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ORIGINAL RESEARCH ARTICLE

Enhancing postgraduate students' learning outcomes through Flipped Mobile-Based Microlearning

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This study examines the effects of implementing a Flipped Mobile-Based Microlearning (FMM) approach on postgraduate students' accessibility, engagement, knowledge retention, overall learning experience and academic achievement. A quantitative multiple methods approach was employed, utilising a two-group quasi-experimental design and a survey questionnaire to gather data. The results suggest that the FMM approach may have positive effects on accessibility, engagement, knowledge retention, overall learning experience and final exam scores when compared to the traditional learning approach. The findings support the efficacy of integrating FMM, highlighting its potential for enhancing the learning process and academic outcomes. These results have implications for educational practice and research, emphasising the value of technology-enhanced learning approaches, active and interactive learning experiences and the promotion of student motivation and attitudes towards learning. This study underscores the broader applicability of FMM and suggests its potential for improving educational outcomes across different educational levels and subject areas.

Keywords: flipped learning; microlearning; postgraduate students' accessibility, engagement and knowledge retention

Introduction

The rapid technological advancements have brought about significant transformations in various aspects of our lives, including how we live, work and communicate. Educational institutions have witnessed a growing interest in innovative pedagogical approaches, particularly those utilising digital technologies, to enhance student learning outcomes.

The integration of digital technologies in education has the potential to revolutionise traditional teaching methods and create more engaging, interactive and personalised learning experiences for students (Yeung et al., 2021). With the ability to communicate quickly and efficiently with large groups of people, it is not surprising that emerging technologies are increasingly being integrated into educational settings to enhance the effectiveness of teaching and learning (Yeung et al., 2021).

With the pervasive availability and adoption of mobile devices, mobile-based learning has emerged as a flexible and accessible mode of education (Kohnke, 2023; Leong et al., 2021; Yeung et al., 2021). Mobile devices, such as smartphones and

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tablets, provide learners with anytime, anywhere access to learning materials, fostering a learner-centred environment (Krygier et al., 2022).

Additionally, the emergence of microlearning as an instructional design strategy has gained attention for its ability to deliver content in bite-sized, easily digestible units, aligning with learners' cognitive processes and facilitating better knowledge retention and accessibility (Hao et al., 2022; Kohnke, 2023; Krygier et al., 2022; Major & Calandrino, 2018; Shine & Heath, 2020). Microlearning can be simply defined as gaining knowledge through short, focused learning activities (Raouna, 2023). It delivers content in small chunks rather than lengthy, complex materials. These bite-sized learning pieces include short videos, articles or audio clips aiming to convey targeted concepts, skills or outcomes (Raouna, 2023).

As traditional learning models continue to evolve, innovative teaching approaches such as flipped learning have shown promise in promoting active learning and student engagement (Al-Zahrani, 2015; Chang et al., 2015; Foldnes, 2016; Kim & Kim, 2017; Shine & Heath, 2020). It can be defined as an instructional strategy where the traditional lectures that would normally occur in class are instead provided outside of class (FLN, 2014). This enables the teacher to utilise class time for more dynamic, interactive and collaborative activities that allow students to actively apply concepts and engage with learning materials (FLN, 2014). Rather than passively receiving information, students are guided by the teacher to construct their understanding through hands-on learning (Al-Zahrani, 2015). Flipped learning is characterised by the reversal of traditional classroom-based instruction and homework activities. It is sometimes referred to as the flipped classroom, backward classroom, reverse teaching or the Thayer method (Shine & Heath, 2020).

The combination of mobile technology and microlearning strategies has the potential to empower students by providing convenient access to educational resources, fostering self-directed learning, increasing engagement and improving knowledge retention, thus positively impacting achievement. By investigating the impact of this innovative approach, this study aims to contribute to the growing body of research on effective pedagogical strategies for postgraduate education.

This study delves into the following key aspects: accessibility, examining the ease of access to educational resources using mobile devices; engagement, assessing the level of student involvement and active participation; knowledge retention, evaluating the effectiveness of microlearning in enhancing long-term retention of information; overall learning experience, addressing the students' overall satisfaction with the course; and academic achievement, measuring the impact of this approach on students' overall academic performance.

Literature review

There has been a growing interest in exploring innovative approaches to enhance the effectiveness of higher education. One such approach that has gained attention is the integration of mobile-based microlearning within a flipped learning environment. This pedagogical strategy shows promise in transforming the traditional learning experience and improving student outcomes.

The promise of microlearning

Microlearning is a rapidly growing topic in the field of e-learning and mobile learning, representing a new learning method within the evolving media ecosystem

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(Hao et al., 2022). It holds great promise in transforming teaching and learning experiences, potentially leading to a paradigm shift and improved educational outcomes (Wang et al., 2021).

Prominent areas of research within microlearning include higher education, particularly in second language acquisition, medical education and vocabulary learning (Hao et al., 2022; Leong et al., 2021; Sankaranarayanan et al., 2023). The increasing number of publications on microlearning corresponds to the growing practical demand for its use in work-based learning scenarios (Krygier et al., 2022; Leong et al., 2021; Sankaranarayanan et al., 2023). Sankaranarayanan et al. (2023) conclude that microlearning has been implemented as an instructional method strategy and an intervention in various educational contexts, including design, teaching methods, professional development, blended learning, language acquisition and adult learning.

Mobile-based microlearning involves using mobile devices such as smartphones or tablets as the primary medium for delivering bite-sized learning materials, often in the form of multimedia content, quizzes or interactive activities (Hao et al., 2022; Kohnke, 2023; Krygier et al., 2022; Sankaranarayanan et al., 2023). According to Markowitz (2020), the essence of microlearning lies in the use of shorter videos that are easily accessible, helping to minimise distractions during the learning process. The creation of microlearning videos goes beyond technological development; it also involves a creative process that integrates cutting-edge educational ideas and instructional design methods (Chang et al., 2015). For example, a study by Ma et al. (2021) found that the experimental group, which utilised microlearning with knowledge maps, exhibited higher levels of learning engagement, performance and a more comprehensive knowledge structure compared to the control group.

Microlearning encompasses various methods, including podcasts, videos, infographics and flashcards (Kohnke, 2023). Unlike traditional classroom learning, these methods offer the advantage of delivering learning material in small, easily digestible chunks that cater to the busy schedules of learners and allow for flexible, self-paced learning experiences (Kohnke, 2023; Major & Calandrino, 2018; Rad, 2023; Shine & Heath, 2020). Microlearning videos, for instance, provide visual and auditory engagement (Kohnke, 2023). Whilst these videos can be standalone, the nature of microlearning encourages students to complete additional tasks related to the video content (Krygier et al., 2022).

Implementing microlearning effectively helps prevent information overload and reduces anxiety that may arise from high demands placed on learners (Krygier et al., 2022). Furthermore, microlearning offers the potential for more effective and enjoyable learning experiences due to its flexible nature (Gill et al., 2020). Students can learn at their own pace and have the freedom to access learning materials anytime and anywhere, leading to enhanced engagement and convenience (Gill et al., 2020). Microlearning promotes effective learning by presenting information in a manner conducive to better comprehension, knowledge retention and application of knowledge (Major & Calandrino, 2018).

However, despite the appealing advantages of microlearning, there are several disadvantages that should be carefully considered. 'The success of microlearning techniques is closely related to the personal characteristics of learners, teachers' propensity to use digital technology, and external factors such as access to learning materials' (Sozmen, 2022, p. 39). In this essence, microlearning can be unsuccessful for acquiring complex skills and behaviours that require extensive practice over time (Díaz Redondo et al., 2021; Jomah et al., 2016; Skalka & Drlík, 2018). Additionally, it may provide

insufficient opportunities for application and feedback, as the brevity of microlessons may foster misconceptions around multitasking and real learning (Jomah et al., 2016). Finally, short microlessons alone cannot provide the depth of processing and retention needed for meaningful understanding and behavioural change compared to longer and more integrative methods (Díaz Redondo et al., 2021; Jomah et al., 2016). Accordingly, for learners to fully comprehend new concepts, adequately connect them to prior knowledge and strengthen cognitive processes to ensure knowledge retention, they need to dedicate ample time to practicing and applying the new concepts and materials (Díaz Redondo et al., 2021). Simply exposing learners to concepts without opportunities for repeated practice and concrete implementation will not guarantee permanent learning or skill development (Díaz Redondo et al., 2021).

Flipped learning

Flipped learning is a pedagogical approach that challenges traditional teaching methods. In traditional teacher-dominated instruction, the emphasis is on the teacher delivering knowledge to students, leaving limited time for student-centred activities in the classroom (Fidan, 2023; Foldnes, 2016). This approach restricts students' opportunities to engage in activities tailored to their individual learning needs and progress at their own pace (Fidan, 2023; Foldnes, 2016). In contrast, the flipped classroom model can be implemented in various educational settings and disciplines, offering flexibility and adaptability (Bergmann & Sams, 2012). Bergmann and Sams (2012) highlight the significant advantage of the flipped classroom approach, which can be customised to meet the specific needs and learning goals of students, regardless of their background or subject matter.

Bishop and Verleger (2013) identify two key movements related to the integration of information technology into education. The first is the global technological movement, which enables the cost-effective integration of technology in education. The second is the ideological movement, in which ideas and concepts related to education are disseminated through technological channels.

Flipped learning has emerged as an innovative teaching and learning method within the broader framework of blended learning (Al-Zahrani, 2015; Hae ja & Chun, 2016). It emphasises learner-centred interactive learning, moving away from traditional teacher-centred lecturing approaches (Al-Zahrani, 2015; Fidan, 2023; Kim & Kim, 2017). Flipped learning also facilitates the development of self-regulated learning strategies and various skills amongst students (Öztürk & Çakıroğlu, 2021).

The flipped learning environment represents a shift from the traditional classroom model, where students engage with instructional content before attending class sessions, allowing for more interactive and collaborative activities during face-to-face sessions (Al-Zahrani, 2015; Chang et al., 2015; Fidan, 2023; Foldnes, 2016; Kim & Kim, 2017; Rad, 2023; Shine & Heath, 2020; Yeung et al., 2021). This approach promotes active engagement and deeper understanding of the subject matter (Al-Zahrani, 2015; Kim & Kim, 2017). It combines online and offline learning methods by utilising video lectures and other resources for initial out-of-classroom learning, followed by problem-solving activities during in-class sessions (Al-Zahrani, 2015; Fidan, 2023; Foldnes, 2016; Kim & Kim, 2017). The flipped learning approach incorporates elements of problem-based learning, active learning, constructionism and direct instruction (Kim & Kim, 2017). By integrating student-centred and teacher-guided approaches, flipped

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learning aims to provide a comprehensive educational experience that fosters active engagement, collaboration, critical thinking, creativity and knowledge construction (Al-Zahrani, 2015; Fidan, 2023; Foldnes, 2016; Kim & Kim, 2017).

To effectively implement the flipped classroom model, students need to be equipped with the necessary skills and resources to engage with e-learning tools (Al-Zahrani, 2015). It is crucial to ensure that students are adequately prepared and supported in utilising these tools. Additionally, considering the workload of students and their individual learning needs is essential in designing meaningful and engaging in-class activities (Al-Zahrani, 2015). Finally, the facilitation of cooperative learning within the context of flipped learning can contribute to enhanced academic performance (Foldnes, 2016).

Effectiveness of Flipped Mobile-Based Microlearning

The integration of Flipped Mobile-Based Microlearning (FMM) holds great promise for enhancing accessibility, engagement and knowledge retention. Research on the utilisation of flipped learning and microlearning demonstrates that this combination improves students' self-regulated learning (Shine & Heath, 2020). The practice of designing and applying microlearning videos within the context of a flipped classroom has shown a significant role in addressing teaching challenges for both teachers and students (Chang et al., 2015). When well-designed and supported by teachers, this combination fosters full engagement and active learning (Krygier et al., 2022) whilst contributing to the improvement of students' autonomous learning, collaborative learning abilities and problem-solving skills (Chang et al., 2015).

Moreover, the flipped classroom model based on microlearning has proven effective in improving teaching quality, stimulating students' learning interest and enhancing their enthusiasm (Nan et al., 2017). Scholars such as Rad (2023) and Ibarra-Cabrera et al. (2021) have demonstrated that microlearning and flipped learning approaches significantly improve learners' skills and motivation for learning. Additionally, Qian et al. (2021) found that the combination of flipped learning and microlearning, along with the application of real-life case studies, is a valuable strategy for enhancing learning outcomes and shaping a more favourable attitude towards learning and practice. Moreover, the flipped classroom combined with microlearning activities has been effective in engaging students, maintaining their active participation and creating positive and enjoyable learning experiences (Dixit et al., 2021).

Furthermore, Hae ja and Chun (2016) found that implementing a flipped learning approach with mobile-based microlearning led to increased self-esteem, motivation and interest amongst students who were able to overcome the limitations of time and space and actively and creatively engage with the learning materials. Zhou and Deng (2018) concluded that integrating microlearning resources into the flipped classroom was a practical and effective teaching model that improved students' learning initiative, enthusiasm and overall learning outcomes. More recently, the findings of Fidan's (2023) study suggest that implementing the flipped classroom with the integration of microlearning resulted in improved learning performance, intrinsic motivation, emotional engagement and behavioural engagement. This study also revealed that the participants had positive perceptions of the benefits of microlearning-supported flipped classrooms, particularly in enhancing their willingness to participate in pre-class activities.

Research problem

Despite the growing popularity of mobile-based microlearning (e.g. Hao et al., 2022; Kohnke, 2023; Krygier et al., 2022; Major & Calandrino, 2018; Shine & Heath, 2020) and flipped learning approaches in education (e.g. Al-Zahrani, 2015; Chang et al., 2015; Foldnes, 2016; Kim & Kim, 2017; Shine & Heath, 2020), there is a research gap in understanding the specific impact of combining these strategies, specifically on postgraduate students.

Whilst some studies have explored mobile learning or microlearning in education, there is a lack of comprehensive research examining the combined effect of FMM on postgraduate students' accessibility, engagement, knowledge retention and academic achievement. Most of the existing research focuses on leveraging self-regulated learning (Shine & Heath, 2020), addressing teaching challenges (Chang et al., 2015), enhancing active learning (Krygier et al., 2022), improving problem-solving skills (Chang et al., 2015), enhancing enthusiasm (Nan et al., 2017) and promoting learners' skills and motivation (Ibarra-Cabrera et al., 2021; Rad, 2023).

Research aim and scope

This study aims to address this gap by focusing on the unique context of postgraduate education and providing evidence-based insights into the effectiveness and implications of a flipped learning and integrated mobile-based microlearning approach. By doing so, it seeks to contribute to the limited existing knowledge and inform the design and implementation of effective educational interventions for postgraduate students.

Therefore, this study specifically addresses the impact of FMM on postgraduate students' accessibility, engagement, knowledge retention and academic achievement.

Research question

The main research question that guides the inquiry is:

- **RQ**: To what extent does FMM enhance postgraduate students' learning process in terms of accessibility, engagement, knowledge retention, overall learning experience and academic achievement?

Methodology

This study implemented a quantitative multiple methods approach to answer the research key question.

Research design

The study design included two main sequential phases. The first phase consisted of a two-group quasi-experimental design as follows:

(1) Traditional group: This group consisted of 10 students and was taught using a lecture-based approach focused on traditional and blended learning activities,

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such as lecturing and PowerPoint presentations. Regular assignments were given after each lecture.

(2) FMM group: This group included nine students and was provided with short videos and quizzes outside the official lecture time through a mobile instant messaging application (WhatsApp group). Lecture time is dedicated to discussions, problem-solving and group learning. The lecturer's role is to facilitate conditions and guide these activities. An illustration of the study design is presented in Figure 1.

The two groups were equal and similar at baseline across the key characteristics of academic performance, Grade Point Average (GPA), technology literacy, mobile and internet access and background. Both groups consisted of postgraduate students enrolled in the same course. This equivalence between the traditional and FMM groups allowed for a meaningful comparison of the different instructional approaches.

In the second phase, a survey questionnaire was developed, consisting of 10 items distributed across four major sections, to assess both groups' views and attitudes

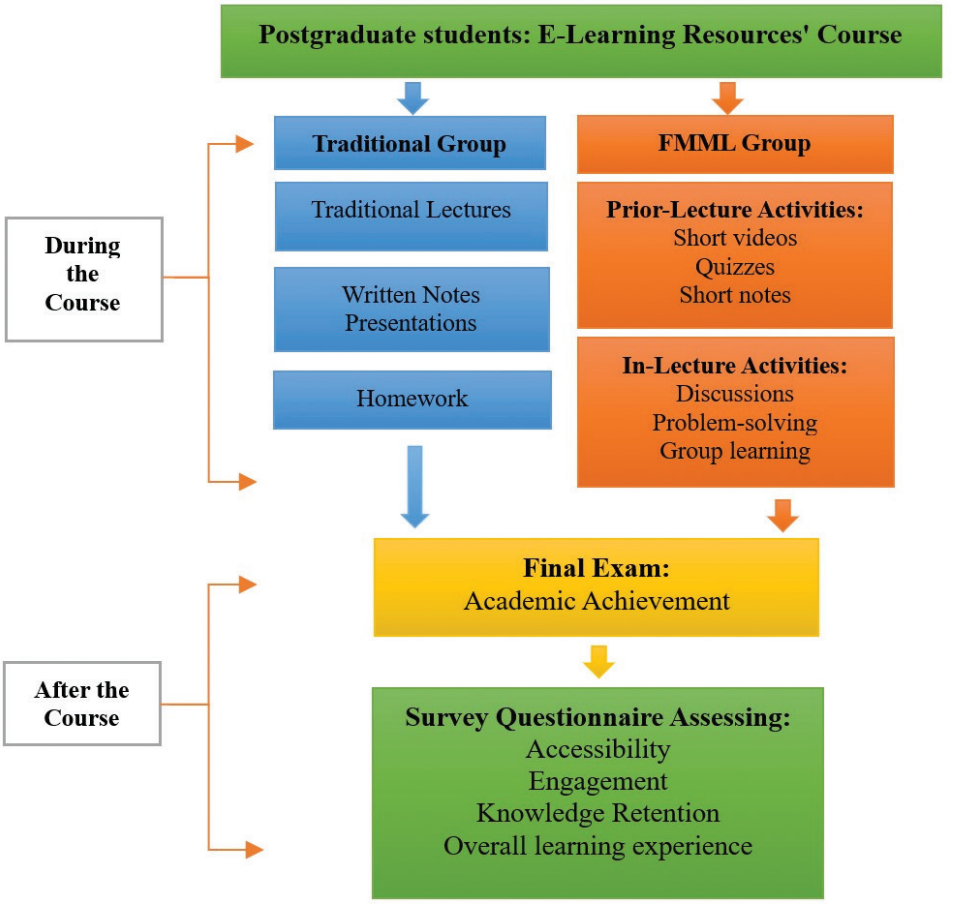

Figure 1. The study design.

towards accessibility, engagement, knowledge retention, as well as their overall satisfaction with the learning processes in the course. See (Appendix 1).

Also, the final exam test was an integral component of the evaluation process. The exam consisted of a combination of multiple-choice questions, short-answer questions and essay questions. The questions were designed to cover various topics and concepts taught throughout the course, ensuring a comprehensive assessment of the students' understanding. The exam results provided valuable insights into the students' academic achievement.

Sampling and participants

This study was conducted in higher education institutions. A total of 19 postgraduate students enrolled in the E-Learning Resources' course (ETEC-605) during the academic year 2023 were selected for this study.

Postgraduate education is a crucial phase in a student's academic journey, typically involving advanced coursework, research activities and specialised training. However, postgraduate students face various challenges, including time constraints, demanding schedules and the need to balance multiple responsibilities. By incorporating FMM, flexible learning opportunities can be provided to postgraduate students, allowing them to access course content anytime and anywhere, which can accommodate their busy lifestyles.

Ethical approval for this research has been obtained from the Faculty of Education at the University of Jeddah. Postgraduate students have been informed about their participation and have provided their informed consent, indicating their willingness to take part in the current study. Participant confidentiality and anonymity are preserved at all stages through data protection measures, upholding ethical standards. Any data gathered remain entirely confidential and are only used for research purposes only.

Validity and reliability

The validity of the questionnaire was examined by three scholars in the field of educational technology and higher education. These experts provided suggestions and approved changes to ensure the questionnaire's validity.

To assess the reliability of the questionnaire, Cronbach's alpha coefficient was calculated, resulting in a value of $\alpha = 0.86$. This indicates a good level of internal consistency, suggesting that the questionnaire items are measuring the intended construct consistently.

Results

Descriptive analysis

Table 1 presents an overview of the results for the two groups. The Traditional group, consisting of 10 participants, had lower mean scores across all measures compared to the FMM group, which consisted of nine participants.

These results suggest that the FMM approach was associated with higher levels of accessibility, engagement, knowledge retention, overall learning experience and academic achievement compared to the traditional approach.

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Testing significant differences

An independent samples *t*-test was performed to compare the means of the two independent groups in the study, namely, the control group (Group 1) and the experimental group (Group 2). This analysis included conducting Levene's test for equality of variances and *t*-tests for equality of means. The specific results and statistical values can be found in Table 2.

The analysis presented in Table 2 provides compelling evidence, suggesting that the FMM approach outperforms the traditional learning approach across all measured dimensions, including accessibility, engagement, knowledge retention, overall learning experience and final exam scores. The results indicate significant differences between the two groups in each measure, as evidenced by the *t*-test statistics and corresponding *p*-values:

(1) Accessibility: $t(17) = -4.37$, $p < 0.001$
(2) Engagement: $t(17) = -5.71$, $p < 0.001$
(3) Knowledge retention: $t(17) = -4.78$, $p < 0.001$
(4) Overall learning experience: $t(17) = -4.07$, $p < 0.001$
(5) Final exam scores: $t(17) = -3.41$, $p = 0.003$

Table 1. Overview of the groups' results.

Group		***M***	**SD**
Group 1: Traditional ($N = 10$)	Accessibility	3.33	0.54
	Engagement	3.63	0.33
	Knowledge retention	3.73	0.47
	Overall learning experience	3.70	0.67
	Final exam scores	76.80	8.70
Group 2: FMM ($N = 9$)	Accessibility	4.33	0.44
	Engagement	4.56	0.37
	Knowledge retention	4.67	0.37
	Overall learning experience	4.78	0.44
	Final exam scores	87.89	4.59

Table 2. Independent samples *t*-tests.

Dimensions		**Levene's Test**		***t*-Test for equality of means**						
		F	***Sig.***	***t***	**df**	**Sig. (2-tailed)**	**Mean difference**	**Std. error difference**	**95% Confidence**	
									Lower	**Upper**
Accessibility	*Equal*	0.051	0.824	−4.37	17	0.000	−1.00	0.23	−1.48	−0.52
Engagement	*variances*	0.348	0.563	−5.71	17	0.000	−0.92	0.16	−1.26	−0.58
Knowledge Retention	*assumed*	0.842	0.372	−4.78	17	0.000	−0.93	0.20	−1.35	−0.52
Learning Experience		2.561	0.128	−4.07	17	0.001	−1.08	0.27	−1.64	−0.52
Final Exam Scores		3.073	0.098	−3.41	17	0.003	−11.09	3.25	−17.95	−4.23

These findings indicate that the observed differences between the two groups are highly unlikely to occur by chance alone. The results provide robust support for the effectiveness of the FMM approach in enhancing various aspects of the learning process.

Discussion

This study investigated the impact of an FMM approach on postgraduate students. A two-phase quantitative study was conducted, using a quasi-experimental design and a survey questionnaire.

The results suggest that the mobile-based microlearning approach in a flipped learning environment may have yielded better outcomes compared to traditional learning, including student-perceived improvements in accessibility, engagement, knowledge retention, overall learning experience and better final exam scores. The findings support the idea that implementing FMM enhances the learning process. The mobile-based microlearning group reported higher accessibility and engagement, whilst also demonstrating better knowledge retention. The overall learning experience was more positive for the mobile-based microlearning group, and their final exam scores were significantly higher.

These results contribute to the existing literature on pedagogical strategies, emphasising the benefits of FMM and its potential to enhance the learning process and educational outcomes (e.g. Chang et al., 2015; Krygier et al., 2022; Shine & Heath, 2020).

Postgraduate students in the FMM group reported higher levels of accessibility, indicating that they were able to easily access learning materials at their convenience. The use of mobile-based microlearning allows students to conveniently access learning materials at their own pace (Hao et al., 2022; Markowitz, 2020). Additionally, they exhibited higher levels of engagement, suggesting active involvement and interest in the learning process. The combination of mobile-based microlearning and the flipped learning environment fosters active involvement and interest amongst students (Chang et al., 2015; Fidan, 2023; Krygier et al., 2022; Ma et al., 2021; Sankaranarayanan et al., 2023).

Moreover, the mobile-based microlearning group demonstrated better self-reported knowledge retention, indicating that the approach facilitated the retention and application of acquired knowledge. Research indicates that the mobile-based microlearning approach promotes better knowledge retention and application (Chang et al., 2015; Hao et al., 2022). The overall learning experience was also reported to be more positive in the mobile-based microlearning group, suggesting that the combination of mobile-based microlearning and flipped learning created a more engaging, motivated, enjoyable and effective learning environment. The literature shows that the integration of FMM creates an engaging and effective learning environment, resulting in a positive learning experience and thus leading to better outcomes (Dixit et al., 2021; Fidan, 2023; Hae ja & Chun, 2016; Hao et al., 2022; Ibarra-Cabrera et al., 2021; Nan et al., 2017; Qian et al., 2021; Rad, 2023; Sankaranarayanan et al., 2023; Zhou & Deng, 2018).

Furthermore, the final exam scores of the mobile-based microlearning group were significantly higher than those of the traditional learning group. This suggests that the mobile-based microlearning approach, when integrated into a flipped learning environment, can contribute to improved academic achievement. Similar studies have shown that the mobile-based microlearning approach, when integrated into a flipped learning environment, positively impacts students' academic achievement (e.g. Fidan,

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2023; Hao et al., 2022; Qian et al., 2021; Sankaranarayanan et al., 2023; Zhou & Deng, 2018).

In summary, these results contribute to the existing body of literature on innovative pedagogical strategies by providing evidence of the benefits of FMM. The findings highlight the potential of this approach to enhance various aspects of the learning process and improve educational outcomes.

Conclusions and implications

In conclusion, the study's findings provide evidence for the effectiveness of FMM in enhancing the learning process for postgraduate students. The results consistently showed that the mobile-based microlearning group outperformed the traditional learning group across multiple dimensions, including accessibility, engagement, knowledge retention, overall learning experience and academic achievement.

The significant differences observed between the two groups indicate that the FMM approach yields superior outcomes compared to traditional learning methods. These findings contribute to the growing body of literature on innovative pedagogical strategies and highlight the potential of FMM to improve educational outcomes.

This study emphasises the importance of incorporating technology and active learning strategies into postgraduate students' education to enhance accessibility, promote student engagement and facilitate knowledge retention. The mobile-based microlearning approach, combined with the flipped learning model, provides students with flexible and convenient access to learning materials, fosters active engagement with the content and supports the application of knowledge in real-world contexts.

The implications of these findings extend beyond the specific context of postgraduate students' education, as FMM has the potential to be applied across different educational levels and subject areas. Also, the findings of this study have several implications for educational practice including the following.

First, the effectiveness of FMM highlights the potential of technology-enhanced learning approaches. Educators can consider incorporating these strategies into their instructional design to enhance the accessibility, engagement and knowledge retention of students. By leveraging mobile devices and online platforms, learning materials can be delivered in bite-sized and easily digestible formats, allowing students to learn at their own pace and convenience.

Second, the positive outcomes observed in the mobile-based microlearning group emphasise the importance of active and interactive learning experiences. The flipped learning model encourages students to engage with learning materials before class, enabling more meaningful and interactive discussions and activities during face-to-face sessions. This approach promotes student engagement, critical thinking, creativity and collaborative problem-solving skills, which are essential for their overall learning experience and academic achievement.

Furthermore, the findings suggest that the integration of FMM can have a significant impact on postgraduate students' motivation and attitudes towards learning. By providing students with flexible access to educational resources and promoting active participation in the learning process, this approach can enhance their intrinsic motivation, self-esteem and enjoyment of learning. This has implications for fostering a positive learning environment and promoting lifelong learning habits amongst postgraduate students.

In summary, the implications of this study suggest that educators and institutions should consider integrating FMM as a means to enhance the learning experience and outcomes of postgraduate students. By leveraging technology and active learning strategies, educators can promote accessibility, engagement and knowledge retention, ultimately fostering a positive and effective learning environment for postgraduate students.

Limitations and research directions

Despite the insights gained from this study, there are some limitations that should be considered. First, this study focused specifically on postgraduate students, who normally enrol in courses in small numbers, so the findings may not generalise to other educational levels or student populations. Additionally, the small sample size limits the conclusions that can be drawn. The effectiveness of FMM may vary across different contexts, disciplines and student characteristics. Future research should explore these variations with larger sample sizes to provide a more comprehensive understanding of FMM's applicability.

Second, this study employed a quantitative research design, basically relying on self-reported measures to assess the outcomes. Whilst this approach allows for statistical analysis and comparison between groups, it may not capture the nuanced aspects of the learning experience or provide in-depth insights into students' perceptions and attitudes. Including qualitative methods, such as interviews, could provide a richer understanding of the students' experiences and shed light on the mechanisms behind the observed effects.

Another limitation is the relatively short duration of the study. The impact of FMM may unfold over a longer period, and long-term effects on students' academic performance and professional development may differ from the immediate outcomes measured in this study. Longitudinal studies that follow students over an extended period would provide more robust evidence of the sustainability and long-term benefits of this approach.

Finally, this study did not explore the specific instructional design strategies or content of the mobile-based microlearning materials. The effectiveness of this approach may depend on the quality and relevance of the learning materials, as well as the pedagogical strategies used to engage students. Future research could delve into these factors to provide more specific guidance on the design and implementation of FMM.

To sum up, this study highlights the need for further investigation into the design and implementation of effective educational interventions for this specific student population (i.e. postgraduate students). Future research can explore additional variables, such as the role of instructor support, student learning preferences and the long-term effects of this approach on students' academic and professional development. Furthermore, future research should continue to explore and refine the implementation of FMM, considering factors such as instructional design, technological support and individual learner characteristics.

Declarations

Availability of data and materials

The datasets used and/or analysed in this study are available from the corresponding author upon reasonable request.

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Appendix 1

Survey on learning experience in both the experimental and control groups: accessibility, engagement, knowledge retention and overall learning experience

Please rate the following statements based on your experience.
(Strongly Disagree / Disagree / Neutral / Agree / Strongly Agree)

Accessibility

(1) I had easy access to the required learning materials.
(2) The learning materials were easily accessible through the provided resources.
(3) I had the necessary resources and tools to engage with the course content effectively.

Engagement

(1) I actively participated in classroom discussions or activities.
(2) I found the course content interesting and engaging.
(3) I was motivated to learn and explore the subject matter.

Knowledge retention

(1) I feel confident in my understanding and retention of the course content.
(2) I can apply the knowledge gained from this course to practical situations.
(3) I believe I will remember and retain the knowledge from this course in the long term.

Overall learning experience

(1) I am overall satisfied are you with learning experience in this course.

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