

The second hypothesis was designed to examine the mediational role of digital competence in university students' M-learning and digital empowerment. After collecting the data, it was analyzed using mediation analysis with a 95% confidence interval and a bootstrap sample of 5000. The results are presented in Table 5.

Table 5: Mediation Effect of Digital Competence between Students' M-learning and Digital Empowerment

Effect	β	*SE*	95% Confidence Interval (CI)		*Z*	*p*	Mediation (%)
			Lower	Upper			
Indirect	.161	.05	.078	.254	3.56	< .001	22
Direct	.561	.06	.435	.684	8.75	< .001	78
Total	.722	.04	.637	.798	17.55	< .001	100

Table 5 provides the analysis for H2. The indirect association between M-learning and digital empowerment through digital competence was statistically significant ($B = .161$, $SE = .05$, 95% CI [.078, .254], $p < .001$). However, given the cross-sectional design, this indirect effect should not be interpreted as evidence of a temporal or causal mechanism. The direct association between M-learning and digital empowerment remained statistically significant ($B = .561$, $SE = .06$, 95% CI [.435, .684], $p < .001$). The total association was also statistically significant ($B = .722$, $SE = .04$, 95% CI [.637, .798], $p < .001$). The indirect effect represented approximately 22% of the estimated total association. This percentage was calculated by dividing the indirect effect by the total effect. It should therefore be interpreted cautiously and not as a direct measure of explanatory importance. The pictorial form of the mediation analysis is presented in Figure 4.

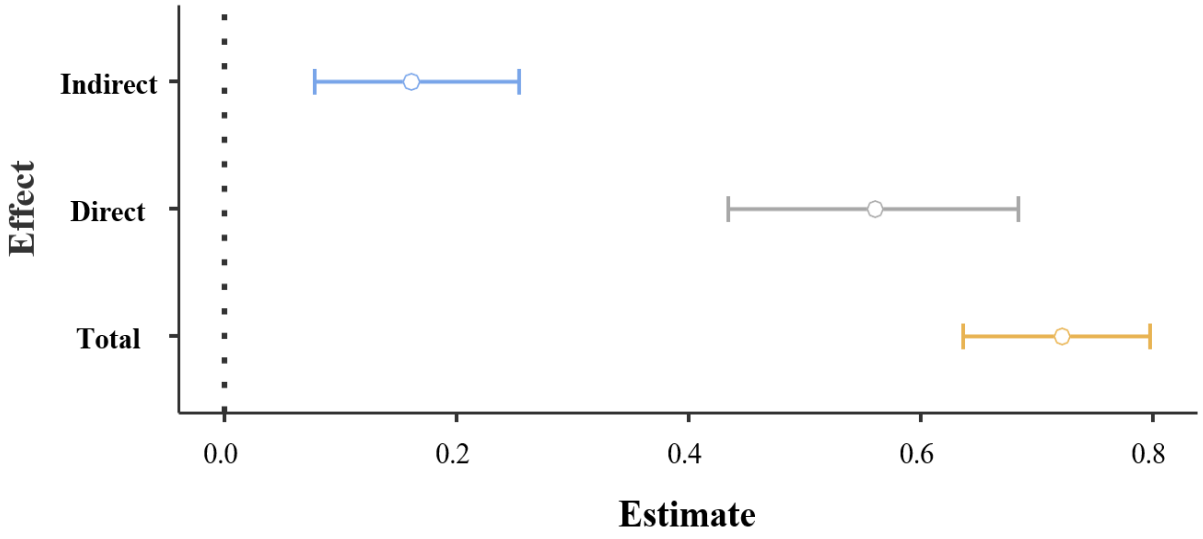


Figure 4: Mediation Plot

Figure 4 presents the estimated indirect association between M-learning and digital empowerment through digital competence. The model was selected because it integrates well-established theoretical concepts from the UTAUT framework, with the addition of digital competence to address the gaps in previous research.

The third hypothesis was formulated to examine the moderating role of technostress on the relationship between university students' M-learning and their digital empowerment. After collecting the data, it was analyzed using moderation analysis at a 95% confidence interval with a bootstrap sample of 5000. The results are presented in Table 6.

Table 6: Moderation Effect of Technostress on Students' M-learning and Digital Empowerment

			95% Confidence Interval (CI)			
Variables	β	***SE***	**Lower**	**Upper**	***Z***	***p***
M-learning (ML)	.542	.06	.427	.665	9.10	< .001
Technostress (TechStress)	.232	.06	.123	.337	4.22	< .001
ML*TechStress	.034	.05	-.059	.128	.72	.476

Table 6 provides the analysis for H3. The moderation analysis assessed whether Technostress moderated the relationship between university students' M-learning and digital empowerment. The results showed that M-learning was a significant predictor of university students' digital empowerment (B = .542, SE = .06, 95% CI [.4227, .665], Z = 9.10, p < .001), indicating that higher levels of M-learning are associated with higher levels of university students' digital empowerment. Additionally, Technostress was also found to be a significant predictor (B = .232, SE = .06, 95% CI [.123, .337], Z = 4.22, p < .001), suggesting that Technostress also independently influences students' digital empowerment. However, H3 was not supported. It was found that the interaction term (ML*TechStress) was not statistically significant (B = .034, SE = .05, 95% CI [–.059, .128], Z = .713, p = .476), indicating that Technostress did not significantly moderate the relationship between university students' M-learning and digital empowerment. In other words, the strength or direction of the effect of M-learning on digital empowerment does not differ based on levels of Technostress. The visual form of the moderation analysis is presented in Figure 5.

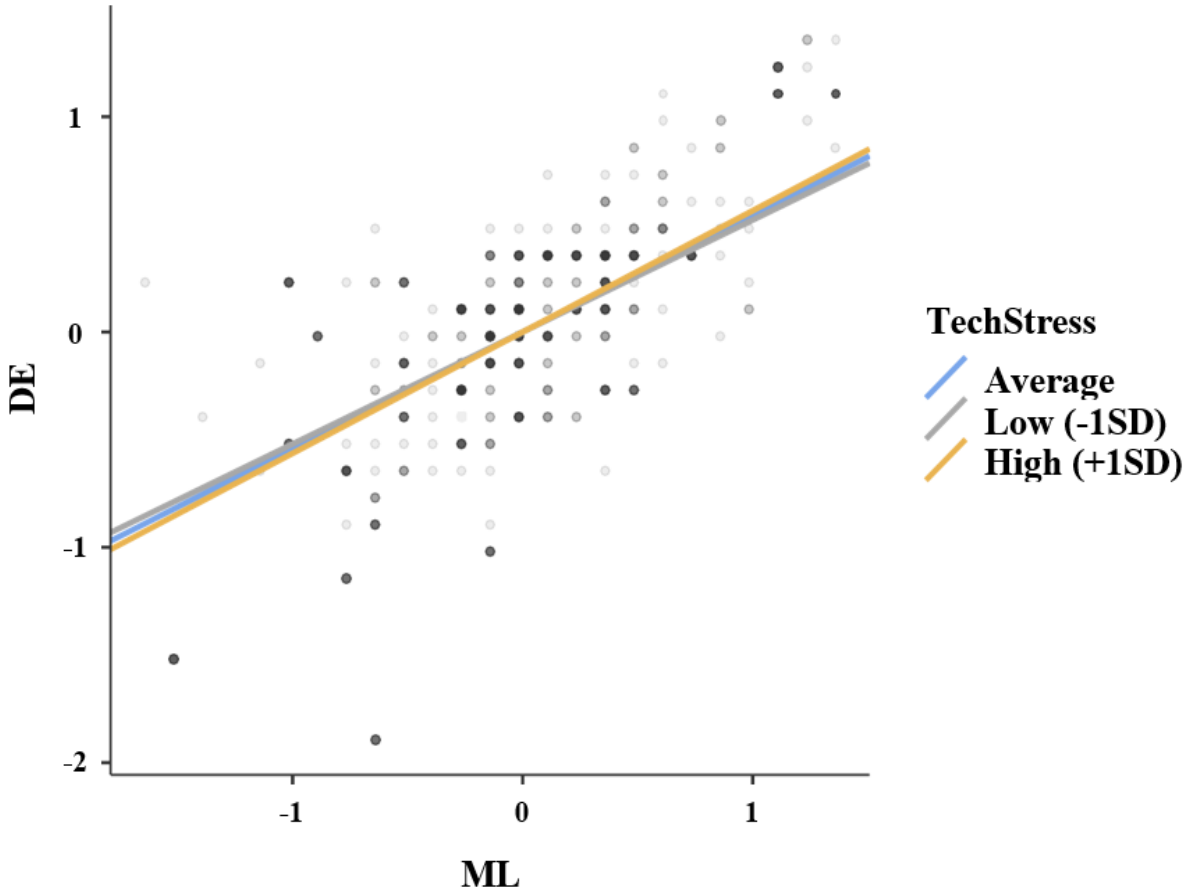


Figure 5: Moderation Plot

Discussion

The present study focused on how M-learning is associated with the digital empowerment of university students, examining the mediating and moderating roles of digital competence and technostress. The data were collected under the principles of UTAUT. Overall, three research hypotheses guided the current study. H1 was tested using simple linear regression. The analysis supported H1 and revealed that M-learning significantly predicts and is associated with students' digital empowerment. This indicates that students who use smartphones effectively can relate it with their digital empowerment. It was also found that M-learning is associated with students' information-retrieving skills. It can help them to use M-learning more effectively to get information and apply it in their academic tasks (Karakaya & Bozkurt, 2022; Matzavela & Alepis, 2021). The current study extends UTAUT's implications in higher education and shows that M-learning has the potential to link it with students' digital empowerment. This also supports a study, which revealed that M-learning can help students control and manage information related to academic tasks (Pérez-Fuentes et al., 2023).

The results for H2 showed that digital competence was strongly correlated with digital empowerment. However, it partially mediates (22% of the total association) the relationship between university students' M-learning and digital empowerment. This shows that H2 was partially supported. This finding supported the results of a previous study, which found that digital competence and skills are essential for helping respondents in M-learning (Svoboda, 2024). It also supported the findings of previous studies, which revealed that digital competence is important to assist students in M-learning contexts (Betancourt-Odio et al., 2021; Lyu et al., 2025). The current study extended the implications of UTAUT for exploring the mediating role of digital competence between M-learning and digital empowerment. This implies that digital competence is an important element required to reinforce students' digital empowerment.

The third hypothesis was tested to explore the moderating role of technostress on the relationship between university students' M-learning and digital empowerment. After applying moderation analysis, it was found that technostress is associated with university students' digital empowerment as an individual variable. However, the interaction effect (M-learning × TechStress) was found to have a statistically insignificant

moderation effect on the relationship between university students' M-learning and digital empowerment. The analysis did not support H3. This implies that technostress occurs when university students work on developing their digital learning skills. These findings indicate that while technostress has a statistically significant direct association with digital empowerment, it does not alter the strength or direction of the relationship between M-learning and digital empowerment. Therefore, no moderating effect of technostress was supported in this study. Accordingly, interpretations regarding the role of technostress should be limited to its direct association with digital empowerment, and no conclusions can be drawn about its conditional or buffering effects within the M-learning empowerment relationship. This finding partially supported the results of various previous studies, which found that digital skills and technostress are strongly correlated with each other (Khlaif et al., 2023; Valta et al., 2024). This may be due to the adaptive strategies students develop over time or the context-specific nature of stressors in digital learning environments (Feng & Liu, 2024). The current study extends the implications of UTAUT at the university level by exploring the moderating effect of technostress on the relationship between students' M-learning and digital empowerment.

Conclusion

This study examined associations among M-learning, digital competence, technostress, and digital empowerment among university students. M-learning was positively associated with digital empowerment. Digital competence showed a significant indirect association within this relationship. Technostress was also independently associated with digital empowerment. However, technostress did not significantly moderate the association between M-learning and digital empowerment. This unsupported moderation hypothesis is a substantive finding because the relationship between M-learning and digital empowerment did not differ significantly across levels of technostress. M-learning was found to be a highly effective learning tool in higher education to significantly enhance students' digital empowerment. While the findings indicate a significant association between M-learning and digital empowerment, these results should be interpreted carefully within the study's survey design, and broader implications for SDG4 should be considered as potential rather than definitive. Moreover, digital competence and technostress are also strongly correlated with university students' digital empowerment. This study is important because it fills a gap in the literature regarding the understanding of relationships between variables within the context of the current study. It provides new directions for M-learning and suggests ways to make it useful in digital environments. However, the insignificant moderating effect of technostress requires further exploration. Future research should examine the causes of the insignificant effect.

Implications

The current study had several practical, theoretical, policy, and research implications. For instance, the findings may inform higher education institutions seeking to support students' engagement with mobile-supported learning. Universities may consider strengthening students' digital competence and providing guidance for managing technology-related stress. These implications are based on observed self-reported associations. The present findings do not show that mobile learning directly improves academic performance or educational equity. Similarly, the current study employed UTAUT to investigate participants' competence and utilization of their abilities to learn and perform in digital environments. This implies that UTAUT can be applied in a higher education context where students utilize digital gadgets, such as mobile phones, for assistance. Moreover, universities are advised to develop a policy and provide an environment that can help them enhance their digital skills, even in non-digital contexts. M-learning is an effective educational approach for improving students' performance. Thus, universities should also conduct workshops and seminars on using digital tools effectively in learning, reducing stress, and enhancing their skills. Furthermore, considering the implications of M-learning, future studies are recommended to replicate the current study with a more diverse range of participants and regions. This can improve the study's generalizability.

Limitations and Future Directions

Despite the significant results, the current study also had some limitations. Firstly, the sample was chosen from a higher education context. Therefore, the results may not represent students at the school or college level. Secondly, the current study explored the partial mediating role of digital competence in the relationship between

M-learning and digital empowerment. However, this limitation can be addressed in future studies exploring the mediating roles of digital competence and other cultural factors to identify the causes of partial mediation. The data were collected using a self-reported survey, which has the potential for common method bias (CMB). The CMB could influence the relationships observed between the variables. To overcome this limitation, future researchers can use Harman's single-factor test or other relevant tests to overcome this limitation. Moreover, as the data were collected using a newly developed scale (DLRS). The current study's data analysis strategy may not fully account for measurement error and the potential overlap between constructs. However, future researchers are suggested to use more advanced techniques, such as Structural Equation Modeling (SEM), to understand the relationship between latent constructs and to account for measurement error. Another limitation was that despite following the process in detail, the moderating effect of technostress was statistically insignificant in the current study. This limitation can be addressed by using more factors in a diverse population to find the causes of the insignificant moderation effect of technostress in said relationships. Lastly, the data were collected from only those participants who were using mobile phones for academic purposes. Thus, the results may not be generalized to those students who do not use mobile devices for their academic tasks. However, this limitation can be addressed in future research by selecting a more diverse sample.

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Authorship and Level of Contribution

A.I.A. and Z.H. conceptualized the study and developed the research framework. A.I.A., S.A., and S.A. collected the data and contributed to the research implementation. A.I.A., M.M.B.S., T.K., and T.H. conducted the data analysis and interpreted the findings. Z.H. and S.A. provided methodological guidance and supervision. A.I.A. prepared the initial manuscript. Z.H., S.A., S.A., and T.H. critically reviewed and revised the manuscript. T.H. and W.A. contributed to the technical and analytical aspects of the study. All authors contributed to the final manuscript, approved the submitted version, and agreed to be accountable for the work.

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