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Mobile seamless learning in Higher Education: an exploratory case study

Aprendizagem Móvel Sem Fronteiras no Ensino Superior: um estudo de caso exploratório

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Abstract

Mobile seamless learning (MSL) has emerged as a transformative pedagogical approach in higher education, offering opportunities for flexible, collaborative, and social learning. Although scholarly attention has increased, systematic implementation remains underexplored. This study examines the integration of MSL principles in a Master's-level distance learning course, drawing on the FRAME and 10-Dimensions MSL (10D-MSL) frameworks. A mixed-methods design combining quantitative and qualitative data was used to evaluate three dimensions: social interaction, learner flexibility, and teaching presence. Results show that the MSL-based course enhanced engagement, fostered creativity, and strengthened collaborative learning. Challenges also emerged, particularly in time management, workload, and balancing formal and informal contexts. Findings highlight the crucial role of mobile devices in enabling autonomous and context-based learning, as well as the dependence on thoughtful instructional design that is aligned with learner needs. Well-structured course design proved essential to overcoming technical and organisational barriers. This research contributes to the understanding of MSL in higher education and offers practical guidelines for educators seeking to implement mobile technologies effectively.

Keywords: Mobile learning; Seamless learning; Higher education; FRAME model; 10-D MSL framework.

Resumo

A aprendizagem móvel sem fronteiras (MSL) tem surgido como uma abordagem pedagógica transformadora no ensino superior, oferecendo oportunidades para experiências flexíveis, colaborativas e sociais de aprendizagem. Apesar da crescente atenção académica, a sua implementação sistemática como quadro pedagógico permanece pouco explorada. Este estudo examina a integração dos princípios da MSL em um curso de pós-graduação a distância, com base nos quadros FRAME e 10-D MSL (10D-MSL). Foi utilizado um desenho de métodos mistos, combinando dados quantitativos e qualitativos, para avaliar três dimensões: interação social, flexibilidade do aprendiz e presença docente. Os resultados mostram que o curso baseado na MSL aumentou o engajamento, fomentou a criatividade e fortaleceu a aprendizagem

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colaborativa. Também surgiram desafios, em particular na gestão do tempo, na carga de trabalho e na conciliação entre contextos formais e informais. Os resultados destacam o papel crucial dos dispositivos móveis para promover a aprendizagem autônoma e contextual, mas igualmente a dependência de um design instrucional cuidadoso, alinhado às necessidades dos estudantes. Um design bem estruturado mostrou-se essencial para superar barreiras técnicas e organizacionais. Esta pesquisa contribui para a compreensão da MSL no ensino superior e oferece orientações práticas para educadores que buscam implementar tecnologias móveis de forma eficaz.

Palavras-chave: aprendizagem móvel; aprendizagem sem fronteiras; ensino superior; modelo FRAME; quadro 10-D MSL.

Introduction

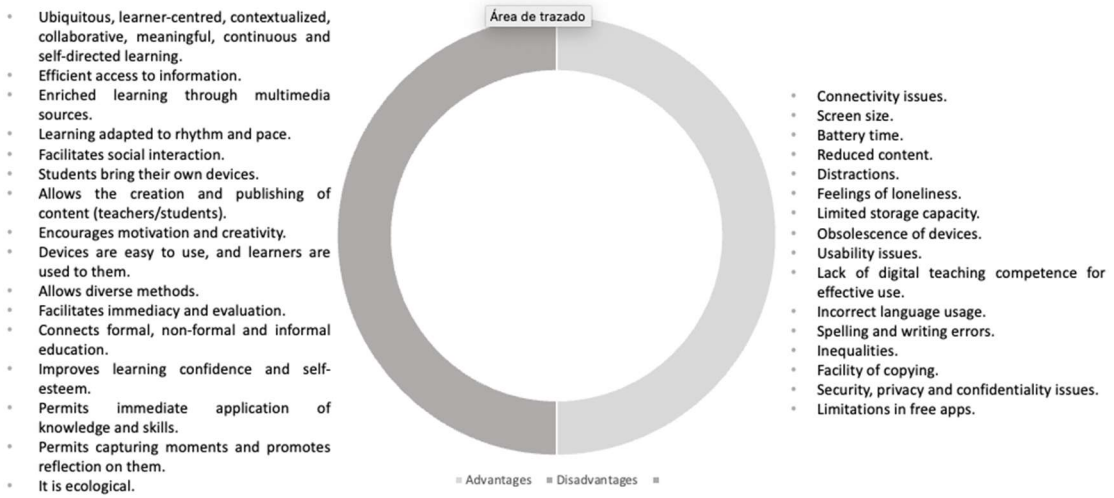
The pervasive spread of mobile devices has revolutionized learning in higher education, fostering the rise of mobile learning (m-learning).The surge in global mobile device ownership and internet connectivity has been a significant enabler. North America and Europe report smartphone adoption rates of around 80% (GSMA, 2021), with similar figures in Spain (Ditrendia, 2020; INE, 2019), reflecting a trend that extends into education, propelled by 'bring your own device' (BYOD) policies and user motivation.

Although reports have traced m-learning trajectory since 2005 (e.g., The Horizon and Innovating Pedagogy report) , its adoption in academia remains slow (Aznar-Díaz et al., 2020), and its underlying pedagogies require further exploration (Crompton & Burke, 2018). This paper examines the practical application of mobile learning (m-learning) in distance higher education, offering insights for educators and researchers seeking to enhance the integration of mobile technologies into academic curricula. It also provides a foundation for researchers investigating the practical applications of m-learning.

Background

U-learning, m-learning, and seamless learning, often used interchangeably, denote a shift from traditional learning paradigms, emphasising anytime-anywhere learning, learner-centricity, and contextual learning that links formal and informal settings (Báez & Clunie, 2019). These modalities point towards an educational evolution, enabled by mobile and other ICTs, to foster personalised, social, and life-wide learning experiences. Several studies have analysed the advantages and disadvantages of using mobile technology for learning. Figure 1 synthesises the main findings (based on: Al-Arabiat, et al., 2015; Brazuelo & Gallego, 2011; Butcher, 2014; Chen & Yan, 2016; Corbeil & Valdes-Corbeil, 2007; Duarte Filho & Barbosa, 2013; Hu & Xu, 2013; JISC InfoNET, 2011; Krotov, 2015; Narayanasamy & Mohamed, 2013; Pimmer et al., 2016; Pollara, 2011; Sundgren, 2017).

Figure 1
Advantages and disadvantages of m-learning

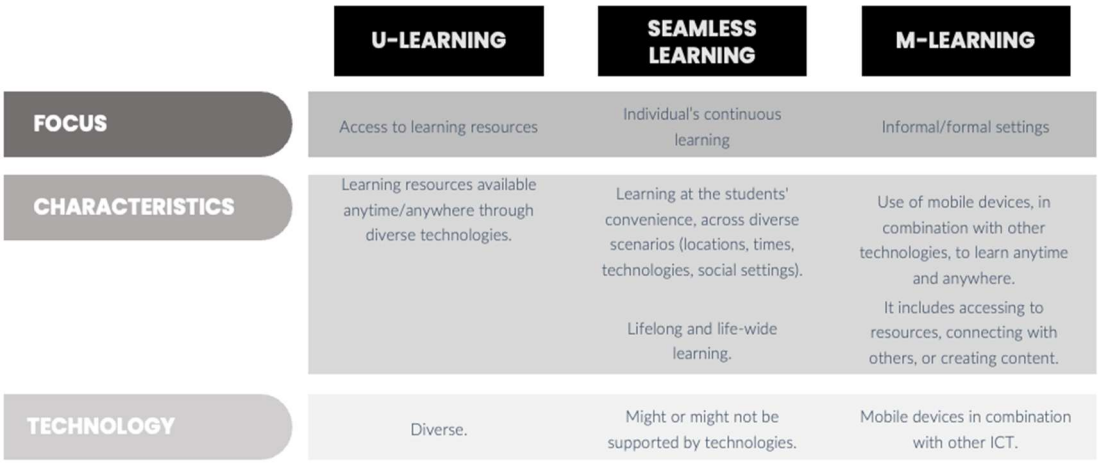


Source: own elaboration.

Seamless learning encourages lifelong and life-wide education, enabling learners to use their preferred tools across contexts and enhancing their autonomy and responsibility (Gros, 2015; Kukulska-Hulme et al., 2021). Ubiquitous learning focuses on resource availability everywhere and anytime, whereas seamless learning further adapts to changing learning habits and scenarios (Yetik et al., 2020). As shown in Figure 2, u-learning, m-learning, and seamless learning differ in their focus and pedagogical implications. While u-learning emphasises ubiquitous access to resources, m-learning focuses on the use of mobile devices to support learning. Seamless learning, in contrast, integrates learning experiences across formal and informal contexts, time, space, and social settings. It emphasises transitions between contexts, personalisation, and the integration of digital tools into everyday life, offering a more holistic and learner-centred approach.

The relationship among u-learning, m-learning, and seamless learning is both evolutionary and complementary. U-learning laid the foundation by emphasising the importance of access to learning resources anytime, anywhere. M-learning built upon this by introducing mobile devices as key enablers of flexible, on-the-go learning. Seamless learning then extended these ideas by focusing on the fluid integration of learning experiences across different contexts—formal and informal, individual and social, physical and digital. Mobile Seamless Learning (MSL) synthesises these approaches, leveraging device mobility and ubiquitous access while emphasising the continuity and contextualization of learning. In this sense, MSL can be seen as a convergence point that operationalises the pedagogical potential of its predecessors into a cohesive, learner-centred framework.

Figure 2
Differences among u-learning, seamless learning, and m-learning



Source: own elaboration.

What distinguishes MSL from its predecessors is its explicit focus on designing learning experiences that are not only mobile and ubiquitous but also pedagogically coherent across contexts. While u-learning and m-learning emphasise access and mobility, they often lack a structured framework for integrating learning across formal and informal settings.

The 10D-MSL model proposed by Wong (2012), along with the pedagogical insights of Sharples and Pea (2014), provides educators with concrete dimensions to guide instructional design, ensuring continuity, personalisation, and social interaction. Rather than focusing solely on access or device use, MSL emphasises orchestrating learning across formal and informal settings, encouraging student motivation and autonomy. This approach supports the creation of enriched learning landscapes where digital and physical spaces converge, enabling distributed control of learning, context-sensitive education, and the transformation of learners' environments into active learning spaces.

Several researchers have attempted to design mobile seamless learning experiences using multiple mobile devices (Baharun et al., 2021; Firssova et al., 2020; Foomani & Hedayati, 2016; Hamid et al., 2019; Nordmark, 2018; Safiah et al., 2020). This has included the creation of various MOOCs, with some tailored specifically to distance education (Amhag, 2017; Bothe & Meinel, 2019; Krull & Duart, 2017; Tabuenca et al., 2018). The advent of the pandemic accelerated this innovation, yielding encouraging outcomes in enhancing student motivation, autonomy, and the integration of learning across diverse contexts. (Ulfa et al., 2020; Baharun et al., 2021). Recent literature robustly supports the relevance and effectiveness of MSL in higher education. Empirical studies demonstrate that mobile seamless learning environments enhance student motivation, engagement, and academic performance, especially when designed to support learning across multiple contexts (Dakir et al., 2021; Putri et al., 2022; Qolbi et al., 2024). However, despite these promising findings, there remains a notable gap in the literature regarding the systematic exploration of how mobile seamless learning can be

holistically integrated into higher education curricula and pedagogical frameworks (Naveed et al., 2023). This study addresses the gap in the literature by applying the 10D-MSL framework in a real-world higher education context, offering empirical insights into how mobile technologies can be pedagogically orchestrated to support flexible, collaborative, and context-aware learning.

Method

Context and Research Questions

This study examines the practical application of MSL in distance education, with a focus on learning design and the facilitation of social constructivist pedagogies through mobile technologies,prioritising the 'seamless' aspect over the 'mobile' one. It aims to support learners in developing knowledge collaboratively (with the teacher and classmates) and flexibly (in terms of time, interests, grouping, synchronicity, resources and types of activities and digital tools), and in utilising mobile devices as educational tools (artefacts). Three key research questions were posed to investigate the benefits of MSL for flexible learning and social learning:

1. Does MSL benefit learning, specifically the flexible one, in distance education?
2. Are mobile devices helpful in learning at a distance?
3. Is MSL suitable to design didactic sequences based on collaborative and social learning?

Design

The redesign of a distance-learning course using mobile devices was grounded in a theoretical framework to deepen understanding of mobile collaborative learning. A mixed-methods approach combining qualitative and quantitative techniques was adopted for a thorough analysis, involving questionnaires, observations, and interviews conducted via Google Forms and Skype. An action-research methodology was followed, encompassing planning, action, observation, and reflection (Burns, 2015), with the teacher acting as both educator and researcher. In our case, planning involved needs analysis and the redesign; action was the three-week implementation; observation combined questionnaires, interviews, and participant observation; and reflection informed the adjustments and recommendations reported in the Discussion. (See also the "implementation phase (act)" description.)

Setting and Participants

The case study centred on a master's course in "Psycho-pedagogy of Lifelong Learning", focusing on the final three weeks of the Spring semester of the 2019/2020 academic year (4-hour on-site learning sessions). Eleven students engaged with content on digital society and educational theory, with their interactions and feedback informing the study's insights into pedagogical and technological practices (details in Table 1).

Most are full-time students and/or have a part-time job, with an intermediate level of technology proficiency. Half have prior experience with distance learning, and all extensively use virtual campuses in their university courses. Table 2 indicates that half of the participants use their mobile devices for over 5 hours daily, primarily for communication with classmates and for accessing resources or messages in the virtual classroom.

Table 1
Demographics, command of technology and technology-mediated learning experience

Demographics	N=10
Age range	
20 -3 0	8
30 - 40	1
40+	1
Personal situation	
Full-time student	4
Full-time job	3
Part-time job	5
Unemployed	1
Homemaker	1
Children	1
Prefer not to say	1
Command of technology	
Beginner	0
Lower intermediate	4
Upper intermediate	5
Advanced	1
Previous distance learning experience	
Yes	5
No	5
Virtual campus use at the university	
Widespread	10
Occasional	0

Source: own elaboration

Table 2
Mobile use and mobile learning

Mobile use and mobile learning	N=10
Mobile use (hours per day)	
0-1	0
1-2	1
2-3	1
3-4	2
4-5	1
+5	5
Mobile use for learning purposes	
To look for information during class sessions	6
To take photos or videos during class sessions	4
To communicate with classmates on academic issues	10
To consult resources	7
To do activities	2
To consult messages from the virtual classroom	6
To consult course planning	5

Source: own elaboration

Research Instruments

Student satisfaction survey

The student satisfaction survey comprised 20 items across four categories: device use, learning experience, course structure, and personal background. It included a variety of question types and used a Likert scale for responses, with one open-ended question. The survey's design was informed by the FRAME model (Koole, 2009), the Mobile-learning pedagogy framework (Kearney et al., 2019), and literature about perspectives and attitudes towards mobile connectivity based on survey analysis (Ata & Cevik, 2019; George, 2019; Hamann, 2015; Hao et al., 2017; Kearney et al., 2019; Kljunić & Vukovac, 2015; Rettger, 2017; Silvestru et al., 2018). The questionnaire's reliability (see Table 3) was confirmed with alpha coefficients which indicated acceptable to good consistency (Charter, 2003; Cicchetti, 1994; Nunnally & Bernstein, 1994). Administered online and anonymously, the survey's results were analysed using the FRAME model's dimensions to interpret the data.

Table 3
Reliability analysis

Subscale	Number of subitems	Cronbach's α
Benefits	11	0.824
Difficulties	8	0.763
Pedagogical design	16	0.883
Teacher's support	6	0.844

Source: own elaboration

Student interviews

In-depth interviews were held with three diverse learners via Skype, focusing on their backgrounds, digital skills, and learning experiences to gather insights into the course's impact. These interviews complemented the research by addressing key questions about prior e-learning and mobile learning experiences, course design feedback, and expectations. The interviews, conducted in mid-April, lasted 1 hour each and were recorded for later analysis.

Teacher-researcher's participant observation

The teacher-researcher engaged in participant observation and critically assessed the learning environment. This approach offered a comprehensive and reflective perspective on the effectiveness and challenges of the mobile seamless learning course, thereby enriching the overall analysis of the study(DeWalt & DeWalt, 2010). Within the scope of this study, the teacher adopts the role of the participant observer, engaging in the instructional process while systematically examining and reflecting on their teaching practice.

Data analysis

Ethical Considerations:

This study complied with international ethical standards for research in the social sciences and humanities. All participants gave informed consent, participation was voluntary, and anonymity/confidentiality were guaranteed.

Data from the questionnaires were analysed using R statistical software and the PLS-SEM (Partial Least Squares Structural Equation Modelling) package, which is suitable for small samples such as our study's ten students. This method analyses relationships between variables without requiring normal data distribution; it handles formative measurement models effectively, allows for the estimatation of models with many constructs and many indicators per construct, even with small sample sizes, and finally often uses bootstrapping to assess the reliability and validity of the model and its parameters, making it ideal for developing theories and predictions in education research. Despite the limited sample size, the findings offer valuable insights that could benefit educators in higher education.

For qualitative analysis, Atlas.ti v8 was employed, utilising a deductive coding method to identify themes from the interviews, which resulted in five initial categories refined into 43 codes. The open-ended questionnaire response was coded using the same category system.

The findings presented below seek to describe the specific cases of the students who participated in the study. The analysis aimed to understand student experiences to enhance course design deeply. For that reason, we have supplemented the surveys with in-depth interviews. The interviews were coded according to key elements such as the design of learning activities for flexible and social learning, and MSL difficulties and benefits in distance education.

Course Redesign

This study outlines the revision of a three-week segment in a master's course that was adapted for remote teaching due to the pandemic, aiming to test a novel mobile learning approach. Originally comprising 4-hour sessions that combined lectures and hands-on activities, the course initially sought to foster active and collaborative learning, enhance digital proficiency, and encourage students to explore resource independently.

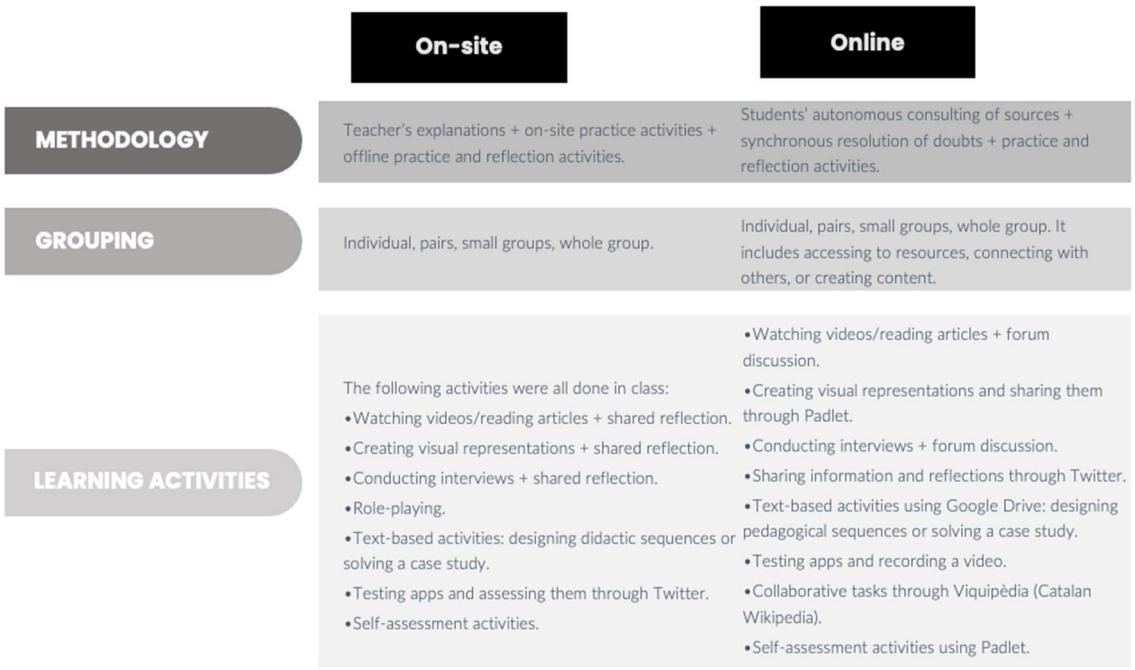
- Feedback on initial proposals, highlighting concerns such as technological constraints and personal obligations, prompted a course redesign to emphasise:
- Flexible learning: This included shortening live sessions to optional 30-minute Skype Q&As, allowing choice in individual or group work, sharing advanced activity details for self-guided study, and setting flexible deadlines.
- Mobile utilisation: Activities were restructured to facilitate mobile access and allow brief offline tasks to overcome connectivity limitations. Essential digital tools were

integrated, favouring familiar platforms like Google Drive and using Moodle for some instructional activities.

- Activity variety: The redesign aimed to cater to diverse learning preferences and digital capabilities, using multiple resources to foster an engaging online learning environment.

Figure 3 summarises the structure designed for on-site teaching and, later, for online teaching.

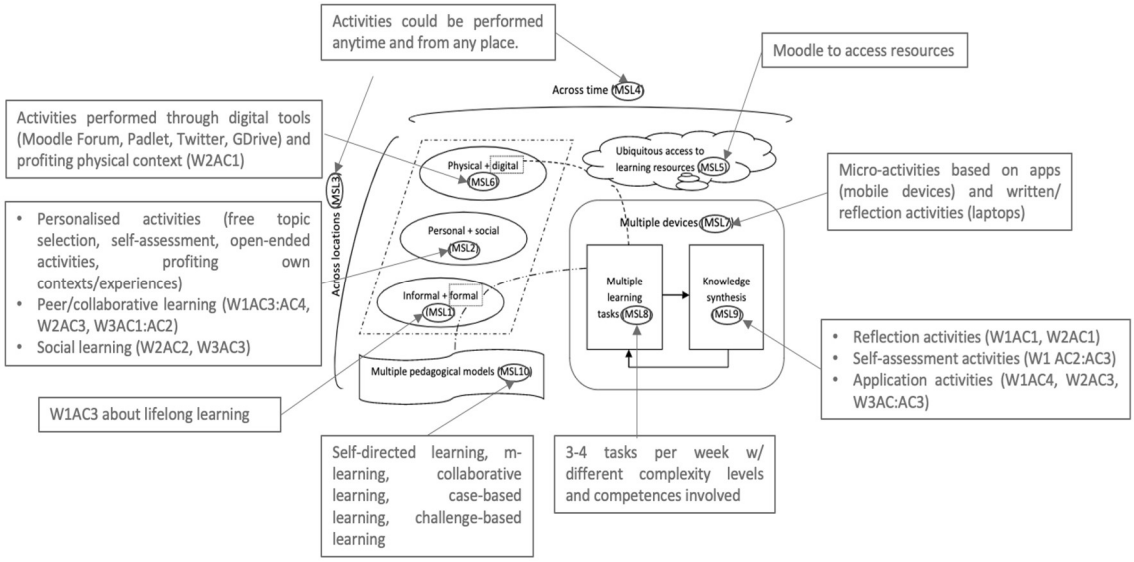
Figure 3
On-site vs online course design



Source: own elaboration.

Wong's (2012) 10-Dimension Mobile Seamless Learning (10-D MSL) framework was used to design a consistent mobile learning experience. For each dimension, actions were taken to adapt the course to meet the MSL requirements (see Figure 4).

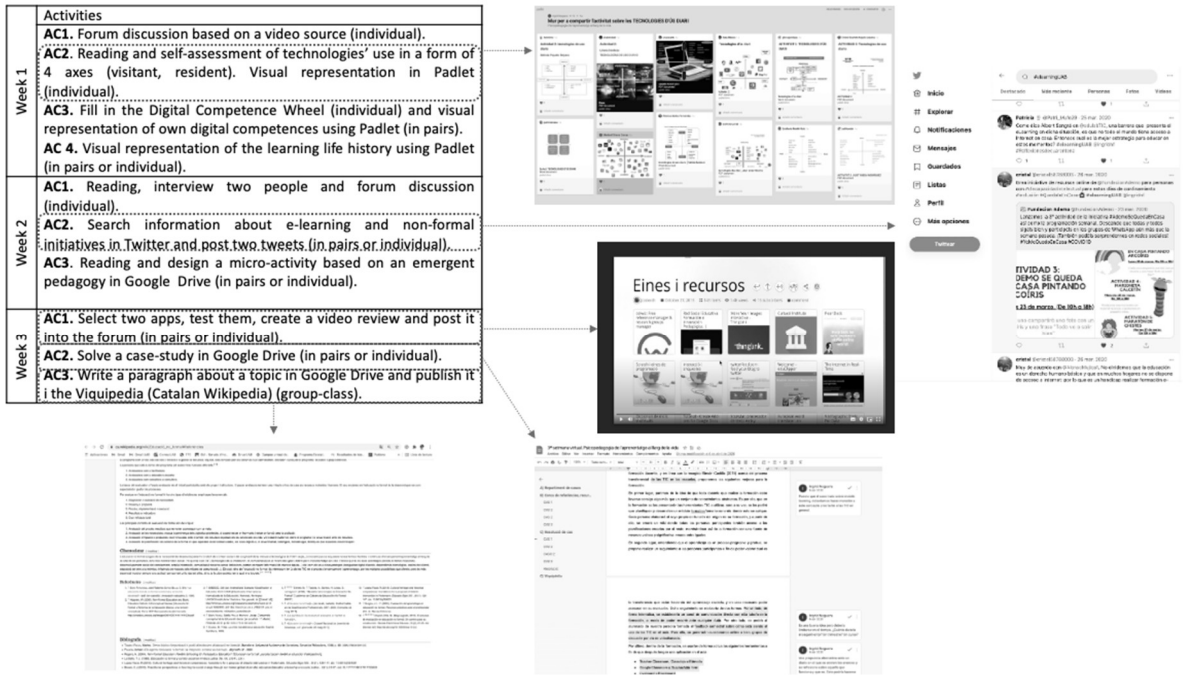
Figure 4
Course redesign based on Wong's (2012) 10-D MSL framework



Source: own elaboration.

In the implementation phase (act) of the course redesign, the Moodle platform was structured every week, featuring a document outlining activities and deadlines, a forum for discussions and reflections, external resources and digital tools, and a PowerPoint presentation covering theoretical content. The didactic sequence for each week is described in Figure 5.

Figure 5
Didactic sequence and screenshots of activities



Source: own elaboration.

Results

Here, the results of the FRAME model's study evaluating the effectiveness of mobile seamless learning in the redesigned course are presented. Data collected from questionnaires and interviews, and their analysis are organised into five main sections:

1. students' perceptions of mobile seamless learning and satisfaction with the course design,
2. students' learning outcomes and performance,
3. social and collaborative aspects of the course,
4. students' use of mobile devices and digital tools, and
5. challenges and areas for improvement encountered by both students and teachers.

These results provide insights into the strengths, weaknesses, and potential areas for refinement in future implementations of mobile seamless learning.

As previously reported, the results in the following areas are based on questionnaires, interviews, and participant observation of the teacher. Questionnaires are analysed using descriptive statistics and the PLS model, while interviews and observations are examined from a qualitative perspective thorugh a deductive coding approach. For the PLS analysis, we grouped the questions into the following latent variables, which serve as a synthesis of the various aspects recorded in the questionnaire (details are provided in Table 4).

After using a bootstrapping technique to assess the consistency and reliability of the model, we got the following results:

- Model Stability: The model is stable and consistent.
- Significant Predictors: i) for MSL1 (Technical Challenges), Course Design (MSL7) appears to have a negative impact, although the standard deviation suggests some variability; ii) for MSL6 (Teacher Support), both Course Design (MSL7) and Social Aspects (MSL5) are positively related with low variability; iii) for MSL2 (Learning Preferences), Course Design (MSL7) appears to be a strong positive predictor.
- Mixed Influences: i) for MSL4 (Time Management and Personal Circumstances Challenges), the influence of predictors varies, with Technical Challenges (MSL1) having a strong positive mean coefficient; ii) for MSL3 (Distance Learning Experience), all predictors seem to influence the outcome positively, but the impacts are moderate; iii) for MSL5 (Social Aspects), Technical Challenges (MSL1) and Course Design (MSL7) both have positive mean coefficients, but the influence of Time Management (MSL4) is negative.

The mean coefficients tell us the average impact of each predictor. Positive values indicate a positive relationship, while negative values indicate a negative relationship. The bootstrapping results corroborate the initial PLS models, adding an extra layer of confidence in the findings. Overall, Course Design (MSL7) continues to emerge as a

significant predictor for multiple aspects of the learning experience. This result aligns with the idea that the course design and its redesign, have been the first factors to impact the whole learning experience.

Table 4
PLS Model

Endogenous Variable	Predictors	R^2
MSL1 (Technical Challenges)	MSL7, MSL6	0.28
MSL2 (Learning Preferences)	MSL7, MSL5	0.81
MSL3 (Distance Learning Experience)	MSL7, MSL1, MSL4, MSL2, MSL6	0.91
MSL4 (Time Management and Personal Circumstances Challenges)	MSL7, MSL1, MSL2	0.42
MSL5 (Social Aspects of Learning)	MSL7, MSL1, MSL4	0.34
MSL6 (Teacher Support)	MSL7, MSL5	0.70
MSL7 (Course Design and Content)	/	/

Note:
- Endogenous Variable: The latent variable being predicted.
- Predictors: The latent variables that we expected to be predictors.
- R2: The coefficient of determination, which indicates the proportion of the variance in the endogenous variable that is predictable from the predictors.

Source: own elaboration

Students' Perceptions of Mobile Seamless Learning

There is a general perception that the experience benefited learning. Table 5 shows that although eight students expressed a preference for on-site learning, they also thought the course offered opportunities for distance learning. Students (over 3.5) felt that the course was of high quality, extended their knowledge of the topics and digital skills, and valued the time spent learning to use the tools positively. More than half of the participants experienced difficulties in balancing work, study, and other areas of life, as well as self-regulation, and feelings of disorientation, but digital skills were not a hindrance.

Table 5
Learning experience

Items	**N=10 (Likert scale: 1 = strongly disagree, 5 = strongly agree)**					
Learning experience	1	2	3	4	5	*Mean*
Preference for face-to-face teaching	0	0	2	1	7	4.5
Feelings of disorientation	2	0	2	4	2	3.4
Difficulties of self-regulation	1	1	2	4	2	3.5
Work/study/life balance issues	2	1	0	2	5	3.7
Greater control of learning	0	5	3	2	0	2.7
Miss teacher's physical presence	0	0	3	1	6	4.3
Miss classmates' physical presence	0	0	3	2	5	4.2
Motivated by technology	0	2	3	3	2	3.5
Likely to devote time to learning how to use tools	0	2	2	3	3	3.7
Difficulties due to low digital skills	2	5	0	1	1	2.6
M-learning as an opportunity	0	2	2	5	1	3.5
Opportunity to learn at a distance in lockdown	0	0	2	4	4	4.2
Quality of the course	0	1	2	4	3	3.9
	0	1	3	4	2	3.7
	1	3	5	0	1	2.7

Learning feelings: content and digital skills Desire to use more mobile devices Preference for more conventional activities	3	3	4	0	0	2.1

Interviews

- "I felt overwhelmed. Sometimes my computer did not work as expected. I would probably not have had as many difficulties in on-site learning. Things improved over time." (Laura)
- "The main issue was having an appropriate space to do activities. You can be connected but it's necessary to be 'well-connected'; that means not only looking at the screen but mentally active." (Elena)

Source: own elaboration

Table 6 shows the students' evaluation of the course design and support (average value of 4.2). All items are highly rated (minimum of 3.6). The worst rated are "time for doing activities", "meaningfulness of activities" and "use of "Likes" by the teacher".

Table 7 presents students' preferences by type of activity. The activities they liked the most were the "Digital Competence Wheel" (7) and the forum debate (6). Writing in Viquipèdia (0) and creating a video recording or creating a visual life story were the worst-rated options (4). The Twitter activity (preferred by 5) caused controversy as some students were reluctant to create an account on that social network. Ultimately, even the more reluctant students participated and enjoyed the activity.

Table 6
Course design and support

Items	**N=10 (Likert scale: 1 = strongly disagree, 5 = strongly agree)**					
Course design and support	*1*	*2*	*3*	*4*	*5*	*Mean*
Design	0	0	3	4	3	4
Resources	0	0	0	7	3	4.3
Activities	0	0	0	5	5	4.5
Content	0	0	2	6	2	4
Time	0	0	4	4	2	3.8
Rhythm	0	0	2	6	2	4
Ubiquity	0	1	0	6	3	4.1
Grouping	0	0	1	2	7	4.6
Topics of interest	0	0	2	6	2	4
Meaningfulness	0	2	2	4	2	3.6
Support	0	1	1	4	4	4.1
Solving doubts	0	0	3	2	5	4.2
Likes	1	1	2	1	5	3.8
Feedback	0	0	1	1	8	4.7
Domain	0	0	0	2	8	4.8
Teacher's attitude	0	0	2	4	4	4.2

Interviews

- "The activities were adapted appropriately; the teacher was very willing, open to adapting the course to our needs. We are very grateful for that, considering the situation". (Elena)
- "It was better than expected. I expected the teacher to lecture and then we read autonomously. We applied the knowledge we acquired." (María)
- "There were several tasks, but it was easy to do them. In that sense it wasn't boring, not repetitive; you were doing the tasks and actively changing from one task to another. That was the best part." (Elena)
- "Being able to organize your own time, taking into consideration your own personal life. We were able to do the activities at different times, not at the same time and day. It was very positive." (Elena)
- "We were able to select the topics that motivated us." (María)

Source: own elaboration

Table 7
Ranking of activities

Type of activity	N=10
Debate (forum)	6
Visual activities (Padlet)	5
Life story (Canva/Glogster)	4
Writing activities (Google Drive)	5
Twitter	5
Digital Competence Wheel	7
Video recording	4
Writing (Viquipèdia)	0

Interviews

- "Recording videos, testing apps and sharing thoughts with classmates was an interesting activity, both at a personal and professional level; it was an implementation activity." (Elena)
- "I was not interested in using Twitter. As a result of the activity, I discovered a useful tool for keeping myself informed. I am currently active on Twitter." (Laura)
- "It [the Viquipèdia activity] was very interesting, amazing. What you write is what will later be visible on the internet. The process was harder than for the rest of the activities, but it was the activity that fostered the most group interaction." (Elena)

Source: own elaboration

Table 8 shows students' overall perceptions of the complete three-week module. They appreciated the distance-delivery teaching mode as a form of continuous learning - despite the pandemic - and the teacher's actions, the type of activities and the course content. They criticized the number of activities and the lack of face-to-face contact.

Table 8
Voluntary open questions

Replies to the open question (selected)
(R1) What I liked the most was the topic. I am passionate about technology. I enjoyed learning new tools for my daily life and for my professional life. The learning activities prompted critical thinking and meaningful learning.
(R4) It is okay to consider distance learning as a form of continuous learning, but not all of us have the same tools or opportunities. Virtual classes are not the same as face-to-face instruction (contact, proximity, motivation, timely resolution of doubts, sharing personal or professional experiences). I missed all these elements.
(R5) The teacher demonstrated great willingness to conduct virtual sessions, set various topics for the activities and adjust the course to meet our class group's needs. However, I think there were too many activities every week, which meant I did not enjoy them. I value all the tools I learned to use.
(R6) Despite the unexpected situation, the methodology and the topics were very interesting.
(R7) Although I do not feel comfortable with the use of technology, I enjoyed attending these virtual weeks, because I felt that I received a lot of support and help from the teacher and my classmates. I also think that, although I always missed face-to-face sessions, I learned a lot. I appreciated the teacher's involvement and the fact that she used many different resources that I had not thought of using. Thank you for making the classes during lockdown dynamic, fun, and enriching.

Source: own elaboration

Students Learning Outcomes and Performance

The outcomes of the students were generally quite good, ranging from 7 to 8.9 out of 10, with an average mark of 8.05 out of 10. The question here is what latent variable acts as a predictor of the mark variable in the PLS model.

From this analysis, we know that, while every latent variable has a negligible effect on the mark, the only two that have a higher impact are:

- MSL1 (Technical Challenges): coefficient = -0.21
- MSL4 (Time Management and Personal Circumstances Challenges): coefficient = -0.18

The combination of those two variables explains a good part of the student's performance. The coefficient is negative, meaning that the higher the challenges, the lower the final mark will be. It is interesting to note that these two variables are closely related, as MSL1 has a strong effect on MSL4. At the same time, a good Course Design (MSL7) has a direct influence on mitigating Technical Challenges (MSL1).

Social and Collaborative Aspects

Teachers noticed that students collaborated more in pairs or groups during the course. However, there was limited interaction on Padlet and Twitter, despite efforts to promote peer engagement. In forum discussions, students mainly addressed the central question without engaging in visual discussion threads, but they did refer to classmates' comments in their responses.

Regarding students' usage and perceptions of collaborative and social activities, Tables 6 and 9 show the activities classmates used for interaction and group work. Students appreciated working in pairs and groups (4.6) and the use of co-writing tools (4.3). Despite preferring asynchronous learning, students felt a lack of some form of synchronous communication with the teacher.

Table 9
Social learning experience

Questions	**N=10 (Likert scale: 1 = strongly disagree, 5 = strongly agree)**					
Social learning experience	1	2	3	4	5	Mean
Opportunity to interact with classmates through activities	0	1	2	5	2	3.8
Likely to participate in group/pair activities	1	0	1	6	2	3.8
Likely to learn asynchronously	1	1	2	5	1	3.4
Interviews • "As the course progressed, the complexity of the activities increased, so we realised it was necessary to do them as a group". (María)						

Source: own elaboration

Table 7 demonstrates students preferred individual activities even if those activities were performed in social tools (e.g., forum, Padlet, Twitter). . The activities that were mainly collaborative were not equally valued. For instance, the written activities that required creation were rated 5 points, while other reflection-based activities performed in pairs or groups were rated 4 points. None preferred the activity that required creating a definition, which was performed by the whole group . In Table 11, the results demonstrate that

students perceived the activities as facilitating interaction with classmates (3.8) and performing activities in pairs/groups (3.8).

Use of Mobile Devices and Digital Tools

From the researcher's participant observation of the , it was apparent that the use of mobile devices and digital tools in distance learning was not as expected, with students not seeking support and often adapting to their preferred methods. They exhibited creativity in their use of digital media and were hesitant to utilise platforms like Twitter. While apps like Padlet and Google Drive had some utility, their full potential was not exploited. Teacher feedback was generally not incorporated into the students' work. The most noteworthy observations include:

- Students rarely sought support even when using new tools; some required technical assistance.
- The use of mobile devices and digital tools deviated from expectations; for example, students created elaborate videos on computers (instead of just filming their faces with a smartphone) and used WhatsApp for collaborative tasks (instead of using Viquipèdia or Google Drive).
- Reluctance to use Twitter; students worked in pairs if one did not want to use Twitter, and only a few responded to classmates' tweets.
- Padlet and Twitter were helpful in teacher feedback and activity acknowledgement thanks to the “like” and “reply” buttons.
- Assignments on Padlet included visual documents, presentations, and infographics.
- Google Drive is useful for feedback but not for monitoring group work, as students did not use it for collaboration.
- Students did not revise work on Viquipèdia based on the teacher’s feedback.
- Students did not utilise app affordances unless explicitly instructed.
- Teacher feedback was generally not used to improve activities during the course.

Tables 10 and 11 report the use of devices and digital tools. Most students used their mobile phones and laptops to follow the course, and most connected to the internet via WiFi. The digital tools Padlet, Glogster and Twitter were used for the first time, but students were familiar with the other tools (Canva, Google Drive, Moodle Forum).

Additionally, most students did not experience connectivity issues, although half of them encountered problems when using the tools. Students were able to access the resources from their devices. The higher-rated tools were those for co-writing and self-assessment, and half of the students highly valued the forum and Twitter.

Table 10
Equipment and prior experience with digital tools

Items	N=10
Devices used to follow the course	
Mobile	7
Tablet	3
Laptop	9
Computer	1
Internet connection	
Mobile data	1
WiFi	9
Ethernet	0
No prior experience with digital tools	
Padlet	9
Canva	3
Glogster	8
Google Drive	1
Twitter	5
Moodle Forum	1

Source: own elaboration

Table 11
Use of devices and digital tools

Items	N=10 (Likert scale: 1 = strongly disagree, 5 = strongly agree)					
Digital tools	1	2	3	4	5	*Mean*
Connectivity issues	3	4	1	2	0	2.2
Ease of consulting resources via devices	0	1	0	5	4	4.2
Issues with tools	1	2	1	5	1	3.3
Likely to use social networks (Twitter)	1	0	4	3	2	3.5
Likely to use a visual app in private mode (Padlet)	0	1	2	6	1	3.7
Likely to use a presentation tool (Canva, Glogster)	0	1	1	7	1	3.8
Likely to use a self-assessment tool (Competence Wheel	0	0	3	2	5	4.2
Likely to use a co-writing tool (Google Drive)	0	0	2	3	5	4.3
Likely to use the forum	0	2	3	3	2	3.2

Source: own elaboration

Table 12 illustrates students' opinions of the usefulness of devices, with laptops perceived as the most helpful device for all activities except writing WhatsApp messages to classmates about course activities, testing apps, tweeting, and recording videos. Mobile phones were nearly as helpful in browsing the internet as laptops. Mobiles were used intensively for WhatsApp. One student said: "We posted all the teachers' posts in Moodle and emails in WhatsApp".

Table 12
Usefulness of devices for doing activities

Activities	Mobile	Tablet	Laptop or computer
Consult textual resources	2	2	7
Browse the Internet	7	2	10
Watch videos	4	3	10
Watch the course presentations	2	2	8
Write emails to the teacher	1	0	10
Write WhatsApp messages to classmates about course activities	10	1	7
Check forum posts	3	2	9
Write in the forum	0	0	10

Activities	Mobile	Tablet	Laptop or computer
Create the 4-axis figure (resident/visitor)	0	0	10
Use Padlet	0	0	10
Fill in the Digital Competence Wheel	1	1	8
Create the list of skills	0	0	10
Write in Google Drive	0	2	10
Do activities in Canva / Glogster	0	0	10
Test apps	10	1	6
To tweet	7	0	4
Record video review	6	0	4

Source: own elaboration

Challenges and Areas for Improvement

The teacher-researcher found that most students possessed adequate digital skills for the course, but improvements were needed in resource formats and virtual role-plays . The use of digital tools has both benefits and drawbacks, with some activities performing well while others fall short. Monitoring and assessment were time-consuming, and students generally did not use teacher feedback for improvement. Key challenges from the teacher's participant observation are:

- Most students possessed the necessary digital skills, but two required additional support.
- Resources should be self-explanatory, and improvements and alternative formats (e.g., videos, infographics) should be considered for next time.
- Synchronous sessions were unattended; students preferred written asynchronous formats for inquiries, in particular, email over forums.
- Using multiple platforms for course distribution was cumbersome.
- Weekly resource creation and tool preparation (e.g., hashtags, Padlet walls, forum topics) were highly time-consuming.
- Viquipèdia's activity was not as successful as anticipated.
- Time-consuming student monitoring: weekly feedback was required, but some students consistently missed deadlines.
- Students generally did not use feedback to improve work, such as Viquipèdia corrections not being implemented.

Discussion and Recommendations for the Adoption of Mobile Seamless Learning

This research contributes to debates on inclusion and accessibility in digital education, demonstrating how flexible learning designs, such as MSL, may reduce (but also risk reinforcing) digital divides, depending on how technological and social barriers are addressed.

The course redesign received high praise from students and teachers. Following the FRAME model, the design incorporated mobile learning aspects, aligning with Safiah's et al. (2020) results, and provided flexibility and independence in learning using mobile devices and digital tools. However, aspects such as rhythm, content meaningfulness,

and social affordances of tools were valued less. Activities with a visual component, in which students excelled, were valued the lowest. Considering these results, any improvement to the design of the course should focus on better spacing of activities, enhancing the explanations of the professional implications of topics, and promoting the use of social affordance tools. Teacher feedback suggested introducing role-plays, converting resources into videos or infographics, and establishing synchronous slots to increase teacher presence. It is essential to consider strategies that encourage students to actively use feedback, as both teachers and assessment play crucial roles in facilitating mobile seamless learning, as highlighted by previous research (Amhag, 2017; Baharun et al., 2021; Foomani & Hedayati, 2016; Hamid et al., 2019).

A closer examination of the lower-rated activities suggests that several contextual factors may have influenced students' perceptions. Activities involving video recording, visual storytelling, or Twitter participation required public visibility and creative production, which may feel uncomfortable for learners with limited experience in open digital environments. Cultural norms around privacy and academic formality, as well as generational differences in social media use and digital identity, may also help explain this reluctance. In addition, the use of multiple digital tools may have been perceived as demanding for students balancing work, study, and family responsibilities. When expectations of a more traditional, lecture-based course met a design emphasising autonomy, flexibility, and social interaction, some friction likely emerged. Clearer communication about the pedagogical purpose of these activities and low-stakes opportunities to practise with new tools could help increase engagement in future implementations

Regarding the use and effectiveness of mobile devices in distance education, our design encouraged the use of multiple mobile devices, primarily mobile phones and laptops, in line with previous studies (Chang & Chen, 2007; Krull & Duart, 2017). While mobile phones were used, as in previous studies (Wong, 2012), for communication, tweeting, testing apps, and browsing the internet, laptops were used for more complex activities.

Although the use of mobile phones differed from expectations, students used them for various course activities. Students enjoyed activities based on self-assessment and the use of Google Drive, but were reluctant to use Twitter. From the teachers' perspective, the affordances of Padlet and Twitter , along with Google Drive's anchored comments, were helpful in providing feedback. However, monitoring student processes in Google Drive proved to be challenging. Future instructions should encourage students to use Twitter and collaborate in Google Drive.

Regarding the suitability of MSL for supporting social learning, students valued having opportunities to collaborate, especially in those tasks that were more complex. However, the social affordances of tools were underutilised. Instructions should be provided to encourage commenting and responding to classmates' deliveries on social networks.

Most of the dimensions of Wong's 10-D MSL framework were implemented. Dimension 1 (informal/formal) should be reinforced as the course design is primarily focused on formal learning; opportunities for informal learning should be considered in conjunction

with formal learning. To reinforce this dimension, future iterations of the course could incorporate simple activities that deliberately connect students' everyday digital practices with the formal tasks of the module—for example, brief mobile reflections captured outside class, following relevant experts on social networks, or applying course concepts during visits to informal learning contexts such as museums. These low-effort strategies would help integrate informal experiences into the structured learning pathway and strengthen the seamless aspect of the design.

Although dimensions 2 (personal/social learning) and 3 (across time) are covered in the current design, in line with Ulfa et al. (2020), the course could be improved by including opportunities for making better use of the context (when not in lockdown) and by promoting more social (not just collaborative) activities. As reported by Firssova et al. (2020) regarding dimension 9 (knowledge synthesis), although there is no explicit demonstration of the integration of prior knowledge, some starting and self-assessment activities fulfilled the function of connecting new and prior learning. The application of MSL implies additional effort for teachers in terms of preparation (more instructions and configuring tools in advance) and monitoring.

The FRAME model helped to design the course for effective mobile learning. Wong's 10-D MSL framework supported the incorporation of strategies for seamless learning. Following Chan et al.'s (2006) definition of seamless learning, learners participating in this course were active (they regulated their learning and engaged in the activities), productive (they produced several learning artefacts), creative (they delivered assignments in diverse formats) and collaborative (they worked in pairs, groups and whole class activities) across different environments and settings (they did activities using various digital technologies and media and interfaced in virtual and face-to-face environments).

Weaknesses of the course design include technical issues, a perceived lack of meaningfulness in some activities, underutilisation of social affordances, time constraints, excessive workload, and monitoring issues. Nordmark (2018) found that time management was a key concern for teachers using MSL. Strengths lie in the improvement of students' digital skills (capacity to use devices and tools effectively and creatively), teacher support and feedback (feedback, knowledge of the subject, solving doubts, support, attitude) and the design (types of activities, resources, opportunity to work in groups, ubiquitous learning). Although students highly appreciated the teaching delivery format , it worth considering that it was the only way to continue learning during the lockdown. Additionally, students' traditional approach to learning may hinder them from fully realising the advantages of MSL for social, informal, and connected learning.

In summary, recommendations for adopting MSL based on the course redesign results are:

1. Consider learners, devices, and social aspects in course design,
2. Measure the extra effort of students and teachers,
3. Ensure students have the necessary digital skills,
4. Include strategies to connect informal and formal contexts,
5. Design activities with diverse complexity and delivery formats,

6. Incorporate multiple formats for presenting information,
7. Plan specific instructions for social network use,
8. Prepare and share necessary instructions in advance,
9. Reinforce teaching presence with mandatory synchronous communication slots, provide qualitative assessment, and define feedback strategies for learning.

Given the small sample of 10/11 participants, the research should be seen as exploratory and the quantitative patterns need to be treated as indicative trends which should be verified through qualitative evidence. The research will in future expand to multiple sites through longitudinal and quasi-experimental study designs which will use behavioural data and independent observer assessments to achieve more stable results. To enhance methodological rigour, researchers may triangulate self-reported data with learning analytics or observational data generated by digital tools

Conclusions

This study evaluated the implementation of Mobile Seamless Learning (MSL) in distance education, exploring its impact on flexible learning, the effectiveness of mobile devices for learning, and the design of didactic sequences for collaborative and social learning.

The findings reveal that MSL enhances flexible learning, with mobile devices playing a key role in the learning process despite less extensive use than expected. MSL proved effective for collaborative and social learning, although there is room to improve social interaction through social networks. This study evaluated the implementation of MSL in a higher education distance learning context, focusing on its impact on flexible learning, the role of mobile devices in the educational process, and the design of collaborative and social learning activities. The findings indicate that MSL enhances learner flexibility and autonomy, supporting active and meaningful learning experiences, which is consistent with Wong's (2012) 10-Dimension MSL framework and aligns with earlier research emphasising the integration of formal and informal learning environments (Ulfa et al., 2020; Baharun et al., 2021).

Mobile devices, particularly smartphones and laptops, played a crucial role in facilitating various learning tasks. However,their usage patterns often deviated from expectations, as students preferred laptops for more complex activities. This finding is consistent with previous research demonstrating the complementary roles of mobile and traditional devices in education (Krull & Duart, 2017; Wong, 2012). Additionally, the social affordances of digital tools were underutilised, indicating a need for improved scaffolding and guidance to maximize student engagement in collaborative activities (Firssova et al., 2020; Safiah et al., 2020).

The results underscore the importance of thoughtful instructional design in addressing technical and organizational challenges, consistent with findings by Nordmark (2018). A well-structured course design was the primary determinant of positive learning outcomes, effectively mitigating challenges such as time management difficulties and

technical issues. While the teaching approach provided flexibility and autonomy, further emphasis on connecting formal and informal learning contexts could deepen engagement and enhance the seamless nature of learning experiences (Yetik et al., 2020).

From a pedagogical perspective, the findings align with Chan et al.'s (2006) framework for one-to-one technology-enhanced learning, thereby reinforcing the value of personalised, learner-centred approaches. However, the additional preparatory efforts required for implementing MSL, including tool configuration and activity design, remain a significant consideration for educators. Moreover, fostering social interaction among students remains challenging, requiring targeted strategies to enhance collaboration and knowledge sharing, particularly in asynchronous learning environments (Amhag, 2017; Hamid et al., 2019).

This study contributes to the growing literature on MSL, offering practical insights for educators and course designers, but some limitations should be noted. The research studied 11 participants as a convenience sample, and outcomes were predominantly self-reported. Future research should investigate the application of MSL in larger, more heterogeneous student populations and explore its adaptation in face-to-face educational contexts. Longitudinal studies are also needed to assess the sustained impact of MSL on learner outcomes over time (Baharun et al., 2021). Behavioural logs and artefact-based assessment should also be implemented. These steps will create an improved assessment method to evaluate effectiveness while showing the specific mechanisms through which the approach delivers results for particular groups of people.

In summary, this research highlights MSL's transformative potential in higher education while identifying critical areas for refinement. Beyond these findings, the study also demonstrates how flexible learning designs contribute to educational resilience in the face of uncertainty, aligning with current priorities in designing robust flexible models.

It is becoming increasingly evident that addressing the challenges associated with time management, social interaction, and technological integration is crucial in fully leveraging MSL as a framework for flexible, connected and learner-centred education in online and hybrid learning environments.

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