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Empowering pre-service teachers' digital competence through nanolearning: A cognitive theory of multimedia learning and locus of control perspective

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Abstract

In this study, researchers investigated the effect of nanolearning on developing digital skills among pre-service teachers, considering the cognitive theory of multimedia learning (CTML) and locus of control to assess the effect of nanolearning on digital skills. The researchers used a mixed methodology, a quasi-experimental approach with two experimental groups and pre- and post-tests. The 56 teachers in the sample study were split into two groups at random. Teachers' opinions on nanolearning were gathered through interviews, and the list of digital skills was determined qualitatively using the three-stage Delphi technique. Three instruments were used in the study. The findings of the study show: There was a statistically significant difference in the average scores of the post-test of digital skills in favor of the experimental group that used nanolearning (audio and image). The results also showed that teachers with an internal locus of control achieved higher scores on the post-test of digital skills compared to those with an external locus of control. Pre-service teachers expressed positive views toward the use of nanolearning to develop their digital skills. Based on the findings, the researcher recommends integrating nanolearning as an essential part of the curriculum in colleges of education at Jordanian universities.

Keywords: CTML, Delphi technique, Digital skills, Locus of Control, Nanolearning, Pre-Service teachers.

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Contents

Contribution of this paper to the literature
This study contributes to the existing literature by integrating nanolearning, locus of control, and CTML to enhance digital skills. The primary finding is that digital skill acquisition is significantly accelerated when audio-visual nanolearning and an internal locus of control are combined. It documents a novel, research-based approach to teacher preparation programs in Jordan.

1. Introduction

Jordanian universities can enhance innovative thinking in the education provided for pre-service teachers, inspired by developments in education, particularly blended learning and nanolearning. These programs should equip prospective teachers, not only as subject-matter experts, but as tech-savvy and skilled educators, able to design and implement innovative learning experiences. In the case of Jordan, blended learning is a highly beneficial and pragmatic approach to deal with the challenges of pre-service teacher education programs, focusing on the increasing demand for cost, time, and human resource savings (Ananzeh & Uraiqat, 2024). Using contemporary digital teaching technologies and learning teaching methods, programs can provide pre-service teachers with innovative and adaptable learning environments. They gain the experience and skills to design and establish similar learning environments for their future K–12 students. These programs also prepare teacher candidates to possess the digital competencies to use computers in efficient and effective ways in the classroom, a 21st-century necessity. The successful integration of the initiative in programs demands a unique value proposition that aligns the goals of faculty, student-teachers, and program management (Aiken, 2025). Innovative thinking in education is provided for pre-service teachers (Vivekananth, 2022). Most applicable to teaching educators, challenging topics like curriculum construction, classroom control, or evaluation strategies. Educational theories that are complex and burdensome are made cognitively less complex by nanolearning, which facilitates a greater understanding and ease of application. Moreover, the application of this approach to the training context enables pre-service teachers to strengthen their internal locus of control and self-regulated learning, which fosters their capacity to be self-reliant and reflective practitioners, an essential outcome when learning support is utilized (Skowerska, Czyżewski, Parnowska, Wyzgał, & Silczuk, 2025). The concepts' interrelations are illustrated in Figure 1.

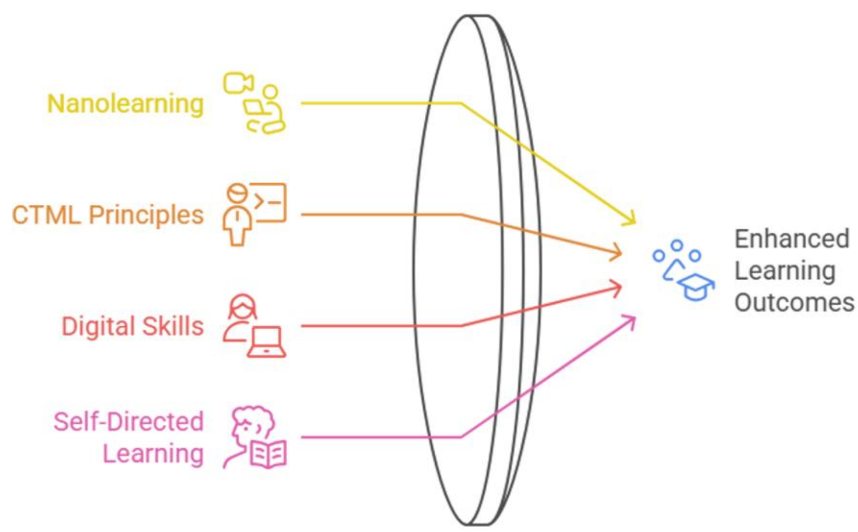

Figure 1. Factors in the Enhancement of Learning Outcome.

2. Literature Review

2.1. Nanolearning

One of the newest developments in digital technology is nanolearning, which helps students achieve their objectives by enhancing their skills and proficiency. It is a device that completes and manages digital transformations by dissecting educational content into minuscule chunks and solving a single, targeted problem each time. Additionally, it improves comprehension and motivates students to obtain and retain new digital content much more thoroughly (Khlaif & Salha, 2021). It is an approach to education that is based on the efficient and engaging delivery of educational information. It enables students to achieve their objectives, improve their learning, and acquire critical thinking, deductive reasoning, creativity, and self-directed learning skills. Additionally, they learn how to interact with the digital component frequently (Roy, Bhattacharjee, & Hossain Ansari, 2024). Because technology makes education so much more convenient, it is a viable option to incorporate nanolearning into the current educational system. This teaching approach is anticipated to improve students' critical thinking skills and focus by allocating adequate time to each session on a specific topic (Sanam, 2023). Additionally, since they can use a variety of devices to complete the learning process, teaching with audiovisuals gives these pupils a great deal of autonomy. Repetition of the lectures will ensure that pupils are not overburdened. Students can progress through the system at a linear level thanks to the constructivist teaching philosophy. Numerous students find nanolearning appealing due to the availability of digital resources, the short duration of the learning process, and the various learning requirements that can relate to nano-assessment and peer assessment activities (Madan, 2021). Numerous advantages of nanolearning increase student productivity. In contrast to traditional approaches, which require students to spend long hours in class, it takes a short period of time to absorb a large amount of information. Students are more likely to pay attention during a lesson, increasing their likelihood of taking in and remembering the instructions. As a result, less time is spent in front of screens by both teachers and students. Students' attention is also greatly captured by nanolearning, which enhances their general focus. Students are excited and eager to attend their lessons because of the use of digital platforms, which offer a variety of educational resources tailored to the individual needs of each student (AL-Shehhi, 2022).

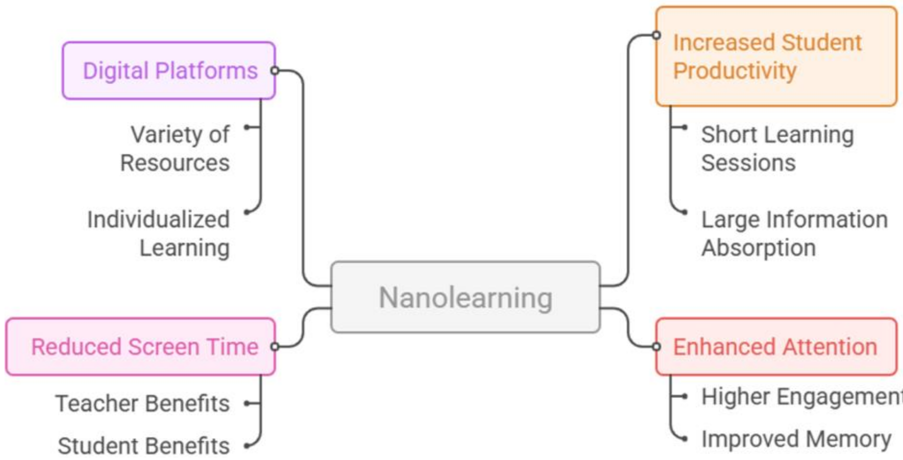

Figure 2. Advantages of Nanolearning in Education.

Figure 2 summarizes the benefits of nanolearning in four areas: lowering screen time, which benefits both the teacher and the student; improving attention and memory; increasing student productivity through brief sessions; and using digital platforms for personalized learning.

When using nanolearning in an e-learning setting, teachers need to utilize multiple platforms and be mindful of time; therefore, the duration of information display should not exceed two minutes. Audio notes can also be used to introduce or recap a new concept. Thus, nanolearning makes it possible to provide knowledge in more engaging ways by employing a range of methods that can be used in conjunction with other e-learning tactics (Astaño, 2025). A paradigm shift in education is brought about by nanolearning, which provides fresh answers to the problems that students face in the digital age. This approach to teaching is effective because it employs short, concentrated units of instruction to capture students' attention and sharpen their focus, which enhances learning outcomes and facilitates material memorization. Students also spend less time in front of screens, which is crucial when learning remotely. Making the most of this strategy requires using interactive digital technology and comprehending the needs and preferences of learners. Because it can be adapted to various learning contexts, including virtual and traditional ones, nanolearning can be seen as one of the potential methods to improve the effectiveness and enjoyment of the learning process (Kayalar, 2021).

It is the educational future because of its ability to adapt to modern problems like scattered attention and information, and cognitive overload. Because it works well in distant and mixed learning environments, this method is a key tool for ensuring that the educational process continues and progresses in a way that meets the needs of the digital transformation (Chamorro-Atalaya et al., 2024). Additionally, nanotechnology is now a crucial component of STEM education. Just as engineering procedures are no longer limited to university students, learning about nanotechnology is now enjoyable and accessible to all, from teachers to graduate students. Furthermore, blended learning environments are increasingly including nanolearning. Furthermore, this type of environment can be utilized to create engaging content for online courses, where students are likely to become distracted, thereby improving their performance and productivity (Azwati, Munir, & Muliati, 2024).

2.2. Digital Skills

The teachers are a cornerstone for building a child's character and developing their intellectual, physical, and psychological skills. With the accelerating pace of digital changes, it has become essential for early education teachers to possess new skills that align with the requirements of the 21st century. In this context, Jordan has been keen on developing learning education teachers by establishing high-quality standards for preparing and qualifying teachers (Assaf, 2023). These standards are based on key pillars such as developmental domains, curriculum, teaching methods, the learning environment, in addition to partnership with the family, and assessment. The focus has also been on self-directed learning, technology integration, developing higher-order thinking skills, and providing support for students with special needs (Muallimin, Fridani, & Nurjannah, 2023). Technical skills are considered a fundamental component of teachers' competence, as they enable them to effectively integrate technology by using tablets, computers, and educational software, creating digital content, and employing augmented and virtual reality applications. Furthermore, the teacher must be familiar with the basics of digital security to protect students' data and educate them on the safe use of digital platforms (Antonietti, Cattaneo, & Amenduni, 2022). Educational skills are no longer limited to reading, writing, and analysis; they have expanded to include digital skills that are essential for keeping up with the demands of the 21st century and integrating into the job market. Digitalization has transformed into an educational tool that leverages the potential of technology, such as virtual reality and artificial intelligence, to enrich curricula. To do this, educators must learn digital skills for planning, carrying out, and assessing (Leoste, Lavicza, Fenyvesi, Tuul, & Õun, 2022). "A collection of digital skills that aid in the efficient and effective use of digital devices, communication applications, and networks to access and manage information" is the definition of digital skills (Galindo-Domínguez & Bezanilla, 2021). They make it possible for people to connect, work together, and solve a variety of issues in addition to efficiently producing and sharing digital information. While the researchers define these abilities as a teacher's ability to use technology in the classroom, from lesson planning to electronic evaluation (Godaert, Aesaert, Voogt, & van Braak, 2022). sees them as a teacher's ability to use computers and the internet to create a variety of instructional content.

Since digital skills encompass a range of basic, integrated competencies, they are crucial for the modern educator. These abilities include creating and managing material for self-study and resolving digital issues that come up when using the internet and contemporary technology. Another essential component is communication skills, which include gathering, storing, and sharing knowledge with others. A teacher's role is no longer limited to traditional curricula; to become a lesson designer and creator of digital educational content, they must now learn production skills. These skills include online interaction, which entails data modification, document recording, and information exchange (Perifanou, Economides, & Tzafilkou, 2021). These abilities are distinguished by their sequential and integrated structure, which starts with digital information skills and progresses to teamwork and critical thinking, creativity, and problem-solving abilities. The importance of beginning with the fundamental ability (digital information) before progressing to more sophisticated abilities is emphasized by this sequence. It is also universal abilities that may be used in most countries across the world, and they are always changing, requiring teachers to stay up to date on anything new, including artificial intelligence (Mogonea, 2025). For several reasons, teachers now urgently need to be proficient in digital skills to meet the expectations of the modern world. The use of cutting-edge tools that facilitate remote and self-paced learning is necessary for several important reasons, the first of which is the inadequacy of traditional teaching methods in managing huge numbers of students. Second, the growing demand for education, which traditional institutions cannot satisfy, is a societal cause. Thirdly, economic considerations emphasize how digital skills fit labor market demands and offer more economical and efficient educational options. Lastly, the significance of e-learning as a critical substitute for the conventional system in times of crisis was illustrated by health-related factors during the coronavirus pandemic (Dolezal, Motschnig, & Ambros, 2025).

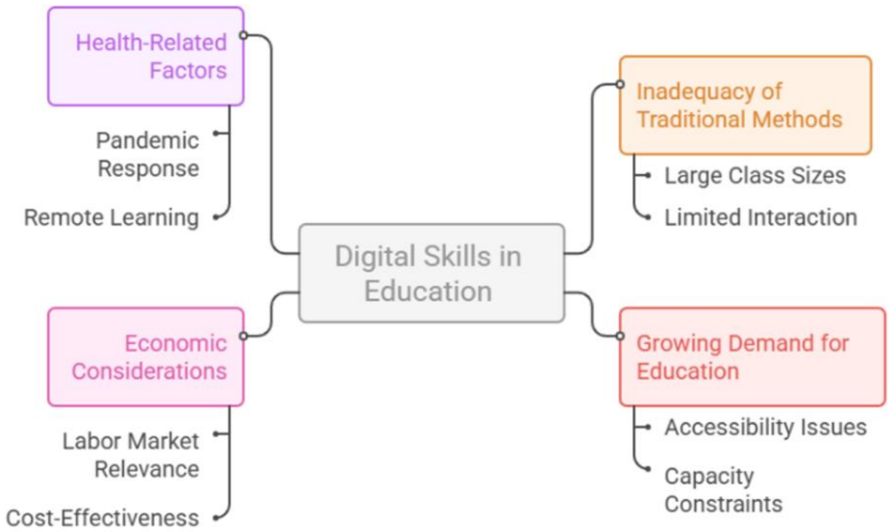

Figure 3. Digital skills in education.

Figure 3 shows the main forces behind the adoption of digital skills in education, emphasizing how they can be used strategically to meet the demands of the labor market and address health crises (like distance learning). Additionally, it shows that digital skills provide a means of addressing growing demand by expanding access and overcoming institutional capacity constraints, as well as overcoming the drawbacks of traditional education, such as packed classrooms.

These changes have caused the teacher's role to shift from solely disseminating knowledge to consulting, facilitating, and creating digital content. Teachers must now utilize technology to deliver lessons, encourage students to use technology for research, and foster interaction and creativity by prompting students to ask questions and utilize technology to create their own educational programs. They also need to focus on knowledge production, develop students' capacity for self-learning, and provide them with the awareness they need to avoid digital risks (Chiu et al., 2024). The nature of digital skills, which are defined by ongoing training due to their rapid evolution, is the most notable of the many obstacles in the way of instructors developing their digital abilities. Teachers from earlier generations are also challenged by the novelty of these talents because they need more time and effort to acquire them. Due to the significant financial outlay required to supply devices and internet networks, it is also an expensive strategy (Chiu, Sun, & Ismailov, 2022). It is challenging to learn these broad abilities in a brief training session because they cannot be limited to a certain topic of study. The second issue is that not all educators and administrators will be receptive to new ideas and conventional approaches. Changing the curriculum for teacher preparation and training and incorporating digital skills into pre-service and in-service training programs are two examples of the practical tactics that must be used to overcome these obstacles (Blanc, Conchado, Benlloch-Dualde, Monteiro, & Grindei, 2025).

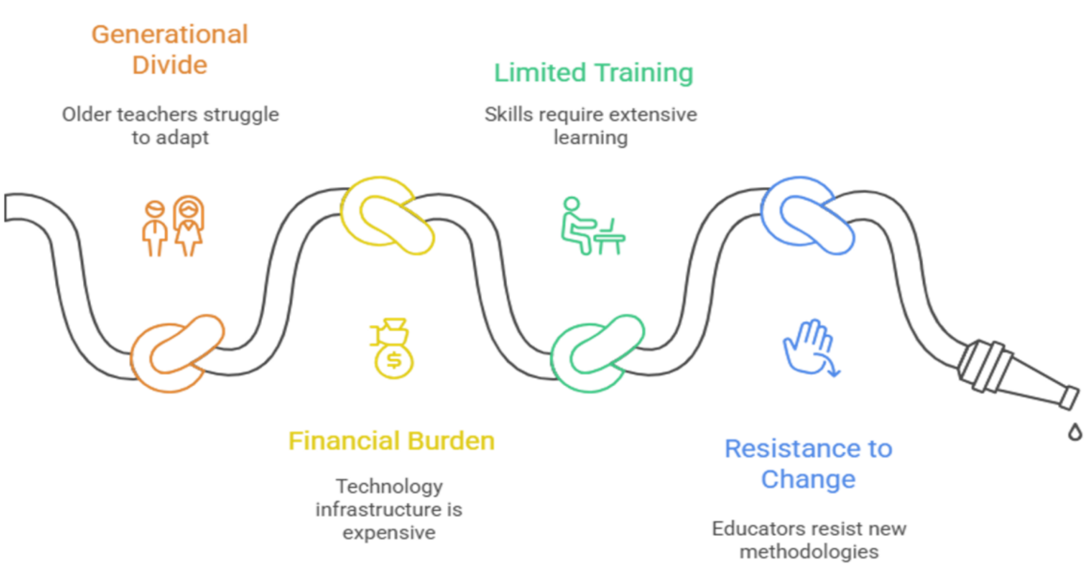

Figure 4. Navigating the Digital Skills Gap in Education.

Figure 4 highlights the "main obstacles" that characterize the digital skills gap in education that restrict the flow of progress; it underlines that conquering these issues is the key to updating a successful education system.

2.3. Internal and External Locus of Control and Learning

Locus of control, a psychological term that gauges how much people believe they have control over their lives, is a crucial part of Julian Rotter's social learning theory (Botha & Dahmann, 2024). This impression has a significant impact on a person's behavior, motivation, and general performance. It plays a crucial part in how people respond to their environment (Daud et al., 2025). Comparing control points that are internal and external This concept is typically divided into two categories.

- Internal Locus of Control: The individuals with this belief have the impression that, in most cases, their success or failure is determined by their capabilities and their effort. This attitude leads to higher motivation and achievement and develops a high level of self-confidence and responsibility (Sari & Fakhruddiana, 2019). They will be more resistant to external pressures, consult others, and learn lessons that come out of the past. Such individuals attribute failure to the absence of personal capacity according to research by Althubaiti, Alharbi, Althubaiti, Alzahrani, and Agha (2025); Kader (2022), and Febriyanto, Finansiya, Tarigan, Hartini, and Safarina (2025), which makes them strive more to gain control and improve their conditions.
- External locus of control: Conversely, individuals with this locus of control project the results to external elements such as fate, luck, or the actions of other individuals. This attitude may make them feel powerless and inactive because they feel that their work is not important (Giri & Sangeeta, 2025). An external locus of control is related to reduced self-control, a lower drive, and a general lack of engagement in constructive activities. Studies indicate that individuals holding this view might struggle to adapt to new situations, withdraw to difficult situations, and have higher levels of melancholy and learned helplessness (Jose & Vijayan, 2021).

Academic achievement and locus of control are strongly correlated because students think that their skills and hard work directly contribute to their achievement. Students with an internal locus of control tend to achieve better academic performance. This is reflected in their motivation, sense of personal accountability, and openness to learning and criticism (Lincă & Matei, 2023). Conversely, an external locus of control is negatively associated with academic success. These students often attribute their academic performance to circumstances beyond their control, which can reduce their motivation to learn and engage with the curriculum. This lack of intrinsic motivation is often a reason for lower academic achievement among this group of students.

2.4. Cognitive Theory of Multimedia Learning (CTML)

A good presentation is a blend of text and visuals, but in the case of good presentations, the blend is crafted to help the approach be congruent with the way the mind works (Mayer, 2024). Mayer's Cognitive Theory of Multimedia Learning (CTML) posits that learners have two channels in which they process different forms of information. One of the channels is the verbal channel that processes the written and spoken language. The other channel is the visual channel, which comprises graphics, pictures, videos, and animations. The materials in instructional designs need to be crafted in a way that they avoid cognitive overloading in the instructional design and materials, because each of the channels has a limited capacity. Instructors also need to guide learners to the relevant materials because instructed learning is centered when educators provide the relevant materials.

Accordingly, effective multimedia instruction is not limited to the simple combination of text and images; rather, it should actively engage learners' cognitive processes by thoughtfully coordinating verbal and visual elements in a clear and focused way. Such integration helps minimize unnecessary cognitive load while promoting deeper comprehension and improving long-term retention (Mayer, 2024).

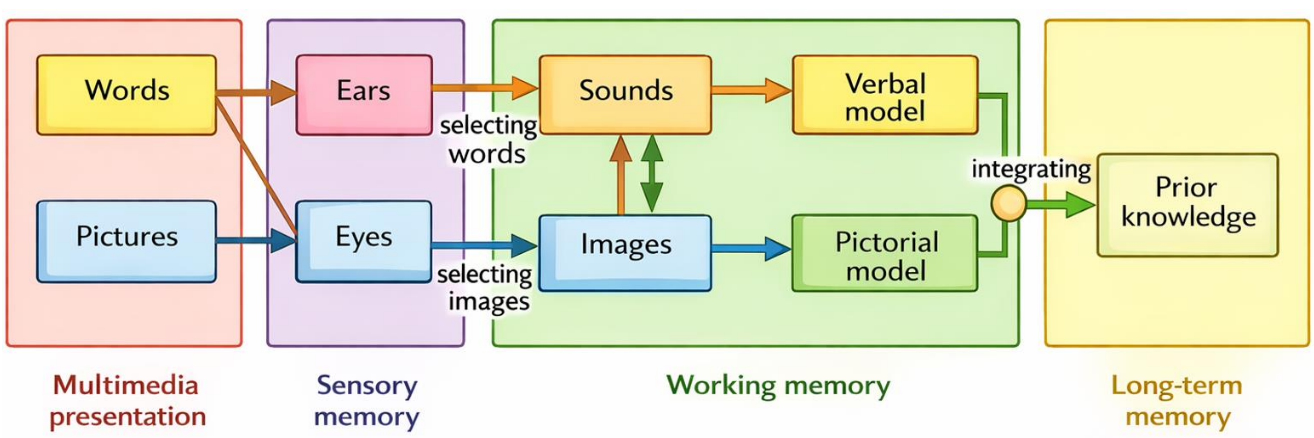

Figure 5. CTML (Mayer, 2024).

Figure 5 shows the text that outlines a cognitive model of human memory and learning, showing how information from multimedia presentations is processed. The model involves three main stages of memory: sensory memory, working memory, and long-term memory (Parong & Mayer, 2021). Sensory memory first receives information from the external world, such as pictures and spoken or written words, and holds transient visual and auditory images as brief sensory replicas. Working memory is the central site of multimedia learning: it temporarily holds and actively manipulates information, processing sensory input, auditory images of spoken words, and visual images of pictures. Working memory also supports cross-modal transformations (for example, converting the spoken word "stave" into a visual image, or imagining the sound associated with a pictured stave); these transformations often depend on mental associations. Conceptually, one can distinguish a raw-data view of working memory (visual and auditory inputs) from a constructed view (mental and verbal models and organized knowledge). Long-term memory serves as a much larger repository of organized knowledge; information must be retrieved into working memory to be used, and new information must be encoded from working memory into long-term memory for durable storage. The learner is an active participant in these processes, constructing meaning through three primary cognitive operations: selection, organization, and integration.

In this process, the learner actively contributes to the development of meaning through the three main cognitive processes of selection, organization, and integration. Selection is the initial stage of the mental process that involves concentrating on pertinent verbal and nonverbal cues. It comprises choosing the data to be added to the working memory. A closer look is provided by Paivio (1986), who describes how verbal stimuli are chosen to create a verbal model and non-verbal stimuli are chosen to create a pictorial model that is transmitted to working memory. Organization: After choosing the knowledge, the learner proceeds to Organization, where they logically and meaningfully arrange the stuff they have chosen. Such a mental process is carried out in both selected words and selected images, which are subsequently arranged into verbal and visual models, respectively, according to Ramlatchan (2019). Integration: Creating connections between the new verbal and visual models is the final step in the process. It is crucial to remember that the ordered information is connected to potential, related information that is already stored in the long-term memory, as Moreno (2006) emphasizes (Teng, 2023). Lastly, as multimedia contains information that can be represented in a variety of ways, such as words, pictures, movement, sound, etc., it is critical to understand how learners process the information to assist them in creating accurate and reliable mental models (Ponce, Mayer, Loyola, López, & Méndez, 2018).

2.5. Research Framework

The research framework in Figure 6 shows the relationships between the different variables under investigation.

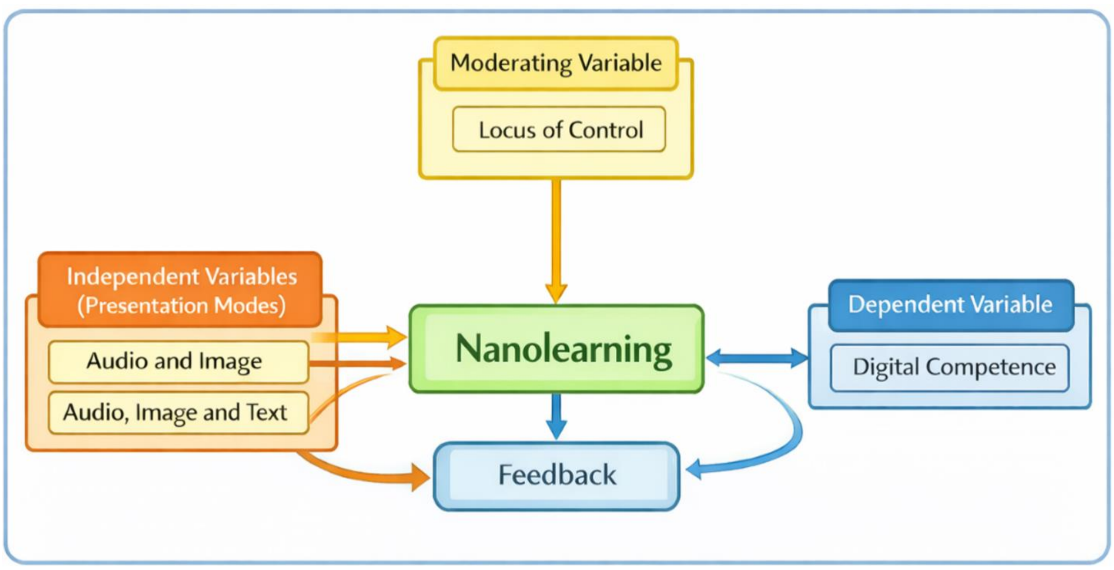

Figure 6. Research Framework.

The research framework depicts three variables. The independent variables are:

Two processing methods: audio with video, and audio, video, and text. The dependent variable is the digital skills of pre-service teachers. The moderating variable is: The Locus of Control. The moderating variable is present in this study and has a strong conditional effect on the relationships between independent and dependent variables. The effect of using the two processing methods (text and audio, and text, video, and audio) on the digital skills of pre-service teachers will be determined.

2.6. Problem Statement

Adoption of digital techniques in educational systems is phenomenal worldwide. Schools and higher education institutions are increasingly moving towards a strategic shift to the digital transformation context, which in turn emphasizes how critical it is to give students, especially pre-service student teachers, the digital capabilities and skills they need. More importantly, equipping pre-service student teachers with highly deemed necessary digital capabilities is essential for maintaining educational continuity and adaptability in unforeseen circumstances. At present, it could be argued that teachers may profoundly lack the specialized digital skills necessary to successfully and effectively integrate technology in classroom settings, and professional development programs that focus on general competence rather than the specific technical skills that apply in practice cause a significant separation and/or discontinuity between theoretical preparation and effective pedagogical practice. While some teacher training programs have set their programs according to a competency-based model, former research has revealed that current teacher training programs are failing to equip future teachers to operate efficiently in this new digital environment (Abdel-Tawwab, 2024; Al-Zahrani, 2024).

Pre-service teachers must have basic digital capabilities and skills to succeed in the digital era. It is extremely important to assess their proficiency and readiness for technological effective use in actual instructional settings. For certain. Enhancing the teaching and learning processes requires both pre-service teachers' professional growth and their ability to adapt to technological breakthroughs. Such a state of affairs, according to Saud (2022), is clear in the Jordanian schooling system.

It seems that the core of the problem is the lack of digital competency witnessed among pre-service teachers, which remarkably impedes great endeavors and serious attempts by the Jordanian Ministry of Education to move forward towards proper and rigorous digital transformation. Despite being competency-based, the current teacher education programs lack the digital skills needed for effective classroom instruction, particularly in unique or diverse instructional contexts. Teachers are unable to effectively integrate technology into their teaching practices, adequately create digital content, and productively employ contemporary teaching techniques due to discontinuity or even dichotomy between theoretical preparation and effective pedagogical practice. Based on this, the researchers propose that new approaches, such as blended learning supported by nanolearning, must be incorporated into pre-service teacher education programs. Teachers can use this methodical approach to enhance their professional and academic capabilities. Their ability to understand and apply modern educational concepts is improved by the common, flexible, and intensive learning platform that nanolearning offers. Additionally, it helps teachers strengthen their technological and analytical skills so that they may be prepared to work with increasingly rapid changes and provide learners with an innovative and integrated learning experience (Astaño, 2025). Figure 7 illustrates the research problem and the relationship between its variables.

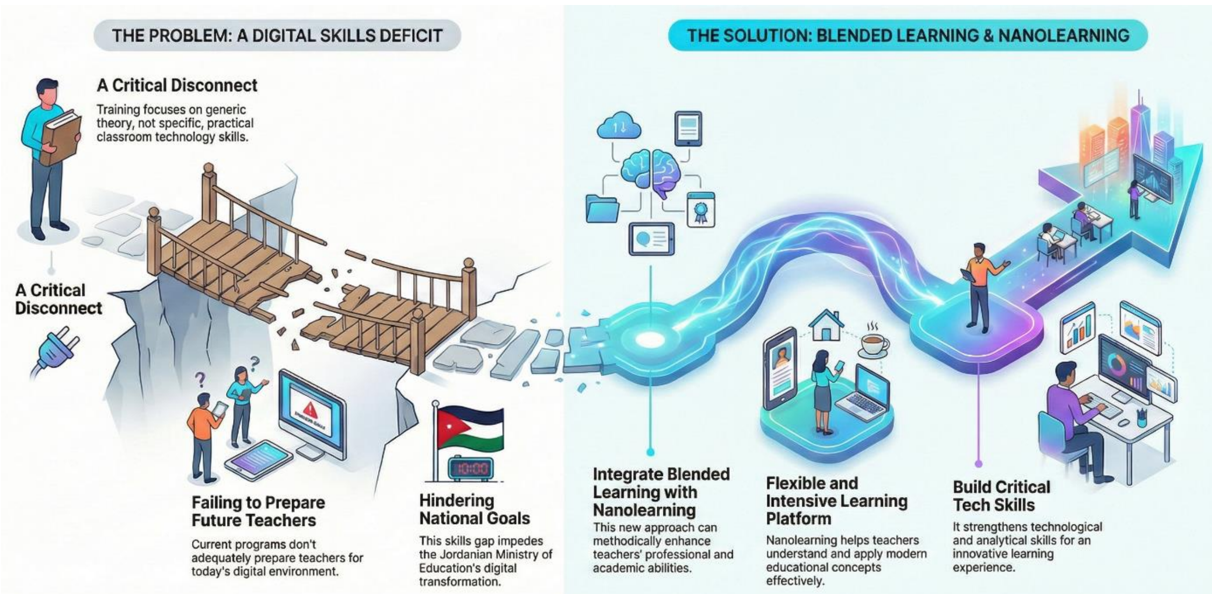

Figure 7. The teacher tech gap: A problem & solution.

Therefore, this study was designed to answer the following questions.

- What core domains of digital competency should pre-service teachers possess for effective technology integration in contemporary classrooms?
- To what extent does instruction delivered via a nanolearning-based teaching method produce statistically significant differences in pre-service teachers' mean scores on a standardized digital-skills scale?
- What is the distribution of locus of control among pre-service teachers at the Faculty of Educational Sciences, Yarmouk University?
- Are there statistically significant differences in pre-service teachers' mean digital-skills scores associated with differences in locus of control?
- Among pre-service teachers characterized by an external locus of control, does the nanolearning-based teaching method produce statistically significant differences in digital-skills test scores?
- How do pre-service teachers perceive the effectiveness, usability, and relevance of nanolearning for developing digital competencies?

3. Research Methodology

The current study focused on examining the effectiveness of different nanolearning approaches in developing digital skills among pre-service teachers at Yarmouk University, considering the CTML and the Locus of Control. The researchers utilized a mixed-methods research approach, combining both qualitative and quantitative methods. A qualitative approach, specifically interviews, was used to gather teachers' opinions on nanolearning. A quantitative analytical method was employed to determine the students' locus of control. Additionally, a quasi-experimental design was used to compare the effectiveness of the various nanolearning-based teaching methods

3.1. Study Population and Sample

The participants for this study were all students who were taking pre-service teacher training as part of the teacher training program at Yarmouk University during the second semester of the 2024-2025 academic year. The researchers' connection as faculty members of the university made conducting the study on students at this university feasible. Cooperation and support from the university administration also made carrying out the research possible. In addition to this, the adoption of several eclectic and innovative teaching methods was also beneficial. The study participants were 56 students; they were randomly assigned to two groups. The first group, which consisted of 29 students, was taught Nanolearning (Audio and Image), while the second group, which consisted of 27 students, was taught Nanolearning (Audio, Image, and Text). The students were taught the following topics as part of the Educational Computer Applications for Early Grades course: digital worksheets, digital storytelling, social media, YouTube education, smartboards, and AI in education. Before the study commenced, a pre-test was administered to measure the level of performance. To verify the groups' equivalence as depicted in Table 1, the t-test was used. The findings of this study demonstrated that there were no relevant differences amongst the groups in terms of pre-test application and observation cards. In essence, this implies that groups share a similar design thinking skill level. The digital skills test research tool was pre-administered to both groups to determine the equivalence of the two groups on the variables of interest to the research. To perform the necessary statistical deployments, the researchers noted the scores. After the necessary conditions were verified, a "T-test" was applied to test the two groups' mean scores. The findings were as follows: Table 1.

Table 1. Equivalence of the two study groups on the digital skills test.

Source	Group	N	M	SD	t	df	Sig.
Nano Learning	Audio & Image	29	17.37	3.649	0.402	54	0.689
	Audio Image, & text	27	16.96	3.099			

3.2. Study Instruments

To achieve the study's objectives, the researchers prepared two instruments.

3.2.1. Digital Skills Test

A multiple-choice digital skills test was developed during the "Educational Computer Applications for Children" course to fulfill the goals of the proposed study. The group participating in the study was given this test both before and after. To determine the course's educational objectives, the test's creation required a first understanding of the course's learning outcomes. Several Yarmouk University faculty members assisted in classifying these goals according to the level of cognition. (remembering, understanding, applying, analyzing, and creating), A table of specifications was created. Initially, 50 test questions were drafted. These questions were then presented to a panel of expert reviewers to ensure content validity. Based on their feedback, several revisions were made, including rephrasing some questions, changing certain choices, making linguistic adjustments, and deleting some questions. In the end, 40 questions made up the final version of the test, with one point given for each right response and zero for wrong or unanswered questions. After that, 19 students from the study population who were not part of the main sample were given the test as a pilot sample. This pilot study's goal was to calculate each item's difficulty and discrimination indices so that unsuitable items might be eliminated. The discrimination and difficulty indices for each test item are shown in Figure 8.

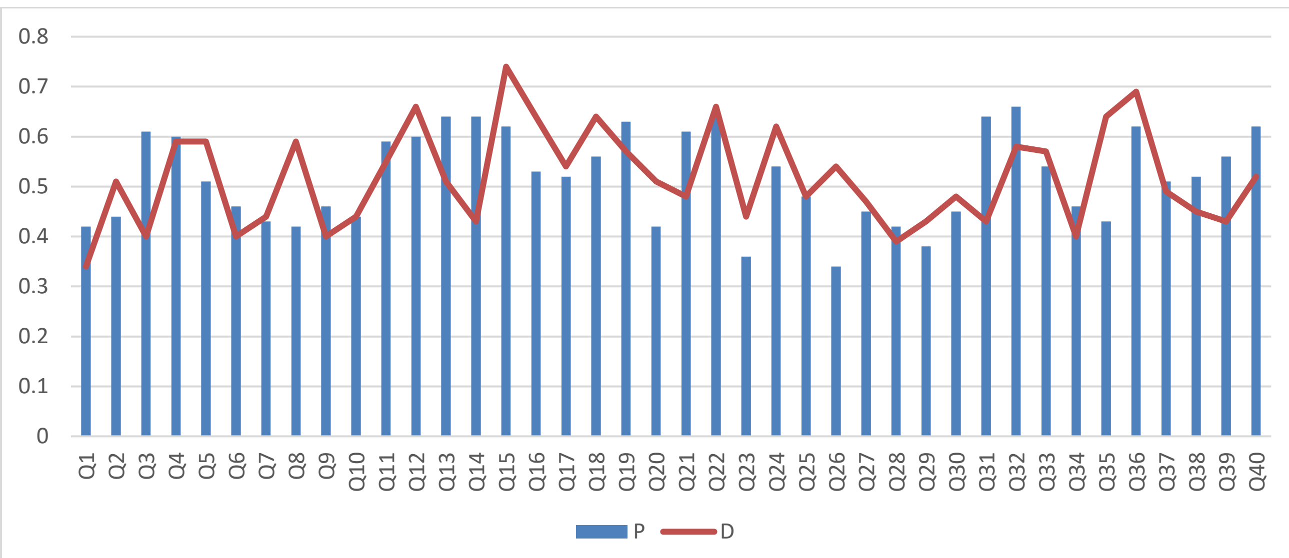

Figure 8. Difficulty and Discrimination of Digital Skills Test.

Analysis of the test findings revealed that item difficulty indices ranged from 0.42 to 0.66, while discrimination indices ranged from 0.34 to 0.66. To ensure the reliability of the test items, the researchers used Cronbach's alpha, which yielded a value of 0.78. This indicates a high degree of reliability for the test. Based on these psychometric traits of both reliability and validity, the test was deemed a suitable and valid instrument for achieving the study's objectives.

3.2.2. Locus of Control Scale

Rotter's internal and external locus of control scale was used. It has 23 main items. Each item has two sentences, one dealing with the internal locus of control and the other with the external locus of control. The examinee is forced to make a choice. Six irrelevant items were added to the scale to disguise its actual purpose and thereby confuse the examinee. A higher score represents an external locus of control, and a lower score represents an internal locus of control. To test the construct validity of the scale, it was sent to several specialists in psychology, measurement, and evaluation to seek their feedback and suggestions concerning the linguistic wording and the ipso facto relevance of the items. The answer to their questions was that no item was changed or deleted from the scale because of their feedback. The internal validity of the scale was subsequently validated through its application to an exploratory sample by correlating the points of the scale with other items, as displayed in Table 2.

Table 2. The correlation coefficients of each item with the total score of the locus of control scale.

N	R	N	R	N	R
1	0.711**	9	0.574**	17	0.723**
2	0.734**	10	0.654**	18	0.509**
3	0.563**	11	0.721**	19	0.681**
4	0.675**	12	0.785**	20	0.706**
5	0.714**	13	0.711**	21	0.765**
6	0.775**	14	0.739**	22	0.719**
7	0.763**	15	0.798**	23	0.679**
8	0.583**	16	0.589**		

Note: **Statistically significant at the $\alpha = 0.01$ level.

The findings of the inter-item correlation analysis showed that there were high correlation coefficients for most of the items of the instrument with the total score. To enhance the internal consistency of the instrument, 5 items whose correlation coefficients with the total score were less than 0.600 were removed. These items are (3, 8, 9, 16, 18). The scale, in its final form, may consist of 18 items. To ensure the stability of the locus of control scale, it was applied to a survey sample, where the Cronbach's alpha coefficient reached 0.83 for the entire scale, and the internal consistency of the instrument was 0.85.

4. Results of the Study

Question one: What core domains of digital competency should pre-service teachers possess for effective technological integration in contemporary classrooms?

A list of digital skill areas that pre-service teachers should possess was developed using the Delphi technique to address this challenge. The Delphi technique was used in three phases by researchers. Thirteen experts were asked open-ended questions in the first round to get their thoughts on the digital skills that pre-service teachers should possess. The opinions of the experts were gathered, edited, and collated, and redundant viewpoints were eliminated in the second phase. The same panel of experts was then given these. To create a list of digital skill areas that pre-service teachers should possess, the procedure was repeated in the third phase. These areas included:

- Search effectively for digital resources.
- Ensure the reliability of data.
- Organize data using tools such as Google Sheets or Excel.
- Use collaboration tools such as Google Workspace, Microsoft Teams, or Zoom.
- Manage virtual classes and engage with students across digital platforms.
- Respect digital communication etiquette and information security.
- Design presentations, educational videos, and interactive tests.
- Use tools such as Canva, Genially, or Google tools to create educational content.
- Understand copyright and licensing when using or sharing content.
- Protect personal and student data.
- Identify basic cyber threats.
- Apply digital security practices in the learning environment.
- Be able to handle minor technical glitches.
- Choose appropriate digital tools for learning objectives.
- Adapt to technology updates and learn new tools quickly.
- Be able to create an electronic portfolio.

Question two: To what extent does instruction delivered via a nanolearning-based teaching method produce statistically significant differences in pre-service teachers' mean scores on a standardized digital-skills scale?

To answer this question, the means and standard deviations of the study sample's scores on the digital skills test were calculated, as shown in Figure 9.

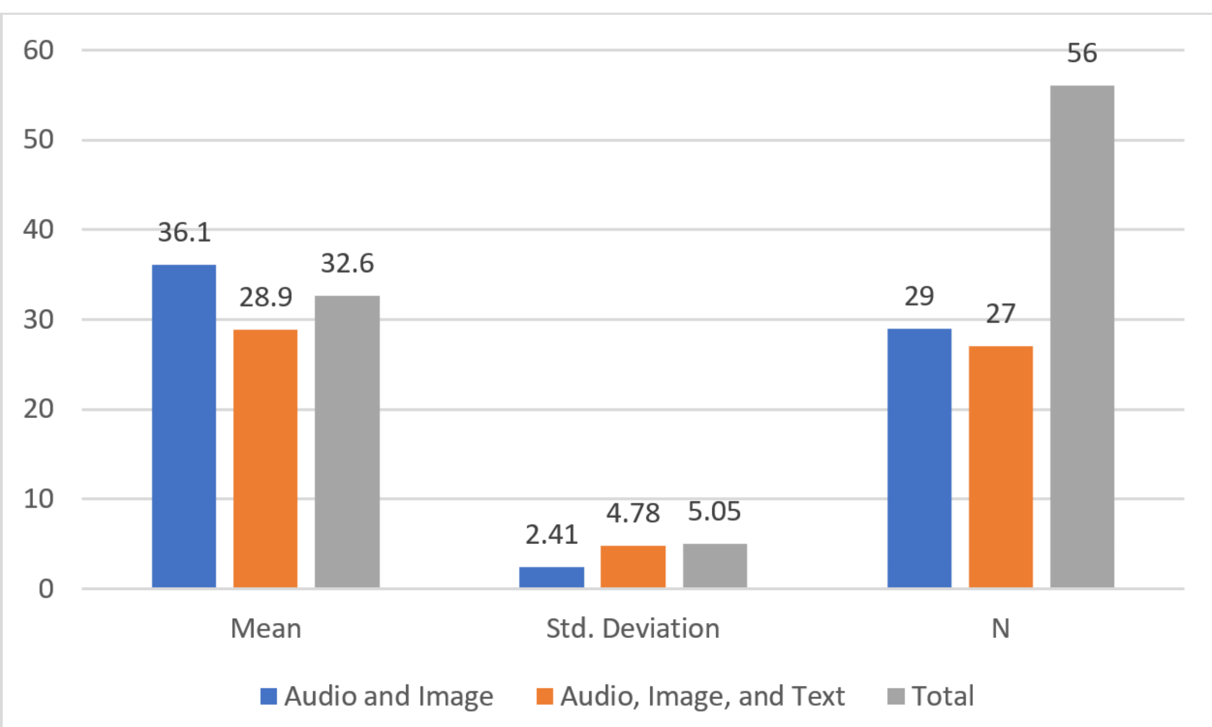

Figure 9. Means and standard deviations of the teachers in the nanolearning method variable.

As shown in Figure 9, the differences in the means and standard deviations among responses from the study sample members to the digital skills test vary with respect to the sample members' responses to the nanolearning method. ANCOVA, analysis of covariance, was used to demonstrate the statistical significance of the differences among the various means, as shown in Table 3.

Table 3. ANCOVA of the post-test scores of teachers in the nanolearning method.

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	984.795	2	492.397	52.397	0.000
Intercept	1349.166	1	1349.166	143.568	0.000
Pre	264.479	1	264.479	28.144	0.000
Groups	671.340	1	671.340	71.439	0.000
Error	498.062	53	9.397		
Total	61154.000	56			
Corrected total	1482.857	55			

The table indicates the presence of significant differences at the ($\alpha = 0.05$) level of significance for the effect of the nanolearning method of teaching on the digital skills test. F-value was 71.439 with a corresponding p-value of 0.000.

The differences were in favor of the nanolearning method (audio and image). To assess the effect of various nanolearning methods on the digital skills of teacher trainees, the researchers calculated eta square (η^2). The value $\eta^2 = 0.4860$ was above ($0.14 \le \eta^2$), which illustrates the effect of nanolearning on the digital skills of teacher trainees to be quite impressive. The ETA square value is interpreted according to the following distribution: The value of the ETA square (η^2) is interpreted according to the following division: From ($0.01 \le \eta^2 < 0.06$), the effect size is minimal. From ($0.06 \le \eta^2 < 0.14$), the effect size is moderate.

From ($0.14 \le \eta^2$), the size of the effect is large. The effectiveness of the nanolearning method in developing digital skills among pre-service teachers was also established. The researchers, for the group of pre-service teachers assigned to the nanolearning technique (audio and image), undertook statistical processing of the findings of the skill test administered before and after the implementation of the strategy. The researchers calculated the mean and standard deviation, and later, the T-test for two paired samples alongside statistical significance to check the differences between the group averages, as presented in Table 4.

Table 4. Significance of the differences between the mean scores of the nanolearning (Audio and image) group in the pre and post-test of the digital skills test.

Nanolearning	Test	N	Mean	SD	t	Sig.
Audio and image	Pre	29	17.37	3.649	-27.451	0.000
	Post		36.01	2.439		

According to the analysis of the findings outlined in Table 4, the differences between means for the group employing nanolearning (audio and image) on the pre and post-digital skills test are a statistically significant difference at the ($\alpha = 0.05$) significance level. The difference in the means was determined by employing the adjusted gain formula; the findings are presented in Table 5.

Table 5. Calculating the effectiveness of the nanolearning (Audio and image) group.

Data	N	Mean of the pre-test	Mean of the post-test	Black	Sig.
Digital skills test	29	17.37	36.01	1.296	Acceptable

Table 5 shows that the degree of effectiveness, based on the adjusted gain value for the digital skills test, is 1.29. This value is greater than 1.2, which is the minimum set by Black for the program's effectiveness. Therefore, it can be concluded that the use of nanolearning in teaching digital skills was effective and contributed to their development among students in the audio and image groups. This indicates that these differences were not a coincidence but rather were influenced by the teaching method.

Question three: What is the distribution of locus of control among pre-service teachers at the Faculty of Educational Sciences, Yarmouk University?

To answer this question, frequencies and percentages were calculated for both internal and external locus of control for the study sample of students from the Faculty of Educational Sciences. Table 6 shows these findings.

Table 6. Classification of pre-service teachers by locus of Control.

Locus of control	Repetitions	Percentage
External	35	62.5
Internal	21	37.5

Table 6 shows that the study sample, consisting of pre-service teachers from the College of Educational Sciences at Yarmouk University, had an external locus of control (62.5%).

Question Four: Are there statistically significant differences in pre-service teachers' mean digital-skills scores associated with differences in locus of control?

To answer this question, the means and standard deviations of the pre-service teachers' scores on the digital skills test were calculated, as shown in Figure 10.

Figure 10 shows that there are some differences in means and standard deviation among responses in the digital skills test across the pre-service teachers for the locus of control variable. To determine the statistical differences among the values, the means of the groups were obtained and analyzed using the ANCOVA test. Table 7.

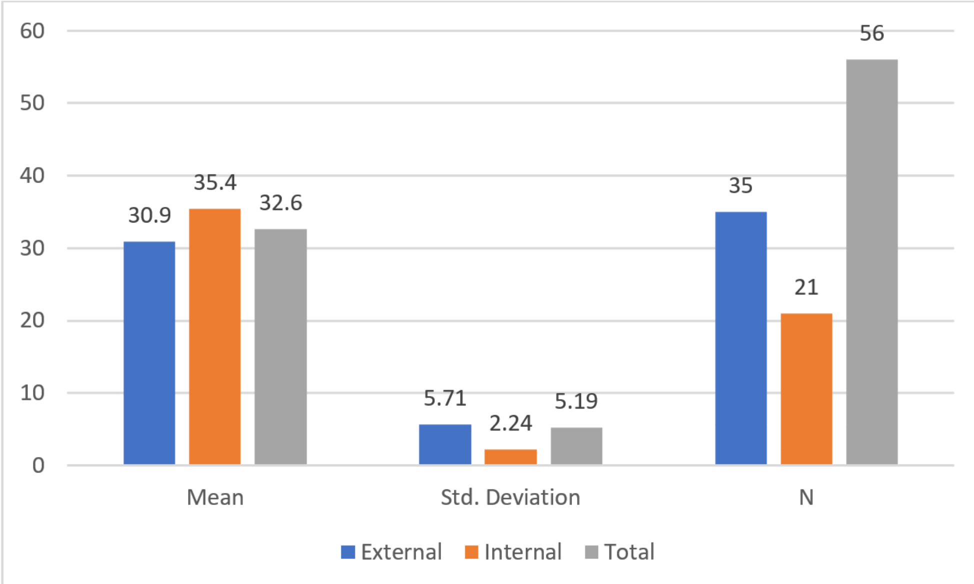

Figure 10. Means and standard deviations of the pre-service teachers in the locus of control variable.

Table 7. An ANCOVA of the post-test scores of teachers in the locus of control variable.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	409.092	2	204.546	10.096	0.000
Intercept	1299.884	1	1299.884	64.161	0.000
Pre	139.358	1	139.358	6.879	0.011
Locus of Control	95.637	1	95.637	4.721	0.034
Error	1073.765	53	20.260		
Total	61154.000	56			
Corrected Total	1482.857	55			

The differences are statistically significant and are noticeable when testing the 'locus of control effect on 'digital skills' ($\alpha = 0.05$). The value of F was 4.721 at $p = 0.034$ level of significance. The differences were indeed in favor of the internal locus of control. To analyze the effect of internal and external controls with their different 'locus of control' on micro 'digital skills' development in pre-service teachers, the value of η square (η^2) was computed, and found to be $\eta^2 = 0.1890$, which is fairly above the accepted value ($0.14 \leq \eta^2$). From ($0.14 \leq \eta^2$), the size of the effect is large. This indeed illustrates the dichotomy in locus of control concerning the development of 'digital skills' in pre-service teachers. Using the control-test approach to 'digital skills development' in pre-service teachers, the effectiveness of the 'Locus of control was also determined, by statistically processing the findings of the pre and post 'digital skills' test in the group, having an internal locus of control as per the test designed to assess the level and degree of retention explained in the passage. The researchers had the group tested for mean, standard deviation, and were also able to postulate what is referred to as paired sample differentiation, along with the presumed test of the differences, within the average of the population sample from which the group was derived, which is referred to as Table 8.

Table 8. Significance of the differences between the mean scores of the internal locus of control in the pre and post-test of the digital skills test.

Data	Test	N	Mean	SD	t	Sig.
Digital skills test	Pre	21	19.285	3.227	22.829	0.000
	Post		35.476	2.249		

The internal locus of control group means scores in the digital skills test pre- and post-application demonstrate marked improvement in effectiveness, which was calculated using the adjusted gain equation in Table 9.

Table 9. Calculating the effectiveness of the internal locus of control.

Data	N	Mean of the pre-test	Mean of the post-test	Black	Sig.
Digital skills test	21	19.28	35.47	1.18	Acceptable

Based on Table 9, the adjusted gain value for the digital skills test is (1.18), indicative of the effectiveness, and this value is below the value of 1.2 that Black designated as the lower bound for the effectiveness of the program, thereby suggesting that it is reasonable to say that the locus of control is effective in fostering digital skills, not high though.

Question five: Among pre-service teachers characterized by an external locus of control, does the nanolearning-based teaching method produce statistically significant differences in digital-skills test scores?

To answer this question, the means and standard deviations of the external locus of control pre-service teachers' scores on the digital skills test were calculated, as shown in Figure 11.

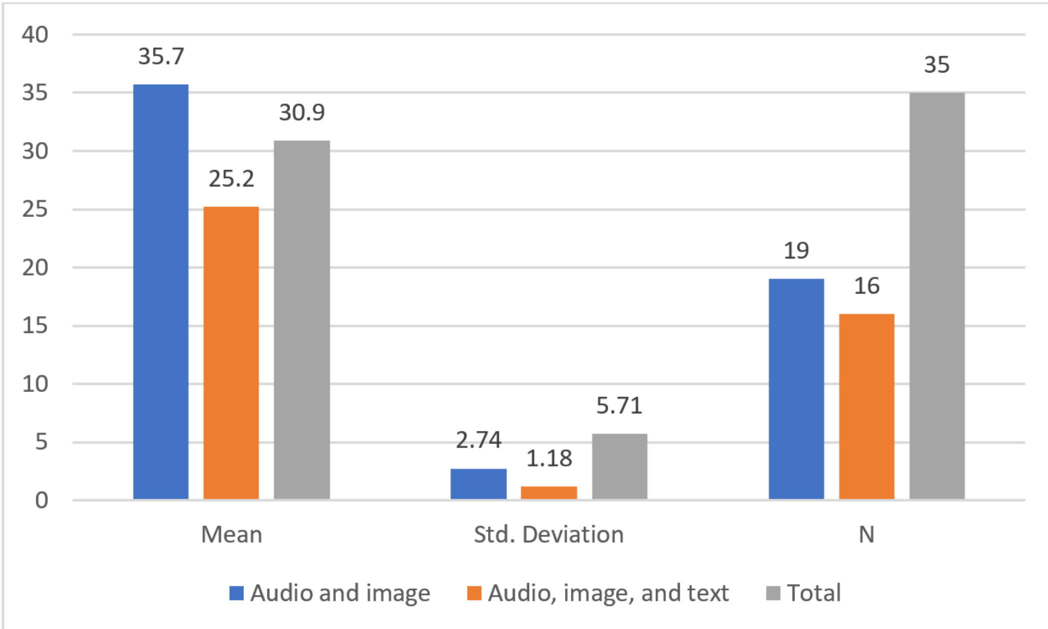

Figure 11. Means and standard deviations of the external locus of control of pre-service teachers in the nanolearning method.

According to Figure 11, there appears to be a difference in the means and standard deviations of the study sample respondents when measuring scores on the digital skills test using the custom nanolearning method variable for individuals with an external locus of control. To illustrate the significance of the statistical differences between the means, the analysis of covariance (ANCOVA) test was employed in Table 10.

Table 10. ANCOVA of the post-test scores of the external locus of control of pre-service teachers in the nanolearning method.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	970.505	2	485.252	109.831	0.000
Intercept	1215.222	1	1215.222	275.052	0.000
Pre	15.303	1	15.303	3.464	0.072
Groups	827.704	1	827.704	187.341	0.000
Error	141.381	32	4.418		
Total	34623.000	35			
Corrected Total	1111.886	34			

The differences in means still favored the nanolearning method (audio and image). F was calculated as 187.341 with a p-value of 0.000. The author computed eta square (η^2) to see how some specific method of nanolearning might influence the formation of digital skills in pre-service teachers with an external locus of control. Pre-service teachers with an external locus of control (η^2) 0.8590) were under a considerable influence of nanolearning in the acquisition of digital skills. From ($0.14 \leq \eta^2$), the size of the effect is large. The researchers also ascertained the effectiveness of nanolearning in the formation of digital skills in the group of pre-service teachers with an external locus of control through the statistical processing of findings obtained from the applied digital skills tests before and after the intervention. The author applied descriptive statistics, computing mean and standard deviation, and used the paired-sample t-test to prove the differences between mean scores of the experimental group in the pre-test and post-test, which are highlighted in Table 11.

Table 11. Significance of the differences between the mean scores of the nanolearning (Audio and image) group in the pre and post of the digital skills test with an external locus of control.

Data	Test	N	Mean	SD	t	Sig.
Digital skills test	Pre	19	16.78	3.809	-20.904	0.000
	Post		35.73	2.745		

As seen in Table 11, the mean of the scores obtained by the nanolearning groups (audio and image) pre and post-test, particularly the pre-service teachers with an external locus of control, demonstrates that there is an efficient, effective, and statistically significant difference at the p=0.05 level. Further analysis of the effectiveness was performed with the adjusted gain method, and the findings can be seen in Table 12.

Table 12. Calculating the effectiveness of the nanolearning (audio and image) group with an external locus of control.

Data	N	Mean of the pre-test	Mean of the post-test	Black	Sig.
Digital skills test	19	16.78	35.73	1.291	Acceptable

According to Table 12, the effectiveness, based on the adjusted effectiveness score, the mastery of the digital skills test attains a score of (1.29), and, since this score is higher than 1.2, the lowest Black proposed for the effectiveness of the program, the conclusion is that the effectiveness of the use of nanolearning in teaching digital skills is confirmed. It has been shown that students in the audio and video groups have made considerable improvements. It has been proven that the differences observed were due to the use of the teaching technique.

Question six: How do pre-service teachers perceive the effectiveness, usability, and relevance of nanolearning for developing digital competencies?

To answer this question, the researchers adopted a qualitative approach. The researchers conducted open-ended interviews with a group of pre-service teachers in the College of Educational Sciences at Yarmouk University (the study sample). After preparing and setting up the interviews, the researchers worked with a sample of pre-service teachers from the College of Educational Sciences, Yarmouk University, as part of the study. The sample was selected purposively. Each participant was briefed that the information and data collected would be used strictly for research and would be kept confidential. They provided written consent before the interviews commenced. Because the participants' responses reflected positive perceptions toward the impact of nanolearning on the acquisition or development of digital competencies, the researcher conducted four subsequent individual interviews, which ranged from 15 to 25 minutes each. The participants agreed to have the interviews audiotaped, and the researcher transcribed the interviews word for word. The researcher edited the transcripts after comparing them with the recordings to ensure that the transcripts were accurate and reliable. The transcribed data were used to conduct a detailed analysis and thorough review of the data to record the transcripts. The researcher read the transcripts multiple times for accuracy and then established clear definitions for the topics, which were aligned with the research questions, to present the findings, accompanied by direct quotes from the participants to enhance the presentation of findings. Alaa noted that nanolearning is integrated, concept-focused, and, as such, benefits. It is a highly effective tool for developing essential digital skills. She believes this method is beneficial for pre-service teachers, as it provides the opportunity to teach the required digital skills in a shorter and more streamlined educational process than the time-consuming traditional curriculum. On the other hand, Hadeel stressed the applicability and flexibility of nanolearning. She expressed that this type of learning provides her with the ability to learn and complete her tasks at her own pace, while educational activities and documents are available to her at any time and in any location of her choosing. This is perfect for her as a student with a packed schedule, as it allows her to learn a new attribute during a busy time and to complete activities when she has the time, without a rigid deadline. Sarah stated that nanolearning is primarily constructive in cultivating a more practical-focused and useful pedagogy. Rather than concentrating on theoretical frameworks, this type of learning provides future educators with the skills and knowledge needed to effectively teach in a classroom. This is useful because it gives educators the skills and tools to implement in their practice. On the contrary, Rama thinks that later nanolearning has even more constructive aspects, such as more flexibility and more rapid information delivery. The absence of a real teacher may inhibit the development of some important skills, such as critical thinking and collaboration. This means that this kind of learning cannot replace the benefits of group debates and engagement with teachers, key parts of the knowledge and skills-building process.

5. Discussing Results

5.1. Nanolearning

The findings demonstrated how well nanolearning works to help pre-service teachers with their digital literacy. This conclusion is explained by the fact that the creation of brief, easily comprehended videos greatly aided in the growth of digital abilities. Nanolearning relies on presenting educational content in small, concentrated units that do not exceed a few minutes. This enabled teachers to access these units anytime, anywhere, whether on their smartphones or computers, which perfectly suits their busy schedules and allows them to learn during short breaks. Since the content is short, the focus is on a single, specific digital skill at a time, such as how to use a specific educational application or an interactive tool. This prevents cognitive overload and makes the information easy to comprehend. It often focuses on the practical aspect. For example, nanolearning also allows for the rapid publishing and updating of content to add new skills or update the use of existing tools, ensuring that the trainee teacher is always learning the latest technologies. Nanolearning with audio and images was superior to nanolearning with audio, images, and text, according to the CTML. Because it is more in line with the speed needed for nanolearning, learners could like the mode that lets them concentrate on auditory and visual explanations. Cognitive overload can result from presenting information in numerous media at once, including text, images, and audio. The learner's cognitive capacity may be exceeded while trying to process text, images, and audio simultaneously, making it difficult to understand and apply the information. On the other hand, information processing is more seamless in the audio-and-visual-only mode, which is consistent with the human information processing system. The human information processing system, according to CTML, depends on two separate channels, each with a finite processing capacity: the auditory channel for sound and the visual channel for text and images. When written text, audio, and images are given in an educational setting, they vie for the visual channel, increasing the cognitive burden and diverting the learner's focus, as shown in Figure 12.

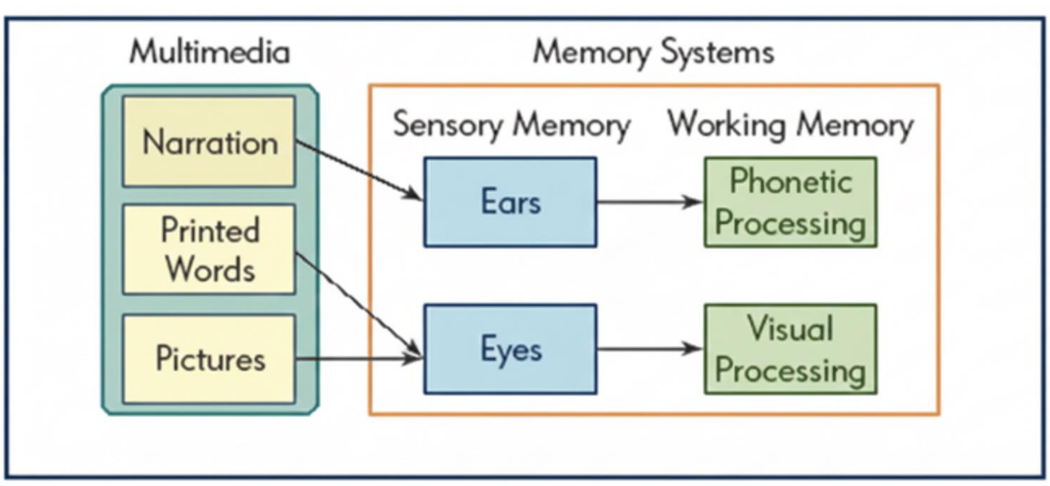

Figure 12. Redundancy Principles (Mayer, 2024).

In this instance, nanolearning is perceived as an innovative and feasible approach, given its text-to-speech feature and picture-based stimuli. The use of written text is eliminated, and cognitive processing is directed toward the auditory channel. This auditory processing, coupled with picture processing, optimally frees the cognitive efforts directed toward the visual channel. This method also aids the cognitive processing of the visual channel by allowing it to work more effectively in the processing of pictures, as shown in Figure 13.

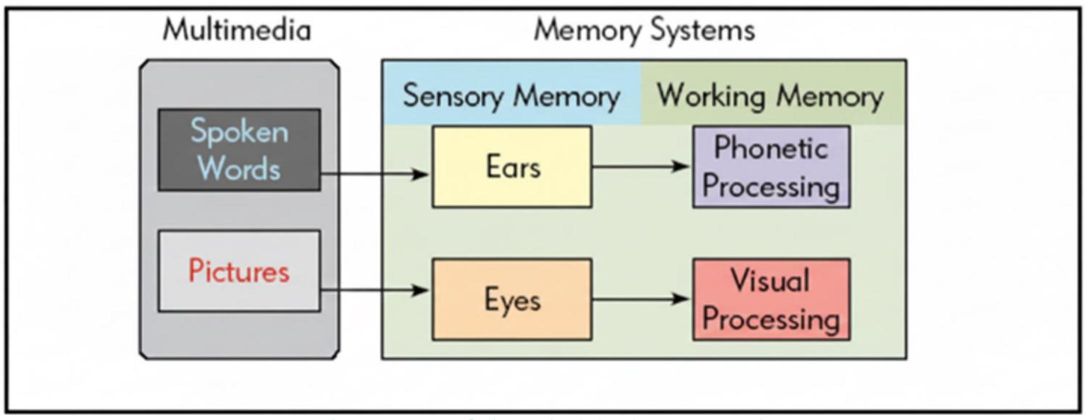

Figure 13. Modality Principles (Mayer, 2024).

According to findings revealed in several studies carried out by Mayer (2024), Teng (2023), and Fong and Aldalalah (2010), this equilibrium reduces the strain on working memory, which in turn enhances the learner's ability to organize and retain information in long-term memory and increases the effectiveness of knowledge acquisition. Because written text and images compete for the visual channel's limited processing resources, the study also demonstrates that presenting both together causes cognitive overload. Because students must split their attention between the two components, this overload strains their mental abilities and hinders learning. However, since audio is processed in the auditory channel and visuals in the visual channel, replacing written text with audio reduces this load and produces balanced and effective information processing. Additionally, compared to their counterparts who used the nanolearning technique with "audio, visuals, and text," teachers with an external locus of control who utilized the nanolearning technique with audio and visuals showed superior success in building digital abilities. Teachers who have an external locus of control typically think that their results are determined by outside variables (such as the classroom setting, instructional resources, or good fortune). The teacher may believe that available tools are simple when using the nanolearning technique with just audio and pictures, which lessens their sense of pressure and boosts their confidence in their ability to provide the intended results. The way teachers present the instructional material may reflect this optimism, which has an impact on students' learning (Fong & Aldalalah, 2010).

5.2. Locus of Control

The results of the study showed that Yarmouk University pre-service instructors have an external locus of control. This outcome could be explained by the nature of student teaching, which necessitates a high level of control over the outside world. The instructor sets up the classroom, regulates activities, and oversees student conduct. The idea that their results depend more on these outside variables than on their own efforts may be strengthened by this emphasis on managing external elements (i.e., the student and the environment).

Additionally, being "pre-service" teachers means they are still in the academic study and training phase. It is also worth noting that they are still in the academic study and training phase. This results in novice teachers feeling as though they are operating in a quasi-compliance mode, where the outcomes of their work, in this case, the evaluation, are a function of their adherence to the directions given by the supervisor, rather than a reflection of their individual contributions. The profession of teaching elementary school children is one field that requires a great deal of environmental adaptability, coupled with a keen tendency to focus on external criteria. This phenomenon was also evident in the results, where teachers with an internal locus of control performed better on the digital skills post-test than those with an external locus of control.

This supports previous studies highlighting the influence of the internal locus of control on the enhancement of digital competencies (Althubaiti et al., 2025; Febriyanto et al., 2025; Kader, 2022). This finding can be explained by the fact that teachers, with an internal locus of control, personally take responsibility for their actions and the outcomes. They believe that they can control the factors that determine their performance and academic achievement. Thus, they actively participate in the learning process, as they are convinced that their skills and efforts are the most important determinants of the outcomes of their activities. On the contrary, teachers with an external locus of control tend to attribute success or failure to some external factors, such as luck and/or fate, disregarding the role of talent, effort, and/or skills, and as a result, they set low expectations for their students, believing that effort will not make a difference.

6. Conclusion

Using Locus of Control and Cognitive Theory of Multimedia Learning (CTML), the researcher in this mixed-method, quasi-experimental study focused on the impacts of nanolearning on the digital skills of pre-service teachers. The researcher conducted pre and post-tests on a sample of 56 teachers, and then randomly assigned them into 2 experimental groups. For the research, the teachers' views on nanolearning, the locus of control scale, and the digital skills test were administered qualitatively. Also, the three-stage Delphi method was utilized to qualitatively describe the target digital skills.

The researcher found that the experimental group that used nanolearning (audio and image) with an internal locus of control developed digital skills better than the other groups. Additionally, the teachers with an internal locus of control were able to improve their digital skills better than those with an external locus of control. Overall, the teachers expressed their views positively on the use of nanolearning to improve digital skills. Thus, the researcher suggests that nanolearning should be integrated into the curriculum of faculties of education in Jordanian universities. The researcher found that nanolearning is a good tool for fostering the development of digital skills, especially with the use of multimedia.

7. Recommendations

The researchers made a few important suggestions after considering the findings of the study. They recommended the use of nanolearning in the education of pre-service teachers and suggested focusing on locus of control during pre-service teacher training. They also recommended the creation of short interactive instructional materials that comply with the principles of Cognitive Theory of Multimedia Learning (CTML). The researchers also suggested that to stay current, the Delphi technique be employed to identify and update the list of necessary digital competencies of educators. Lastly, they suggested conducting more qualitative research in the form of focus groups or interviews to explore the lived experiences of teachers in more depth.

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