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Impact of active methodologies on the digital competencies of elderly

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It is essential to develop digital skills in the demographic group represented by elderly once digital exclusion becomes a growing concern in an increasingly technological world. This study aims to evaluate the effectiveness of flipped classrooms and microlearning on the digital literacy of adults over 50 years through a virtual course. With the implementation of a descriptive, correlational, and longitudinal approach, the research considered six consecutive two-month periods, ranging from elemental to advanced levels of expanding their digital skills. The final sample included 112 Mexican participants (93 women and 19 men) with a mean age of 64.30 years and an average schooling of 13.6 years. The results reveal that participants' satisfaction with the pedagogical approaches is positively associated with developing their digital skills and increasing their confidence to apply them. Altogether, these findings highlight how a structured learning environment, combined with emotional support and active practice, not only facilitates the acquisition of technology skills but also empowers older people, enabling them to approach the digital world with confidence. In conclusion, this study emphasizes the importance of implementing pedagogical approaches that address the specific needs of elderly, promoting their digital inclusion and the development of their autonomy in the use of technology.

KEYWORDS

digital inclusion, elderly, flipped classroom, digital skills, online education, technology confidence

1 Introduction

Access to the internet and digital devices such as computers and cell phones has been universalized, allowing more people to participate in the digital economy and access online services. Even though this digitalization provides new opportunities to manage daily activities, it also has challenges like the need to adapt continuously to technological advances and develop digital abilities. However, not all the population sectors have experienced this process equally. On one hand, the young are immersed in technology from an early age, so they acquire digital competencies intuitively. On the other hand, other groups, such as elderly and those with less educational and economic resources, face meaningful barriers to mastering these tools (Blažič and Blažič, 2020; Mubarak and Suomi, 2022).

Diverse investigations have identified multiple obstacles that complicate how elderly access digital technologies, including psychological (Paul et al., 2023), socioeconomic, cultural (Gomez-Hernandez et al., 2022), and health factors (Tomczyk et al., 2023), besides the lack of suitable infrastructure or willingness to learn (Holgersson and Söderström, 2019). These difficulties contribute to preserving the so-called digital divide that not only refers to the diversity of access to technological resources but also the needed ability to use them effectively. Recent studies such as Mubarak and Suomi (2022) and Marimuthu et al. (2022) have shown that this divide persists and is getting deeper, unreasonably affecting elderly.

The theory of the digital divide has two main stages. The first is related to the trouble with access to information and communication technologies (ICT), a situation that has been considered mainly through accessibility policies. Nevertheless, once the access has improved, a second stage has emerged, known as "the second digital divide," which focuses on the capacity to use available technologies effectively. In this stage, the digital generational divide is more evident (Hunsaker and Hargittai, 2018; Hargittai et al., 2019).

On one side, there are "digital natives" people who have grown up in an entirely technological environment, and they are characterized by the development of multitasking abilities, preferential to visual language instead of textual one. On the other side, "digital immigrants" are the people who have had to adapt to the digital world in the later stages of their lives (Kesharwani, 2020). Notwithstanding, many of them have been able to integrate into this, and they are sub-estimated due to the technological lack of their generation, which complicates the second digital divide.

This growth in the digital divide is because of the new applications and digital content that require advanced digitized abilities that are not fully accessible to everyone. Although access to ICT has enriched, the lack of adequate training in digital competencies limits the capacity of many people to entirely take advantage of these technologies, participate in the digital economy, and access online services. As a result, the absence of digital competencies entrench the digital divide, particularly among elderly and other vulnerable groups.

It is essential to recognize that elderly require a long adaptation period to familiarize themselves with digital technologies. They often need to ask multiple questions, repeat concepts, and have a sense of belonging and utility to comprehend the basic digital abilities fully (Martínez-Alcalá et al., 2021; Mubarak and Suomi, 2022). Therefore, it is relevant to guarantee that elderly can access accessible educational and sustainable programs designed to reduce the digital divide that disproportionately influences this group (Mubarak and Nycyk, 2017; Carney and Kandt, 2022). According to UNESCO, digital literacy covers competencies, for instance, access, management, understanding, creation, and evaluation of information through digital technologies, and it is a vital part of closing this divide (Law et al., 2018). Digital literacy not only must focus on using tools and programs, but also on creating a digital identity and the capacity to use the technological resources regularly and meaningfully (Leaning, 2019).

It is fundamental to adopt an integral approach to digital literacy that allows people to develop the necessary abilities to use technology effectively. Moreover, considering the diverse capacities and learning paces of each person. It is vital to guarantee equal digital inclusion and decrease the digital divide in a more interconnected society.

1.1 New pedagogical approaches: flipped classroom and microlearning

In the present educational sector, in which technology and access to information have profoundly revolutionized traditional methodologies, it results from the need to research innovative pedagogical approaches. This section concentrates on two of these methodologies, such as flipped classroom and microlearning, analyzing how they can foster learning and the participation of this age group.

In the last decade, an emergent approach that has gained recognition is the flipped classroom, a methodology highly encouraged due to its capacity to transform learning dynamics and place the student in the center of the educational process. This approach has become popular in distinct educational sectors for its potential to elevate academic results and its adaptability to different audiences (Strelan et al., 2020), including elderly who require more specific methodologies to achieve effective learning.

A flipped classroom encompasses the idea that students must review the theoretical lessons at home through videos or online materials, and later, they dedicate time in class to practical activities or discussions (Goedhart et al., 2019). This method facilitates that students can learn at their own pace since its flexibility of checking the material as many times as needed before participating in synchronic classes (Zainuddin, 2018). It is particularly significant in the case of elderly over 50 years old, who frequently require more time to assimilate recent content because of the differences in learning paces compared to young students.

Distinct investigations have evidenced that flipped classrooms have a meaningful effect on academic results (Strelan et al., 2020). Additionally, it has autonomy (Yoon et al., 2020; Challob, 2021), motivation (Zainuddin and Perera, 2019; Debbag and Yildiz, 2021), knowledge retention (Tutal and Yazar, 2021; Förster et al., 2022), and autoregulation abilities (Shyr and Chen, 2018; Nacaroğlu and Bektaş, 2023) in diverse educational contexts. Furthermore, a flipped classroom prompts active learning in which students are responsible for their progress, following the principles of andragogy that emphasize the importance of self-direction in elderly adults' learning. Allow for the possibility of materials that develop autonomy before joining the synchronic sessions, and old students can ask more reflexive questions and participate in more enriching debates. What is more, this preparation allows them to comprehend better the content and contribute ideas and unique perspectives during the sessions, which ameliorate the learning experiences for everyone. In this sense, the mentor changes its role from the only source of knowledge to a facilitator who guides, clarifies doubts, and offers personalized feedback, improving the quality of learning.

Referring to microlearning, known as "learning in small chunks," has emerged as a significant tendency in current education. It is characterized by offering educational content in brief fragments, which lets students assimilate the information effectively. This approach, as defined by Kapp and Defelice (2019) and Reinhardt and Elwood (2019), consists of instructive units that foster active participation and concise activities designed to reach the specific learning objectives (Fidan, 2023). Similarly, microlearning has favorably impacted the student's motivation (Sozmen et al., 2021). Since the information is shown in a more accessible and attractive way, it reduces information overload, which allows students to concentrate

on their learning and maintain their interest in a long educational process. Reducing the amount of information that students must process, this approach prompts a manageable learning experience and is less overwhelming (Kossen and Ooi, 2021). Recent investigations have proved that microlearning not only increases the participation of the students (Manning et al., 2021) but also upgrades their self-regulation abilities (Shamir-Inbal and Blau, 2020) and academic results (Nikou and Economides, 2018). These findings are predominantly relevant to elderly who can benefit from a learning approach that respects their pace and learning style.

Concerning flipped classroom and microlearning, both approaches encourage a more inclusive and motivating learning environment. Not only do they make the learning process more accessible and attractive, but they also combine the flexibility of microlearning with the active responsibility of a flipped classroom, prompting better participation and motivation on behalf of the students.

Despite the demonstrated benefits of the flipped classrooms and microlearning in educational settings, there is a notable paucity of literature analyzing their application in elderly adults' learning. Most studies have focused on the effectiveness of these methodologies in younger groups, where the results have been largely positive. This divide in research represents both a challenge and an opportunity to understand better how these techniques can be adapted and effectively applied to enhance digital literacy in elderly. It is critical to explore and validate these approaches in a context specific to this demographic, as it is not only about adjusting methodologies but also about creating an inclusive environment that allows older adults to fully access technological advances and enhance their digital competencies.

In this context, the main goal of this study is to evaluate how a flipped classroom and microlearning contribute to digital literacy in elderly through the online training. Among the specific objectives, it analyzes the impact of a flipped classroom in developing digitized competencies in this age group, assessing the effectiveness of microlearning in retention and applying digital skills in their daily lives. Likewise, the participants' individual experiences are searched. In addition, their perceptions about how these competencies influence their daily routine and independence sense. To conclude, a satisfaction survey is attached to have the participants' opinions about the approaches used in the courses.

2 Materials and methodologies

2.1 Study design

The research design was descriptive, correlational, longitudinal, and suitable to evaluate the effectiveness of virtual classroom and microlearning approaches implemented in a literacy program directed to people over 50 years old. The descriptive approach allowed for recollecting and analyzing both quantitative and qualitative data about features, experiences, and acquisition of digital abilities during the different stages of the course. Moreover, the design is correlational since it looks to identify the possible relations among the implied variables, including the level of digital literacy, level of confidence, and effectiveness of the approaches like a flipped classroom and microlearning.

To sum up, a longitudinal perspective was considered since the participants of the groups were active throughout six consecutive two-month periods taking the following levels: *Digital Abilities 1 (June–August 2022), Digital Abilities 2 (September–November 2022), Digital Competences 1 (February–April 2023), Digital Competences 2 (June–August 2023), Digital Competences 3 (September–November 2023), and Digital Competences 4 (February–April 2024)*. This longitudinal approach allowed us to observe the evolution of digital competencies from the participants over time and in distinct moments of their training (Figure 1).

2.2 Participants

Initially, the study included 157 Mexican participants over 50 years old. Nevertheless, there was a dropout rate of 28.66%, so the final sample consisted of 112 elderly people who participated in a

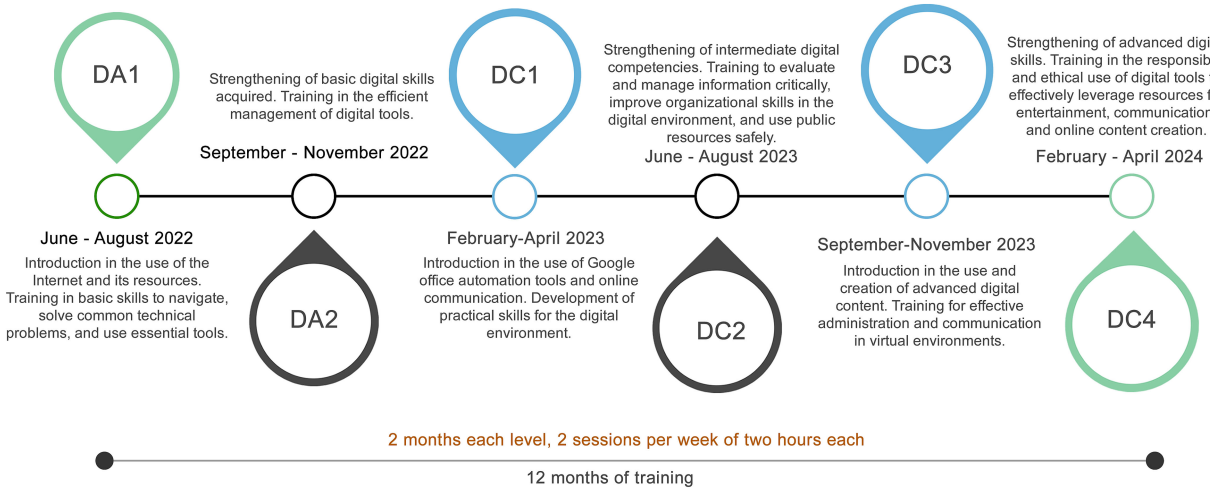

FIGURE 1
Program levels and longitudinal perspective. A sequential learning structure is illustrated, ranging from basic to advanced digital skills.

training virtual course on digital literacy. The average age of the participants was 64.21 years. The gender distribution was 93 women and 19 men. The average educational level of the participants was 13.6 years, which reflects an intermediate academic level within high school education and university studies (Table 1).

The sample selection was not probabilistic, based on the availability of the participants to integrate themselves into the course, answer questionnaires, and participate in interviews. What defined the admission criteria was to ensure that the participants demonstrated their willingness to participate actively, facilitating their adaptation and learning to digital tools. Furthermore, each participant needed to have access to a digital device. For example, a computer, laptop, or tablet and a stable internet connection guarantee their effective participation in synchronic sessions and proposed activities.

For the organization of the participants, there were eight groups with 14 and 15 members each. All the participants were Mexican. Before beginning the courses, there was an explanation of the purpose of the study to the participants and obtaining digital informed consent. It is vital to highlight that all the members were independent, which means that others did not need to sign for them or intervene during the process.

2.3 Pedagogical approaches and program structure

2.3.1 Program levels

The digital literacy program was composed of six consecutive levels: *Digital Abilities 1 (DA1), Digital Abilities 2 (DA2), Digital Competencies 1 (DC1), Digital Competencies 2 (DC2), Digital Competencies 3 (DC3), and Digital Competencies 4 (DC4)*. Each level lasted 2 months, with two sessions per week of two hours each, adding 12 months of training. Eight groups started simultaneously, each one with the support of two trained instructors specialized in gerontology and digital competencies.

2.3.2 Pedagogical approaches

The program had its basis on two principal pedagogical approaches: a flipped classroom and microlearning, which were implemented complementarity to maximize the participants' learning effectiveness (Figure 2).

2.3.2.1 Before the session: flipped classroom preparation

Prerecorded materials included theoretical videos of 5 min and practical videos from 10 to 15 min were distributed through the application of WhatsApp instant messaging. These resources were designed with a micro-learning approach, providing brief, clear, and specific content facilitating autonomous assimilation. The video links were shared 48 h before the session started, letting participants study at their own pace and at the most suitable moment. Microlearning was applied as an essential complement to a flipped classroom, emphasizing the acquisition of chunks of content. Each video was designed to embrace a particular topic consistently, guaranteeing that participants could assimilate information without feeling overwhelmed by the quantity of the content. Additionally, focusing on practical resources and illustrating the procedures or configurations that participants must apply in real situations leads to the transference of acquired knowledge to their daily practice.

2.3.2.2 During the session: interactive and practical learning

Synchronic sessions took place through the platform video conferences Zoom and were structured into three elemental parts to maximize interactivity and practical learning:

- *Start-up activity:* Each session begins with a ludic activity or an integration game designed to foster beneficial interaction and prompt the relationships among the participants. Formerly, there was brainstorming about the concepts that would be part of the session based on the content of the previously checked videos.
- *Development activity:* In this stage, one of the instructors practically demonstrated the procedures and configurations

TABLE 1 Socio-demographic characteristics of the participants.

		Frequency	Percentage	Mean
Gender	Women	93	83.04%	
	Men	19	16.96%	
	Total	112	100%	64.75
Schooling level	Primary	5	4.46%	
	Secondary Education	20	17.86%	
	Higher Secondary Education	13	11.61%	
	Technical	13	11.61%	
	University	56	50%	
	Master's degree	4	3.57%	
	Specialty	1	0.89%	
	Min	Max	Mean	SD
	6	18	13.6	3.33
Age	Min	Max	Mean	SD
	54 years	81 years	64.21	5.43

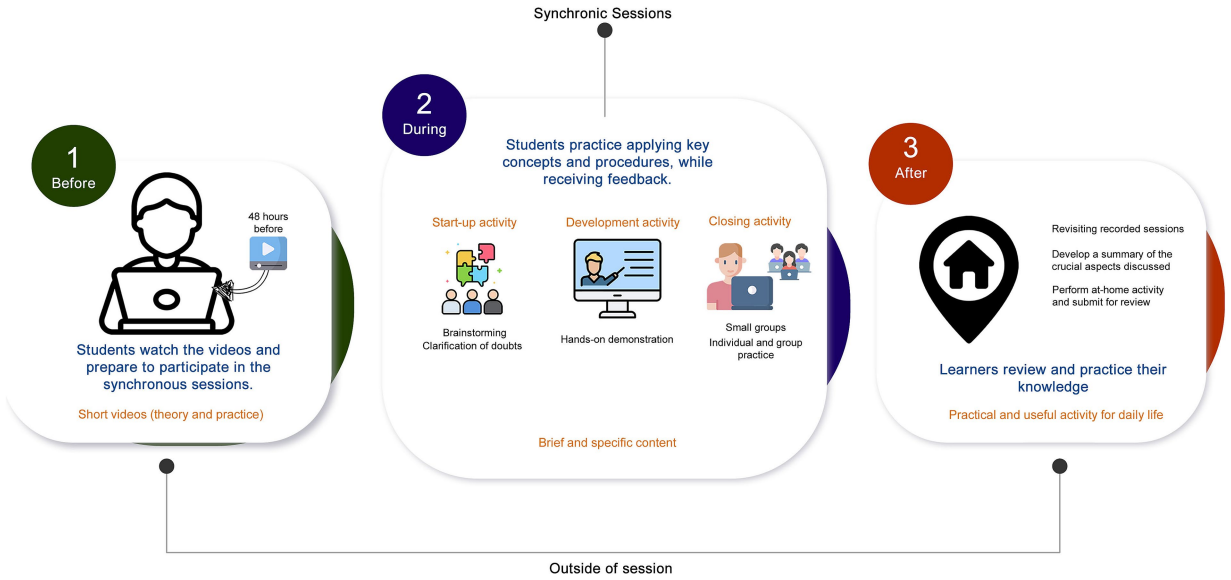

FIGURE 2
Pedagogical approaches implemented (flipped classroom and microlearning). The pedagogical strategy is structured in three phases: prior preparation with brief content, synchronous guided practice session, and subsequent application in practical activities to reinforce learning.

explained in the videos. This activity was essential to reinforce the practical processes and provide a detailed visual guide about the actions carried out by the participants.

- *Closing activity:* During the last part of the session, the instructors organized the participants into small groups to share their screens and practice what they had learned. Each instructor was in charge of a reduced group of approximately seven participants, facilitating greater participation and personalized attention. The instructors were available to solve doubts, respecting the individual pace of each participant. At the end of the session, the participants had to elaborate a summary of the crucial aspects discussed, and there was time to ask and answer questions, clarifying any possible doubts.

2.3.2.3 After the session: reflection and knowledge consolidation

After each session, participants reviewed and consolidated their understanding by revisiting recorded sessions, summarizing the crucial issues discussed, and practicing on their own. The microlearning approach remained integral, ensuring that brief, focused content reinforced retention and encouraged continuous, self-paced learning.

It is relevant to highlight that the microlearning approach was constantly integrated into all the synchronic sessions, ensuring that brief and specific contents promoted knowledge retention and encouraged autonomous and progressive learning among the participants.

2.4 Instruments

2.4.1 Pre and post evaluations

- *Satisfaction survey of the approaches:* this questionnaire was designed to evaluate the participants' perception of pedagogical methodologies used in the course. It was applied at the end of the course to each level, letting pick information about the general satisfaction and effectiveness perceived of the applied methods. The questionnaire utilized a Likert scale, containing aspects of "Very unsatisfied" to "Very satisfied."
  - Very dissatisfied: The approaches did not meet my expectations. Also, they were not beneficial for my learning or development.
  - Dissatisfied: The approaches had some positive aspects, but I generally did not find them satisfactory or efficient.
  - Neutral: The approaches were adequate but did not excel in effectiveness or usefulness to my learning.
  - Satisfied: The approaches met my expectations and were valuable for learning and development.
  - Very satisfied: The approaches exceeded my expectations and were extremely useful and productive for my learning and development.
- *Self-evaluation questionnaire about confidence:* This instrument measures the confidence of the participants while using digital tools, such as the Internet, e-mail, social networks, word processors, applications in the networks, and virtual meetings. In addition, it can solve technical issues. The same as the DigCom that was applied during the pre and post-intervention moments. It is classified into four categories according to the score obtained:
  - 35–70: Low confidence
  - 71–105: Moderated confidence
  - 106–140: High confidence
  - 141–175: Very high confidence
- *DigCom Questionnaire:* this questionnaire measures the level of digital competencies of the participants based on the study of DigCom. It was applied at two points in time: before and after the intervention, which allowed for a comparison of participants' progress. The results were classified into four categories according to the score obtained in the test:

- 0 to 6 points: There are no digital abilities
- 7 to 14 points: Basic digital abilities
- 15 to 22 points: Intermediate abilities
- 23 to 30 points: Advanced abilities

- *Interviews:* Open interviews were carried out individually once the 12 months of the program had finished. Each interview lasted from 30 to 45 min. These sessions used video callings, which were recorded for their later qualitative analysis. The interviews were structured based on essential questions that show the participants' individual experiences, their perception of their learning process, and the challenges faced throughout the course.

These instruments enable us to have an integral vision of the impact of the flipped classrooms and microlearning approaches on the digital literacy of participants older than 50, advancing the evaluation of the program's effectiveness.

2.5 Statistical analysis

It considered a longitudinal perspective to evaluate the effectiveness of the approaches. Pearson's correlation analysis was used to determine the linear relationship between two variables, such as satisfaction with applied approaches and level of digital competence and satisfaction with applied approaches and confidence levels; age and level of digital competence; and years of schooling and level of digital competence. At the same time, contrasting pre-and post-digital competency scores. Furthermore, comparisons were made based on Student's *t*-tests for dependent samples, contrasting the pre-pre and post-post scores in the six consecutive levels of competence.

Regarding the qualitative analysis, a thematic analysis was adopted in which the interviews conducted with the participants were transcribed and coded, looking for recurrent patterns and vital themes. This process allowed us to explore in depth how the pedagogical approaches influenced their learning and how these experiences were connected to their levels of digital competence, providing a comprehensive view of the results of the intervention.

3 Results

3.1 Relationship between satisfaction with the approaches and digital competencies

A strong and significant positive correlation was found between the post scores of satisfaction with approaches (flipped classroom and microlearning) and the level of digital competencies ($r = 0.7538$, $p < 0.001$). This finding indicates that both the flipped classroom and the microlearning contribute significantly to the digital literacy of older people.

Figure 3A shows the relationship between the level of digital skills and satisfaction with the approaches used for post-intervention. Therefore, we can observe an upward trend and a general pattern, which suggests that participants with more advanced digital competencies (on the right of the X-axis) achieve higher satisfaction levels (at the top of the *Y*-axis).

3.2 Relationship between satisfaction with the approaches and levels of confidence

The results show a moderate and significant positive correlation between the post-satisfaction results with the pedagogical approaches implemented and the participants' confidence levels ($r = 0.6210$, $p < 0.001$). This correlation indicates that participants who perceived these pedagogical approaches as effective also reported gaining confidence to apply the digital skills acquired in practical contexts.

Figure 3B presents the relationship between confidence levels while using digital tools and satisfaction with the approaches used. It is possible to observe an upward trend. Most points on satisfaction levels of 4 to 5 and confidence values of around 73 (moderate confidence) to 130 (high confidence). Some isolated points in lower satisfaction levels (3 points) indicate that despite having a positive trend, not all participants with high confidence levels in digital tools reported high satisfaction. On the contrary, they were neutral. These cases represent 3.57% of the participants, a non-elevated percentage.

3.3 Relationship between levels of digital competencies and levels of confidence

When analyzing the results of the digital skills post and the confidence levels post, a moderate-high, and statistically significant positive correlation was found ($r = 0.6756$, $p < 0.001$). It indicates that as participants improve their digital skills, their self-confidence in using technological tools also increases.

Figure 3C shows the relationship between the levels of digital skills acquired and the participants' confidence levels. The data distribution reflects that participants with intermediate and high levels of digital competence tend to manifest higher confidence levels. The trend line present in the graph confirms this upward relationship. It is worth noting that some isolated points represent participants with high levels of digital competence but with more varied levels of confidence, or vice versa.

It is relevant to note that the effectiveness of the approaches applied to develop digital competencies in older people may be affected by additional factors such as age and schooling. Hence, we analyze this relationship to understand how these factors impact the development of digital competencies, which is crucial for designing inclusive and effective training programs.

3.4 Relationship between age, years of schooling, and level of digital competencies

It distinguishes a moderate negative correlation between the age of the participants and their level of digital competencies ($r = -0.3928$). It indicates that although age is a factor to consider, it does not entirely determine the ability to learn and use digital tools. Among participants over 65 years, 52% managed to improve their digital skills to an intermediate level, and 6% advanced even to an advanced level. These results highlight that, whereas age can present unquestionable challenges in acquiring digital skills, an appropriate

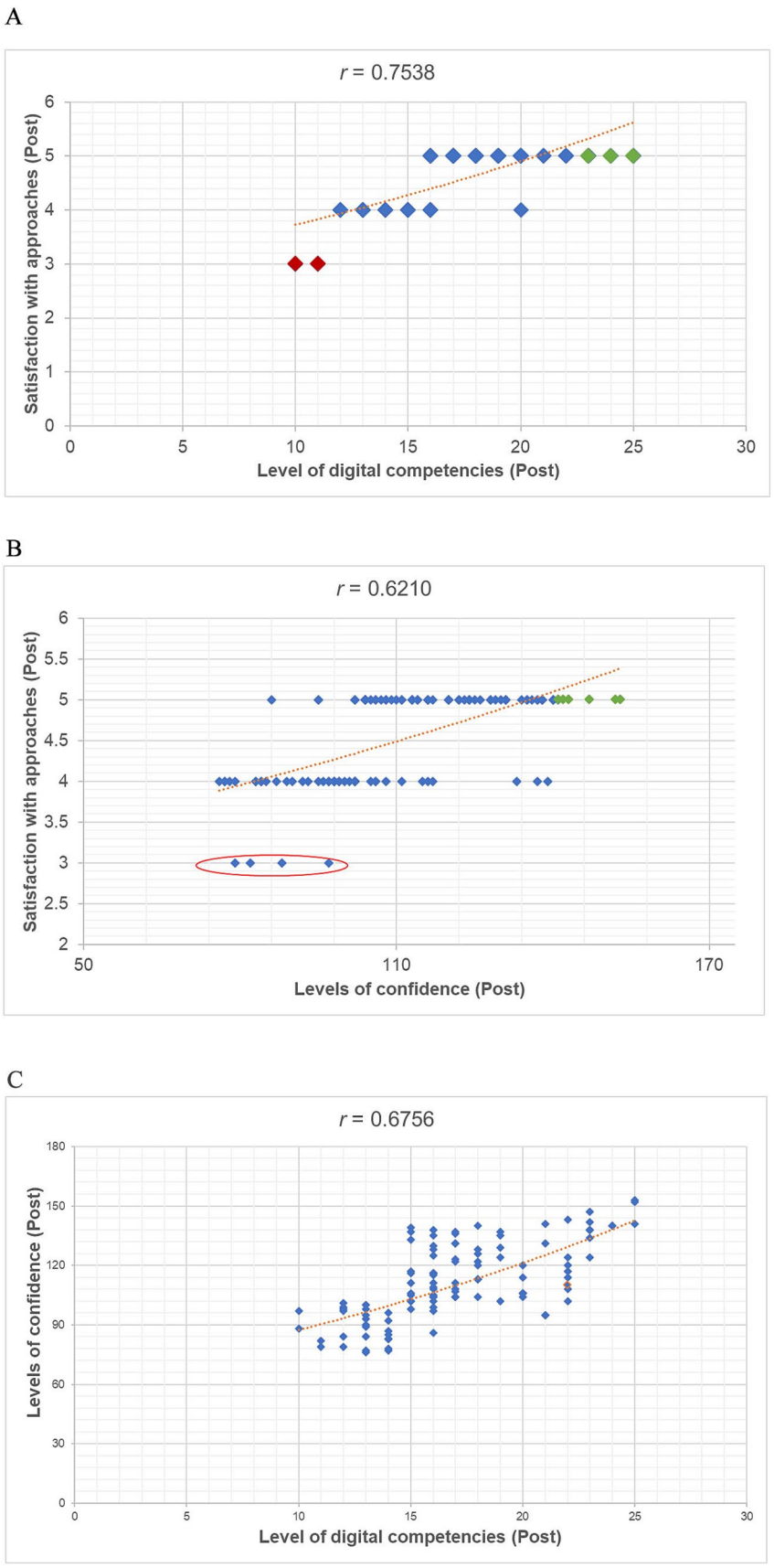

FIGURE 3
(A) Shows the relationship between satisfaction with the implemented approaches and digital competencies (r = 0.7538). **(B)** Shows the relationship between satisfaction with the approaches and participants' confidence levels (r = 0.6210). Finally, **(C)** shows the relationship between levels of digital competencies and confidence (r = 0.6756). In each graph, a positive correlation is observed, indicating that higher digital competencies and confidence levels are associated with greater satisfaction with the approaches employed in the program.

approach adapted to the learning needs of this age group allows participants to experience significant improvements (Figure 4).

The results reveal a moderate and statistically significant positive correlation between participants' years of schooling and their level of digital competencies ($r = 0.6174$, $p < 0.001$). It indicates that years of education have an approving influence on digital competencies level, but it is not the only factor. While people with more years of schooling tend to have higher digital skills, we also observed that participants with less schooling could reach intermediate and advanced levels, suggesting other factors. For example, pedagogical approaches play a significant role in the development of their skills (Figure 5).

3.5 Enhancing digital competencies

The data indicate that basic digital skills significantly increased after the intervention. Initially, the pre-level DA1 mean was 1.67, a relatively low figure suggesting a low level of digital skills. Subsequently, the mean rose to 4 in the first post-assessment (DA1)

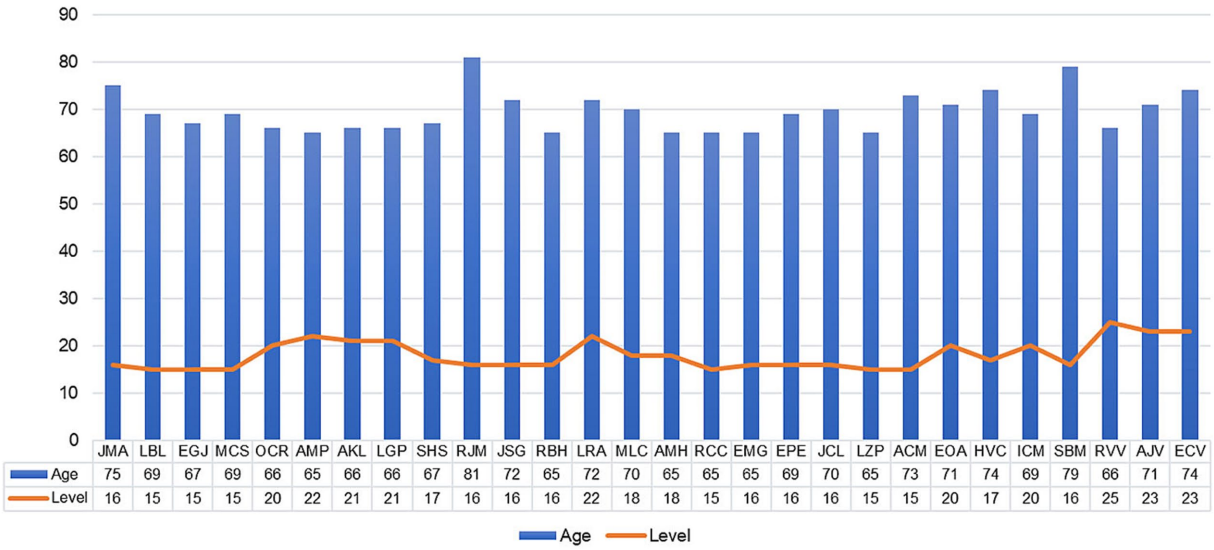

FIGURE 4
Relationship between age and level of digital competencies in participants over 65 years of age.

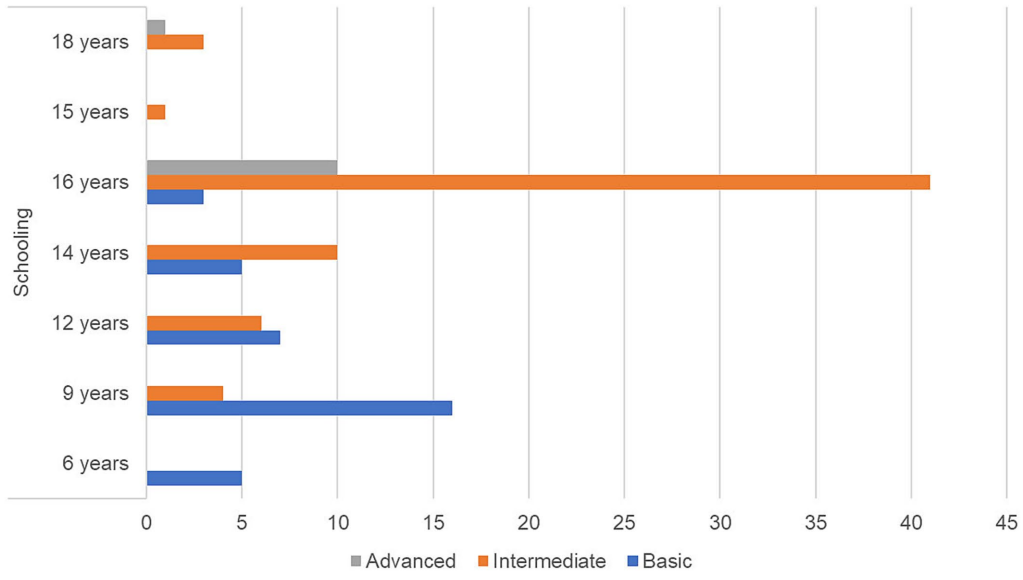

FIGURE 5
Relationship between years of schooling and level of digital competencies. It shows how the number of years of schooling is associated with different levels of digital competencies, highlighting that those with more schooling tend to reach intermediate and advanced levels compared to those with less schooling.

and reached 6.04 in the second post-assessment (DA2), reflecting a considerable change in the digital skills acquired by the participants. This progressive increase is a sign of continuous learning and reinforcement of digital competencies as the intervention progresses.

For intermediate digital competencies, the data show an even more marked improvement. The pre-DC1 level mean was 6.04. After the intervention, the mean increased to 10 at the first post-assessment (DC1) and 13.13 at the second post-assessment (DC2). This pattern of increase indicates that participants not only improved their competencies but also continued to develop them between the two post-assessment evaluation phases.

In regards to advanced digital competencies, the results show a more modest increase compared to the other levels. The pre-level DC2 mean was 13.13, while the post-assessment (DC2) mean stood at 14.54 and the latter at 16.84. Even though these values suggest some progression, the increase in advanced competencies is less pronounced. Consequently, it could imply that the intervention was less effective in developing advanced skills, which may insinuate the involvement of other factors (Figure 6).

Table 2 presents the difference between the means (Pre) and means (Post) of 6 consecutive levels:

- *Basic digital competencies:* Significant improvement ($t = 0.0422$), indicating a statistically significant difference ($p < 0.05$) between pre-and post-intervention means.
- *Intermediate digital competencies:* Representative increase ($t = 0.0134$), supporting the effectiveness of the intervention.
- *Advanced digital skills:* No meaningful change ($t = 0.1499$) does not reach statistical significance ($p > 0.05$), indicating that the slight increase in advanced skills could be due to external factors or random variation without a conclusive effect of the intervention.

3.6 Qualitative analysis of participant interviews

3.6.1 Participants' perception

Through the implementation of quantitative analysis of the interviews carried out with the participants, four crucial categories reflect the perceptions about the impact of the flipped classrooms and microlearning approaches in their learning process. These categories are: *Satisfaction with course approaches and structure, Continued practice and application of knowledge, Increased autonomy and confidence, and Appreciation of emotional support and community*. Hereunder, the findings for each category are described in detail (Figure 7).

3.6.1.1 Satisfaction with the approaches and course structure

Most of the course participants expressed great satisfaction with the flipped classroom and microlearning approaches, highlighting that being in advance prepared for the sessions improved their understanding and use of the content during the synchronous sessions. In particular, participants emphasized the early delivery of materials and videos, which allowed them to adequately prepare and attend the synchronous sessions with greater confidence and familiarity with the topics. This preparation, typical of a flipped classroom approach, was especially appreciated because it optimizes class time and provides the opportunity to ask questions and delve deeper into more complex concepts.

> *With the previously sent videos, I feel that I have a better idea of what the class will be about. As a result, I can follow it at a better pace. RAN, a woman of 60 years-old.*
>
> *I liked receiving the videos of the topics beforehand. Also, they were short and very complete. MRA, 75-year-old woman.*

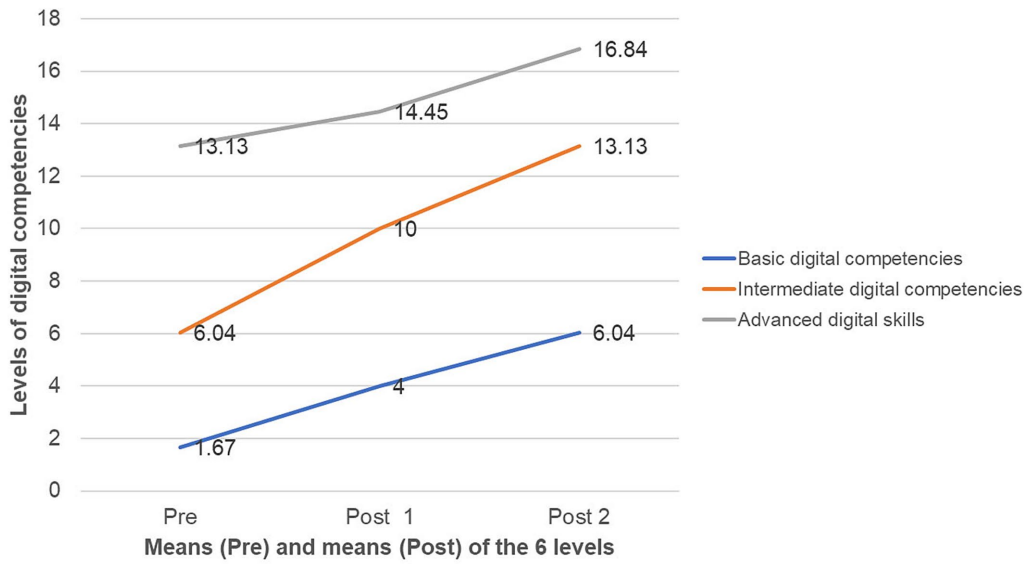

FIGURE 6
Progression of digital competencies in the different levels of intervention.

TABLE 2 Student's *t*-test results comparing pre-and post-intervention levels of digital competencies across basic, intermediate, and advanced skill levels.

	Pre DA1	Pre DA2	Post DA1	Post DA2
Mean	1.67	4	4	6.04
t	0.0422			
	Pre DC1	Pre DC2	Post DC1	Post DC2
Mean	6.04	9	10	13.13
t	0.0134			
	Pre DC3	Pre DC4	Post DC3	Post DC4
Mean	13.13	14.54	14.54	16.84
t	0.1499			

> *It is very beneficial to pause and roll back to the videos when I do not understand something. It allows assimilating the information little by little. ACM, a 72-year-old man.*

This flexibility is a core aspect that reinforces the autonomy of the elderly, allowing each individual to adapt the content to their personal needs and preferences. As can be seen, the comments demonstrate that the flipped classroom approach contributed to more proactive and efficient learning.

The aspects highly valued by the participants were the organization and structure of the course since the delivery of easily accessible and quick review materials contributed to reducing stress and making the learning process a more accessible experience. Moreover, the synchronous session structure not only allowed them to learn actively but also to experience an environment of support and individualized attention, which made it easier for them to understand the topics and gave them more confidence in practicing their skills.

> *The best thing was having the videos in a short format. It allowed me to see all the content in a reasonable amount of time without feeling like I was falling behind. This format helped me get much more out of the course content. MNM, 60-year-old female.*
>
> *The course has been very unlike others I have taken. I believe that having the videos and material beforehand and in a brief format gave me so much confidence. In addition, it allowed me not only to learn but also to enjoy the process because I could know what I would see in the session and review as many times as necessary. MLG, 72-year-old female.*
>
> *I consider it valuable to review the topics and watch the videos previously because I can review them several times if I need to, and it does not feel too hard. TOL, 64 year old female.*

Accordingly, the flipped classroom approach and the microlearning structure implemented in the digital literacy program proved their effectiveness in promoting meaningful and satisfying learning among the participants, who especially valued the brevity and flexibility of the materials.

3.6.1.2 Continuous practice and use of knowledge

A fundamental aspect that emerged during the interviews was the importance of continuous practice in the learning process. The participants expressed that the opportunity to practice in class with the visual materials permitted them to reinforce what they had learned in real-time in a controlled and guided environment. Similarly, it was a chance to experience digital tools without worrying about making mistakes. The comments reflected a clear understanding that active practice both reinforces knowledge and acts as a catalyst to develop practical abilities.

> *I liked to put into practice what I learned in each session, and it helped me feel that I was moving forward. AMP is a woman of 65 years.*
>
> *At first, I was afraid of making mistakes, but thanks to my instructors, their teaching methods, and practice, I feel more confident and can do things I did not dare to do before, like making video calls or handling programs I did not know formerly. LCZ, a 65-year-old woman.*
>
> *His way of guiding us through the practices made me confident that I can do it, sometimes it is frustrating not to remember the steps, but by practicing, I feel that the knowledge is sticking, and now I can look things up on the internet, use Drive and do online meetings. EMZ, 58-year-old female.*

As can be seen, for many participants, this active practice represented both an improvement in their technical skills and a significant change in how they perceive technology and their learning process. Altogether, participants commented that having a safe space to practice allowed them to make mistakes without fear and that this trial-and-error dynamic in a supportive environment made it easier for elderly to transform mistakes into learning opportunities. Importantly, by breaking down the information into specific steps and accompanying it with a visual guide (development and closing activity), participants assimilate the content without feeling overwhelmed, focusing on one task at a time and applying the knowledge in an interactive and collaborative environment. This perception highlights the effectiveness of the microlearning methodology, which allows for reducing the cognitive load and maintaining the participants' interest.

3.6.1.3 Gain in autonomy and confidence

Another recurrent pattern was the gain in confidence and autonomy of the participants who used technology. Throughout the interviews, there was evidence that many experienced a meaningful change in their perception of digital tools. Their confidence was significantly enhanced when they had to surf the internet, use applications, and solve technological issues. A critical aspect of this process was the emphatic and patient environment provided by the instructors, who were essential elements in building this confidence.

> *I am thankful for being with you and learning since I did not know how to use the computer, and now I use it without being afraid of breaking it down. Thanks to all the instructors for what we learned. Thanks for the material, the videos, and the constant practice. MST is a woman of 63 years.*
>
> *So now I can prove the saying that it is never too late to learn. Despite my fears and apprehensions, this course made me more*

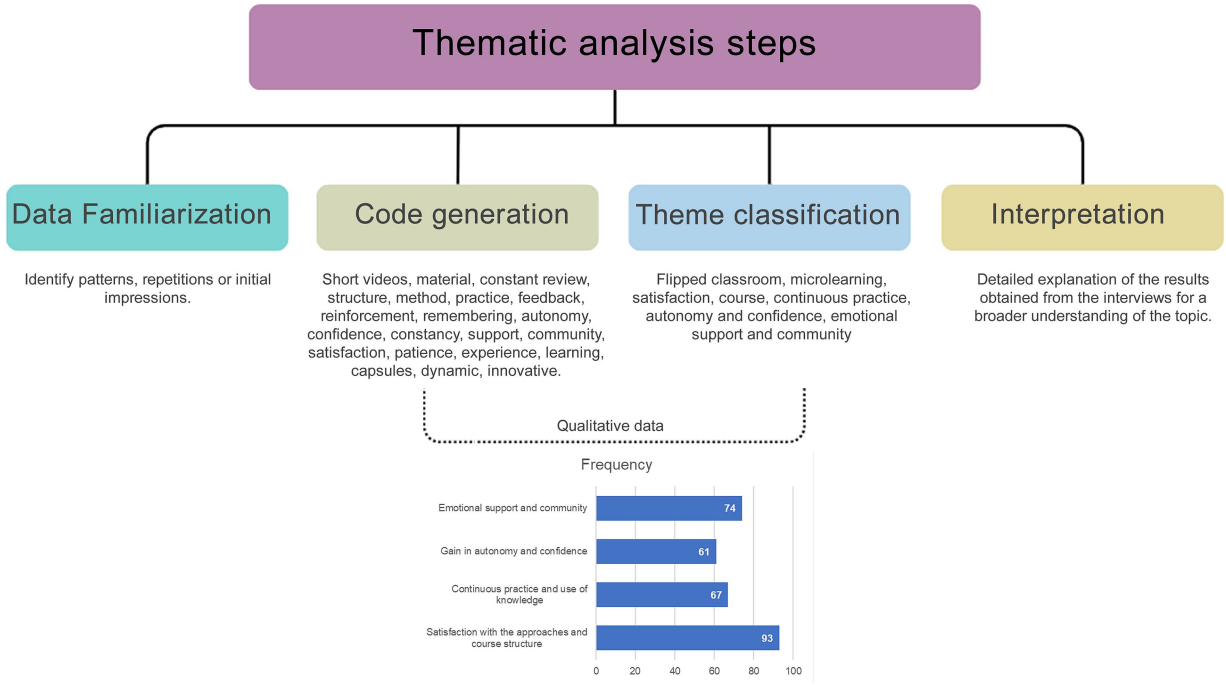

FIGURE 7
Stages of the thematic analysis conducted in the study, from familiarization with the data to interpretation of the qualitative results.

> *confident in using the computer and the internet because they took us step by step, without haste, to the goal. MED, 63-year-old woman.*

Mistrust of technology is a common barrier faced by many elderly. They may feel that technology is beyond their understanding or that they are too "old" to learn something new. Therefore, when an older person succeeds in sending their first email, completing an online form, or sharing a document online, they experience a significant boost in confidence. These small victories are considerable steps for them and enable them to feel more comfortable learning in groups where they can share their experiences and challenges.

These divisions of statements emphasize the importance of teaching approaches that permit elderly to prepare adequately and have specific questions during the sessions. Not only does it ameliorate the comprehension of the material, but it enables them to feel more confident and autonomous in their learning process.

3.6.1.4 Emotional support and community

Finally, emotional valuation and construction of a community show an essential aspect of the participants' experiences. During the interviews, it was clear that the learning environment focused on teaching techniques and bonding among participants and instructors. Most participants mentioned that they could interact with their partners and instructors, something that a flipped classroom allows since this approach prompts collaborative learning, active participation, and mutual support, reinforcing participants' beneficial emotional experiences. The participants commented on the importance of sharing their learning with others and having the support of the group.

> *Congratulations on being so empathetic and intelligent, and to my partners, thank you for sharing your experiences and particularly the participation in group tasks, the group's coexistence came naturally; in other words, trust and respect increased, and we had an incredible time. EOA, 75-year-old woman.*

Because of this sense of community, participants were more motivated to be actively involved in the sessions and were willing to help and learn from each other. Meanwhile, the instructors were recognized for their ability to create an atmosphere of trust and respect, which encouraged participants to feel comfortable expressing their doubts and difficulties.

> *Learning with you is easy, with great human beings who have great patience and dedication, together with the love and respect they have when teaching their classes. Congratulations, astonishing team. AOG, 64-year-old woman.*

> *Excellent course. To my instructors, thank you. All of you had a great attitude of service and were always ready to answer our questions. Congratulations and thank you all. AJV, a 71-year-old male.*

This emotional support is crucial for effective learning, especially in groups that may experience technology-related anxiety. The categories identified demonstrate how flipped classroom and microlearning approaches contribute significantly to participant learning. By encouraging active practice, enhancing autonomy and confidence, providing an effective teaching structure, and promoting a supportive emotional and community environment, these approaches create a comprehensive educational framework that meets

the specific needs of learners, especially elderly seeking to adapt to an ever-changing digital world.

4 Discussion

The main contribution of this study resides in the demonstration that the implemented pedagogical interventions (flipped classroom and microlearning) can significantly upgrade the digital skills of elderly through online training. The results indicate that the participants' satisfaction with the methods used contributed positively to the enhancement of their digital competencies. These methodologies not only facilitated access to relevant content but also promoted more active and participatory learning, which is essential for acquiring digital competencies.

Remarkably, there is limited evidence on implementing the flipped classroom in this demographic group. Most studies focus on the effectiveness of these methodologies in educational contexts aimed at younger students, where the results have been positive (Hyypiä et al., 2019; Awidi and Paynter, 2019; Fulgueras and Bautista, 2020; Aidoo et al., 2022). Whereas the evidence on flipped classrooms in elderly is limited, the success observed in other groups suggests that these approaches could be equally effective in the learning process and developing technological skills among this age group. Previous studies on young people have found that flipped classroom-based activities both enhance learning and foster more exceptional interaction and engagement among students (Aslan, 2021; Fuchs, 2021). Concerning elderly, this methodology could benefit learning by promoting socialization and teamwork, essential aspects for them.

The present study also reveals a positive relationship between participants' satisfaction with the pedagogical approaches and their confidence to apply the acquired digital competencies. Those who perceived these methods as effective showed a greater understanding of the content but also experienced enhanced confidence in using the digital tools, which is essential for developing autonomous abilities. The connection between positive perceptions of teaching methods and confidence in applying acquired skills has been supported by previous research, particularly in studies evaluating the effectiveness of the flipped classroom. For example, Kevin Fuchs found that student confidence increased when students experienced more control and autonomy over their learning process (Fuchs, 2021). In our study, we observed that elderly, like other learners, gained confidence by familiarizing themselves with the content in advance, reducing their anxiety about learning new digital competencies.

Likewise, the authors (Hyypiä et al., 2019) emphasize how prior preparation reduces students' anxiety, a critical aspect for elderly who face challenges in understanding and applying new technologies. The possibility of reviewing materials before class gives them greater confidence and better preparation, and their participation in synchronous activities becomes more active and efficient. In this sense, the flipped classroom promotes an environment where students can take more responsibility for their learning, facing the sessions more confidently and favoring a positive learning experience. Another study (Fulgueras and Bautista, 2020) stresses that the flipped classroom enables students to be actively involved in their learning process, promoting autonomy. In our study, we observed that the approaches implemented were especially valuable for the participants, who were allowed to prepare previously and then put their knowledge into practice in a collaborative and supervised environment and were able to overcome initial barriers of insecurity and experience a gradual development in their digital confidence.

A remarkable relationship was observed between the level of digital competence and the participants' confidence level. At the same time, as individuals improve their digital skills, they also experience an increase in their confidence to use technological tools. Based on the aforementioned, it is critical to foster self-confidence for individuals to take advantage of the opportunities offered by digitization in today's society. Previous research has pointed out that increasing confidence in digital abilities is significant for the empowerment of elderly in the digital environment (Vasilescu et al., 2020). For this reason, educational programs must be directed toward strengthening the self-confidence of this group from the beginning of the learning process since greater self-confidence can facilitate their active participation in digital life (Schirmer et al., 2023). Likewise, developing digital competencies contributes to increased autonomy, quality of life, and control over daily decisions, which is especially relevant for elderly seeking to maintain their independence (Blažič and Blažič, 2020; Pihlainen et al., 2021).

Our study would also suggest that age and years of education influence, but do not determine, the development of digital competencies. We observe that people with more formal education tend to show higher digital competencies; however, it is also notable that some participants with lower levels of education reached intermediate and even advanced levels of proficiency, underscoring the relevance of other factors in the digital literacy process. It is consistent with studies that suggest that formal digital skills education is associated with better use of technologies and greater digital literacy (Nygren et al., 2019; Llorente-Barroso et al., 2021). Regarding age, the results of our study show a negative trend, in line with previous research (Gil, 2019; Vasilescu et al., 2020), indicating that younger individuals, having grown up in a digital environment, generally present extensive ICT proficiency compared to older adults. However, age alone does not determine the ability to learn and use digital tools. Additionally, elderly may experience broader difficulties due to unfamiliarity with technology. In some cases, the presence of cognitive or physical barriers, we have observed that willingness to learn and to adapt are key factors in overcoming these limitations.

During the interviews, participants highlighted that the opportunity to practice in a controlled environment with access to visual materials strengthened their understanding of digital tools. This experience emphasizes the effectiveness of the microlearning methodology, which allows elderly to assimilate concepts gradually and apply them immediately, thus facilitating deeper learning (Hlazunova et al., 2024). As previous studies suggest, practice-oriented teaching fosters students' independence and ability to demonstrate actions autonomously (Gil, 2019; Schirmer et al., 2023). The interaction between previous activities and classroom sessions is fundamental, as the content must be displayed as comprehensible as possible and directly linked to classroom practice (Hoshang et al., 2021). In addition, emotional support and community building were considered essential by the participants. Interaction with peers and instructors was a crucial aspect of the flipped classroom. The findings reveal that ICTs play a humanizing and emotional role, especially in contexts of vulnerability, such as social isolation, and low digital skills, among others (Llorente-Barroso et al., 2021). This emotional support

not only allows participants to feel connected but also contributes to their independence and confidence while using technology (Taipale, 2019).

All in all, the results indicate that the flipped classroom and microlearning approaches, combined with an emotionally supportive and communal environment, create an efficient educational framework that meets the specific needs of older people as they adapt to a constantly evolving digital world. These findings align with the objectives as they reflect the positive impact of these approaches on the development of digital competencies and participants' perception of their independence and quality of life.

4.1 Limitations

This research has limitations that should be addressed in future studies. First, the sample of 112 participants is not fully representative of the general population of elderly in Mexico, as it is mainly composed of 93 women vs. 19 men and has a relatively high level of education (13.6 years of schooling on average), which could have influenced the results. In addition, all participants were required to have access to digital devices and a stable internet connection, which limits the applicability of the results to those without these resources. Another factor to consider is the lack of a control group, which prevents us from attributing the results exclusively to the methodologies used, a limitation that will be addressed in future studies. Finally, although a significant improvement was observed in basic and intermediate digital skills, no relevant change was found in advanced skills, suggesting that the 12-month intervention period may not have been sufficient to assess the long-term impact on more complex digital skills.

4.2 Future research directions

Future studies should address some of the limitations identified in this research. One key area is the inclusion of a control group to allow for a clearer attribution of results to the methodologies implemented, such as flipped classroom and microlearning. Establishing control groups in subsequent studies will enhance the validity of the findings and provide more robust evidence of the effectiveness of these approaches. Additionally, future research will extend the training period by six additional months (a total 18 months of training) to evaluate the long-term impact of the program on more complex digital skills, ensuring a more comprehensive assessment of its effectiveness. These adjustments aim to deepen our understanding of how to improve support digital literacy development in older adults.

5 Conclusion

This study contributes to the understanding of how effective pedagogical methodologies can positively impact the development of digital skills in elderly and strengthen their self-confidence in technological contexts. The findings emphasize that, when combined with a supportive and structured environment, these approaches significantly improve not only the technical skills but also the self-confidence of elderly participants in using digital tools.

The implications of these findings are highly relevant for both educational practitioners and policymakers. The study shows that older adults, regardless of their educational background, can successfully acquire essential digital skills through adaptive and well-designed learning experiences. By overcoming common barriers such as digital anxiety and the perception of technology as inaccessible, these methodologies promote active, participatory learning, contributing to a more inclusive digital society.

A key observation is the strong correlation between the improvement in digital skills and the increase in participants' confidence. This suggests that as individuals acquire more digital competencies, they also experience a boost in their self-confidence, leading to greater autonomy and empowerment in their daily lives.

Moreover, the incorporation of qualitative data, particularly through participant interviews, enriched the analysis by providing a deeper understanding of the factors influencing the effectiveness of the methodologies. This qualitative approach allowed us to capture participants' subjective experiences and perceptions, offering a complementary perspective to the quantitative results.

In conclusion, this study underscores the importance of adopting learner-centered approaches, based on practical engagement and accessible resources, to empower older adults in navigating the digital age. The implications of this research extend beyond the immediate context, offering valuable guidance for future educational programs aimed at fostering digital inclusion and improving the technological self-confidence of older populations. Future research could build on these findings by examining the long-term impacts of these methodologies and exploring the role of control groups to strengthen the evidence base. This study contributes to the understanding of how effective pedagogical methodologies can positively impact the development of digital skills in elderly and strengthen their self-confidence in technological contexts. In a world where technology plays an increasingly prominent role in everyday life, it is crucial that all demographic groups, including elderly, have the opportunity to benefit entirely from digital advances.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethics committee approval was not required for this study because before beginning the courses, there was an explanation of the purpose of the study to the participants and obtaining digital and verbal informed consent. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin.

Author contributions

CM-A: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JC-A: Conceptualization, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. VM-L: Investigation, Validation, Visualization, Writing – review & editing. LA-L: Data curation, Formal analysis, Investigation, Project administration, Resources, Validation, Visualization, Writing – original draft. CG-V: Data curation, Formal analysis, Investigation, Project administration, Resources, Validation, Visualization, Writing – original draft.

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The author(s) declare that no Generative AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1524636/full#supplementary-material

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