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Research article

NANO-MOOCs to train university professors in digital competences

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ABSTRACT

Rapid changes in technology force Higher Education Institutions (HEIs) to generate policies and permanent digital adaptations in their exercise of forming professionals through university professors. HEIs -in their permanent desire to qualify teaching faculty and graduate high-level professionals-develop continuous training events to strengthen and update techno-pedagogical skills that allow giving concrete responses to the needs of a globalized society during a human-educational crisis that arises from the COVID-19 pandemic. This study aims at analyzing whether nano-MOOCs improve digital teaching competences in university professors since in the scientific literature, this topic does not show with certainty the effectiveness of these types of courses in teacher training. By conducting a quantitative descriptive-inferential, comparative quasi-experimental research (pre-test and post-test) and with a sample made up of 297 faculty members from Universidad Técnica del Norte (UTN, Ibarra-Ecuador) belonging to the five academic units that compose it, it was identified that the teaching staff has limitations in two of the areas of competence that are articulated by INTEF Common Framework: creation of digital content and security; nevertheless, they did show optimal skills in the areas of information and information literacy, communication and collaboration, and problem solving. The findings also determined that online training based on a nano-MOOC format becomes a successful alternative for university faculty training, 83.84% of the participants under study improved their level of digital competence. These results show that an efficient customizable training can be achieved in less time and adjusted to the needs and characteristics of the professors. The criteria of various authors in this field are ratified with this research, it is, therefore, relevant to evaluate the level of digital competence of teachers and, based on that, be able to plan a personalized training program.

1. Introduction

The abrupt arrival of technical-technological innovation tools in Higher Education has led to develop new digital ecosystems and pedagogical models where the teaching-learning process is not based on physical and individual interactions between the teacher and the student. Massive open online free courses, also known as MOOCs, are an example of this educational approach. The objective of MOOCs is to facilitate the acquisition or updating of knowledge on a continuous and permanent basis through open access to high-quality educational didactic resources (Rizvi et al., 2022).

At the moment, family and educational environments look for a permanent, growing and systematic offer of open and free online courses. These are offered and required from sectors of the population of all kinds in the world (Abad et al., 2014), despite its popularity, this system continues to show high dropout rates (Luik and Lepp, 2021), only 5% and 10% of the people who enroll complete and finish a course in a MOOC format (García-Peñalvo et al., 2018). Recent studies indicate that this issue is due to various factors, including: users' individual behavior, context (geographical, socio-economic, cultural, among others) in which they develop (Rizvi et al., 2022) and the instructional design (ID) of the course (Gómez-Galán et al., 2017).

The instructional design in a MOOC plays a fundamental role when it comes to plan, develop, and implement a course; it focuses on the analytical and systemic process to integrate technology in a techno-pedagogical way with the theoretical-practical content, resources (texts, videos, forums, images, podcast, simulators, among others), learning activities and evaluations necessary to generate a virtual environment that favors the construction of knowledge and the user's persistence. In some cases, MOOCs present a simple, traditional ID

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without major methodological innovations (Gómez-Galán et al., 2017); that is, they concentrate on presenting a series of resources (videos) and activities in a uniform way and with a predetermined sequence (Rizvi et al., 2022), causing the student to lose interest and not complete or finish the course.

On the other hand, Reparaz et al. (2020) point out that one of the variables related to dropping out a MOOC is motivation; that is, the interest and level of involvement with the academic contents and activities of the course to promote learning and professional development (Estévez et al., 2021). University professors can make the decision to enroll in a course motivated by their desire to learn, increase their confidence, improve the quality of the teaching-learning process, obtain a certification that guarantees their knowledge, and even avoid criticism from colleagues and students (Ryan and Deci, 2020). In this regard, users can choose only parts of a MOOC according to their goals or interests (Maya-Jariego et al., 2020).

Within this setting, the development of a Nano-MOOC or Nano Open Online Course (NOOC) arises, and it refers to a micro course (nano-course) that is developed in a "just in time" way, which means that users can achieve the skills required in a short time to improve their digital competence and perform more effectively in the personal and professional spheres (Basantes-Andrade et al., 2020a). On the other hand, Sánchez-Azqueta et al. (2019) consider that NOOCs are small training doses that, within a broad learning program, represent a specific topic that can be spread or disseminated in an isolated way.

Nano-MOOCs maintain the MOOC philosophy, online and open courses; the main difference between the two lies in the duration (estimated time) to complete the online course. Time-and-dedication relationship in hours and weeks that the user (student-participant) requires to complete the course in a MOOC is between 32 to 72 h, while in a nano-MOOC is between 1 to 20 h (Benavidez et al., 2019). Users can choose and academically pass each of the NOOCs by completing a certain number of learning hours (LH) and receive a certification (diploma or badge) that validates their participation.

For Basantes-Andrade et al. (2020a) personalized development of a course in nano-MOOC format implies addressing a specific topic based on the analysis of the following key factors: context (where?), Users (for whom?), Objective (for what?) and strategies (how?) the latter should be a nano-learning experience (topic, time, learning content, activities, assessment, and certification). Higher Education Institutions that produce nano-MOOCs must be clear about these key factors in order to respond effectively to the academic-training requirements and teaching staff needs, combining theory and methodological practices of ICT in the development of their daily work.

Tourón et al. (2018) and Gómez-Galán et al. (2017) suggest that knowledge updating and improvement of university actors should be considered under a corporate education perspective and according to their training needs. This study allows to approach the use of new learning ecologies in the teacher training process. It contributes to the scientific-academic literature with the results of the implementation of nano-MOOCs to improve university professors' digital skills, who are the protagonists of their learning experience (Estévez et al., 2021) to innovate and apply teaching-learning techno-pedagogical proposals in the educational environment, in which, technology is a fundamental part of various personal and professional activities of both teachers and students.

2. Teacher digital competence

The concept of digital competence originated in 2006 as one of the eight key competences proposed by the European Parliament and the Council to strengthen lifelong learning, which stems from the need to develop the skills and abilities required to perform effectively and efficiently in the personal and professional sphere throughout life (Rodríguez-García et al., 2019). ICTs went from being supporting tools in the classroom to becoming an indispensable part of current pedagogical processes (López-Belmonte et al., 2019). In order to effectively integrate ICT in the classroom, it is necessary to establish the relationship between technology, pedagogy, and content (Habibi et al., 2020), where not all teachers have the necessary prior training (Garzón-Artacho et al., 2021).

The demands and requirements of the digital society, and particularly in the midst of a pandemic caused by COVID-19, requires teachers to train, update or improve their knowledge, as well as their instrumental, cognitive, attitudinal and digital skills to provide an effective response to this training modality. Consequently, the necessity to develop teacher digital competence (TDC) arises, being this understood as the sum of techno-pedagogical and communicative skills to function effectively in the new educational contexts that technologies are generating (Basantes-Andrade et al., 2020a).

During the last years, digital competence has been the focus of attention, analysis, and study by the scientific community in recent years. There are several publications that have emerged in the educational technological field at different levels and contexts, where they coincide in the need to train teachers to redefine their role according to the demands of the global environment in which they operate (Rodríguez-García et al., 2019; Nyikes, 2018; Caena and Redecker, 2019; among others); given this requirement, various international institutions have developed models and conceptual frameworks with the aim of establishing a common reference that allows characterizing teacher digital competence, its areas, dimensions, standards, among other aspects.

Cabero-Almenara and Palacios-Rodríguez (2020), Cabero-Almenara and Martinez (2019), Lázaro-Cantabrana et al. (2019), Padilla-Hernández et al. (2019), Rodríguez-García et al. (2019) and Silva et al. (2019), point out the following frameworks as the more solid: UNESCO-ICT Competency Framework for Teachers, Digital Competence Framework for Educators (DigCompEdu), International Society for Technology in Education (ISTE) Framework for teachers and the Common Digital Competence Framework for Teachers (INTEF). Beyond the similarities or differences that can be found in this classification (Table 1), all of them concur on the use of technology to transform personal and professional productivity focused on the demands of the 21st century.

Based on these frameworks, Cabero-Almenara et al. (2020) conducted an assessment study through expert validation. The results obtained determined that the European Framework for the Digital Competence of Educators (DigCompEdu) stands out from the rest, being followed by the Common Digital Competence Framework for Teachers (INTEF). On this issue, they stated that the result is logical because INTEF was based on the DigCompEdu project for its development. It should be noted that this study is not decisive in the use of DigCompEdu since the results arise from the experts' appreciation in the Spanish context. In this research, the INTEF common framework was considered as a reference due to its approach and similarity with the sample under study.

Teacher digital competence frameworks have determined a line of research focused on achieving educational quality through the use of technology. Several studies analyze and compare these frameworks in order to establish their main characteristics and differences in teacher training (Cabero-Almenara et al., 2020; Prendes et al., 2018; Castañeda et al., 2018; among others). Other researchers have focused their interest on determining the relationship between digital competence with demographic variables such as gender, age, generation, academic level, among others (Casillas-Martín et al., 2020; Basantes-Andrade et al., 2020b; Cabrera et al., 2019; Beltrán and Vota, 2018; among others) however, it is not yet possible to generalize or extrapolate the results obtained in each of these investigations, given that the context in which they are developed is different.

As evidenced in the bibliographic review, the development of teacher digital competence is approached from different angles, the objective of this paper is to analyze whether nano-MOOCs improve teacher digital competence of university professors.

Table 1. Teacher digital competence conceptual frameworks.

Conceptual framework	Publication	Areas or Dimensions	Levels
UNESCO ICT Competency Framework for Teachers	2019	- Understanding the role of ICT in education - Curriculum and evaluation - Pedagogy - Use of digital skills - Organization and administration - Teacher Professional learning	- Knowledge acquisition - knowledge deepening - Knowledge creation
Digital Competence Framework for Educators (DigCompEdu)	2017	- Professional Engagement - Digital Resources - Teaching and Learning - Assessment - Empowering Learners - Facilitating Learners' Digital Competence	- Newcomer (A1) - Explorer (A2) - Integrator (B1) - Expert (B2) - Leader (C1) - Pioneer (C2)
International Society for Technology in Education (ISTE) Framework for teachers	2017	- Empowered professional - Learning catalyst	- Apprentice - Leader - Citizen - Collaborator - Designer - Facilitator - Analyst
Common Digital Competence Framework for Teachers (INTEF)	2017	- Information and Information literacy - Communication and collaboration - Digital content creation - Security - Problem solving	- Basic - Intermediate - Advanced

3. Methodology

This study is a descriptive-inferential, comparative quasi-experimental type of research since the cause-effect relationship is studied (Posso, 2011); in other words, two stages were carried out: a diagnostic study (pre-test) and a further analysis after the training of faculty members through nano-MOOCs (post-test). The objective of this paper is to analyze whether nano-MOOCs improve university professors' TDC. The population under study consisted of 588 faculties from UTN, distributed in all academic units: Education, Science and Technology (FECYT, acronym in Spanish); Administrative and Economic Sciences (FACAE); Engineering in Agricultural and Environmental Sciences (FICAYA); Health Sciences (FCCSS); Engineering in Applied Sciences (FICA); and the Graduate Faculty (IP).

The simple random sampling calculation of this finite population established a 96% of reliability and a margin of error of 4%. For the distribution of the sample, it was necessary to carry out a proportional allocation in both faculties and gender. The total consists of 297 professors, of whom, 34.34% are women and 65.66% are men. 45.12% of the professors are between 20-40 years old, 39.73% between 41-55 and 15.15% between 56-74 years old. for the inferential and descriptive analysis of the data, the SPSS v22.0 statistical software was used.

The research questions were the following: What level of digital competence do UTN professors have? And do courses with nano-MOOC format allow to improve teachers' digital competence? In order to answer the first question, a questionnaire was designed based on the five areas of competence according to INTEF (2017); For each of these, a specific number of items was grouped (Table 2).

The pre-test was applied over the use of ICT in teaching with a total of 33 items; a Likert scale was established for each item as an ordinal psychometric instrument, made up of five response alternatives, in order to avoid bias and increase the reliability of the questionnaire, ranging from 1 corresponding to "I do not use it", 2 corresponding to "I use it a little", 3 corresponding to "I use it moderately", 4 corresponding to "frequently" and 5 corresponding to "I use it very frequently." This instrument was validated by ten experts and has a reliability (α) of 0.9370. A factorial analysis was integrated into this process as one of the most applied methods to obtain evidence on the validity of a construct (Morata-Ramírez et al., 2015), through which it is confirmed that the 33 items that make up the research instrument have a very high reliability (0.919); therefore, it could be applied with guarantees of soundness in the investigation.

Table 2. Areas of digital competence and description per item.

Areas of digital competence	Description of the items
Information and information literacy	Web browsing. Online storage. Information management. Teaching portfolio. Office automation. Online professional improvement and updating. Basic technological solutions.
Communication and collaboration	Online communication. Bibliographic databases and managers. Network collaboration. Social networks. Use of mobile devices
Digital content creation	Effective presentations. Augmented reality. Interactive videos. QR code. Podcast Timelines and infographics. Graphic organizers. Gamification. Shared and collaborative learning. Online assessment
Security	Digital identity. Dissemination and visibility of the research. Netiquette. Data protection and copyright. Energy saving. Digital security systems
Problem solving	Basic configuration of digital devices. Recover deleted files. Connectivity. Virtual learning environments. Solution of academic-educational problems through technology.

All this work was conducted in accordance with the Ethical Guidelines for Educational Research of the British Educational Research Association (BERA, 2018) and the code of ethics of Universidad Técnica del Norte (UTN, 2012). The teaching faculty who voluntarily decided to participate in this study signed a written informed consent form. This study was approved by the Ethics Committee of the University Center for Scientific and Technological Research (CUICYT) of Universidad Técnica del Norte (N° 0000000691) in order to guarantee confidentiality and anonymity of the participants. The same instrument was applied for both pre-test and post-test.

Using the pre-test results, an online training proposal based on nano-MOOC was made. In the first instance, two pilot courses were implemented in order to check its functionality and improve later editions. Five courses were developed using the Moodle platform, called ABNOOC, which covered two areas of competence in which the participants showed greater limitations: areas 3 and 4 regarding digital content creation and security. The topics covered were: 1) Symbaloo: personalized learning itineraries; 2) Effective online presentations; 3) Sway: tool for Flipped Classrooms; 4) Security and data protection; and 5) Copyright.

The PACIE methodology was used as an instructional design for the Virtual Learning Environment. This presents an innovative approach that allows to strengthen the student's micro-curricular objectives achievement, supported by the communicational and didactic tools provided by ICT, and focused on mediation and tutoring (Basantes et al., 2018).

The structure of nano-MOOC courses, according to the methodology mentioned, is divided into three blocks (Basantes-Andrade et al., 2020a): 1) PACIE or zero, which focuses on the management, communication and interaction of students with the virtual learning environment; 2) academic, which contains the compulsory and complementary study material in various digital formats in order for the student to develop the academic activities previously planned and, after an evaluation, assess the knowledge and the learning achievements; and 3) closing, which allows to give a response to any concern or to an unfinished process in the course.

Table 3 shows the internal structure of nano-MOOCs in this study, which are based on the three PACIE blocks, these group the resources and teaching strategies according to their nature and functionality.

All courses in nano-MOOC format were implemented with a duration of 180 min and the post-test was applied after completing them. The pre-test was the first activity that the professors performed, while the post-test was carried out later. Descriptive and inferential statistics were used to analyze the data obtained from the two questionnaires in order to extract useful inferences for the research community (Hernández-Sampieri and Torres, 2018). The non-parametric Kolmogorov-Smirnov test was used in order to verify whether or not the sample scores follow a normal distribution, and the non-parametric Wilcoxon test was applied in order to verify the second question of this research and know if there were statistically significant differences.

4. Results

4.1. Pre-test results

The results from applying descriptive statistics show a global vision of the competence under study that UTN faculty have. With the frequency of use of technology in the five areas of digital competence based on INTEF, a weighted value of 3.21 was obtained as a measure of central tendency, in general, the respondents put moderately their digital competences into practice (Figure 1).

Figure 2 shows the comparison of the difference in the means obtained in each of the areas of competence (Area 1: Information and Information Literacy; Area 2: Communication and Collaboration; Area 3: Digital Content Creation; Area 4: Security and Area 5: Problem Solving) between the academic units at UTN.

After determining the non-parametric nature of the data distribution, the Kruskhal-Wallis test (Table 4) was used to find out if there are significant differences between the areas of competence. The results revealed that university professors have greater limitations in area 3: creation of digital content and area 4: security.

Considering the results obtained, along with the high acceptance of university professors (93.27%) to update or improve their knowledge of digital skills through nano-MOOC, teacher training was planned and executed according to their training needs in areas 3 and 4.

4.2. Pre-test and post-test analysis results

To start the comparative analysis between pre-test and post-test, the Kolmogorov-Smirnov statistic was used (Table 5) in order to verify the normality of the data, and based on this, apply a parametric or non-parametric test. For this purpose, two hypotheses were raised: a) H_1: the data did not come from a normal distribution and b) H_0: the data came from a normal distribution.

As it can be seen in all areas of digital competence, p. value is < 0.05, therefore, H_0 is rejected and the alternative hypothesis (H_1) is accepted since the data do not come from a normal distribution; therefore, in order to perform the comparative analysis in a related design, the nonparametric Wilcoxon test was used. The results from the comparative analysis between the pre-test and the post-test based on the averages obtained from the two competence areas addressed in this study (creation of digital content and security) show a positive variation in the level of digital competence (Table 6) of the professors participating in the study.

Two hypotheses were established independently for each addressed area: H_0: There is no significant difference between the pre-test and post-test in relation to areas 3 and 4; H_1: There is a significant difference between the pre-test and post-test in relation to areas 3 and 4. In both cases the null hypothesis is rejected, and the alternate hypothesis is accepted since p. value is < 0.05; therefore, there is a significant difference between the pre-test and the post-test in relation to areas 3 and 4 of digital competence. In area 3 of competence (digital content creation), 225 teachers improved their average with respect to the pre-test while only 72 of them remained with the same level of competence. This means that there was an increase of 75.75% of people who use tools for Digital Content Creation. Regarding area 4 (security), 127 faculty members improved their digital competence between the beginning and the end of the intervention (training through nano-MOOC) whereas 170 university professors kept the same pre-test result. There is an increase of 42.76% of professors who use tools for Security.

Finally, a general comparative analysis of teachers' digital competence was performed (Table 7) and two hypotheses were proposed: a) H_0: the use of nano-MOOC does not allow teacher training in digital competences in less time and b) H_1: the use of nano-MOOC allows teacher training in digital competences in less time.

Since p. value is < 0.05, the alternative hypothesis is accepted and the null hypothesis is rejected, therefore, the use of nano-MOOC allows teacher training in digital competences in less time. The 249 teachers involved in the training have improved their level of digital competence in comparison to the pre-test results. It should be noted that 16.16% (48 professors) of the faculty obtained the same result as in the pre-test; therefore, there is a significant increase of 83.84%, which shows an improvement regarding the practice of their digital competencies using nano-MOOCs.

Table 3. Internal structure of nano-MOOC courses.

PACIE/nano-MOOC Blocks	Sections	Level of learning	Contents-description	Teaching strategies	Resources
Block zero (Starting phase)	Information	Basic	Tutor teacher introduction and nano-MOOC course description (objectives, content organization, learning methodology, timing, evaluation rubric)	Learning Profile configuration in Moodle First survey on course interest Introduction of participants	Video recorded by experts Online survey (Forms) Forum-video (Flipgrid)
	Communication	Basic	Introduction to the environment Communication channels		(Wink) multimedia Tutorial
	Interaction	Basic	Social and supportive	Participation	Forum
Academic block (Development phase)	Exposition	Intermediate	Objective		Resources-platform
			Thematic contents	Masterclass	Interactive multimedia Resources (web 2.0 y 3.0)
	Rebound	Intermediate	Self-criticism activity	Discussion forum	Moodle forum
	Construction	Higher	Activity assignment	Workshop: peer review (P2P) Study of cases	Resource-platform (peer review P2P)
	Verification	Higher	Dissemination of results or Evaluation	Learning assessment	Resource-platform (peer review P2P)
Closing block (Closing phase)	Negotiation	Intermediate	Certification (badges)	Certification with QR code	Resource-platform
	Feedback	Higher	Survey	Satisfaction final survey	Online survey (Forms)

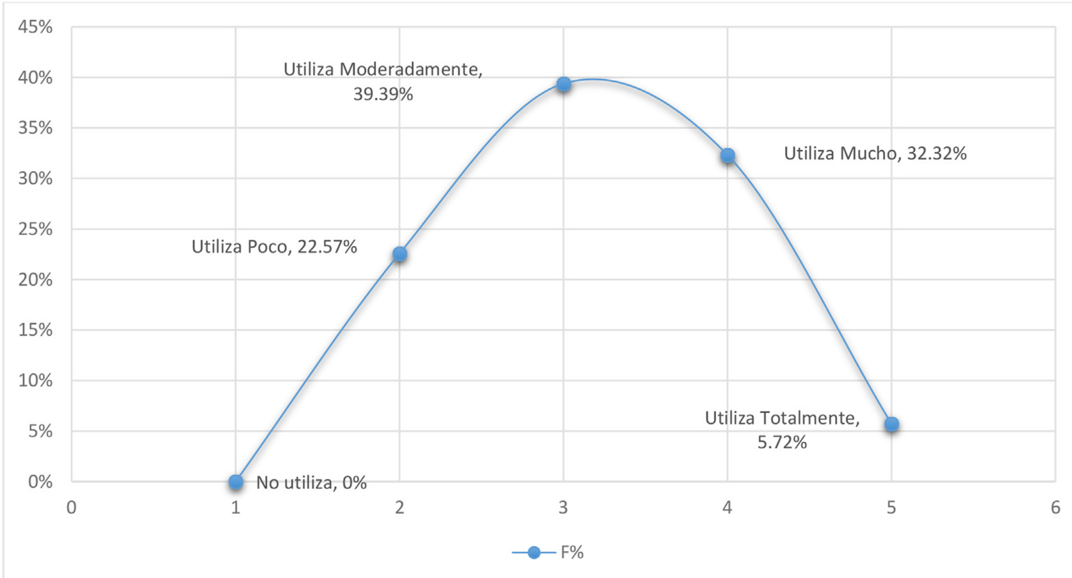

Figure 1. University faculty digital competence according to their own perception.

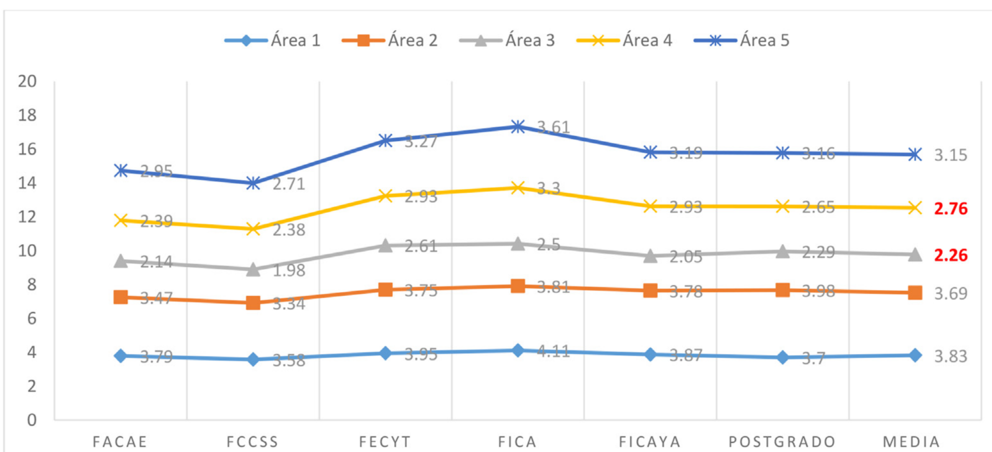

Figure 2. Average by areas of teacher digital competence, pre-test. Note: FACAE, Faculty of Administrative and Economic Sciences; FCCSS, Faculty of Health Sciences; FECYT, Faculty of Education, Science and Technology; FICA, Faculty of Engineering in Applied Sciences; FICAYA, Faculty of Engineering in Agricultural and Environmental Sciences and IP, Faculty of Postgraduate.

Table 4. Kruskal Wallis based on the areas of digital competence.

Areas of competence	N	Mean rank
A1	6	25,33
A2	6	23,17
A3	6	4,17
A4	6	10,00
A5	6	14,83
Total	30	
Asymptotic Sig (P. value)		,000

a. Kruskal Wallis test.

Table 5. Kolmogorov-Smirnova normality test.

Average	Statistical	P. Value	Assessment
Pre-test-A1	0,074	0,000	<0,05 R–H0
Pre-test-A2	0,096	0,000	<0,05 R–H0
Pre-test-A3	0,125	0,000	<0,05 R–H0
Pre-test-A4	0,085	0,000	<0,05 R–H0
Pre-test-A5	0,073	0,001	<0,05 R–H0
Pre-test-Overall Digital skills	0,071	0,001	<0,05 R–H0

5. Discussion and conclusions

The demands of a globalized society require teachers with techno-pedagogical skills and abilities that allow them to innovate the teaching-learning process (Cabero-Almenara and Martínez, 2019). From this point of view, this study provides solid scientific-academic evidence that concretely demonstrates that nano-MOOCs contribute to the solid development of digital competences in professors. This research confirms what Basantes-Andrade et al. (2020a) and Tourón et al. (2018) affirm about the importance of evaluating the level of digital competence in teachers in order to plan a personalized training. It is concluded that the result of this diagnostic evaluation should not be generalized given that the institutional and personal contexts in which university professors work is different.

Table 6. Comparative pre-test and post-test analysis in relation to digital competence 3 and 4.

	Area 3				Area 4			
	N	Mean rank	Sum of ranks	Asymptotic significance (bilateral)	N	Mean rank	Sum of ranks	Asymptotic significance (bilateral)
Negative ranks	0a	0,00	0,00	0,000	0a	0,00	0,00	0,000
Positive ranks	225b	113,00	25425,00		127b	64,00	8128,00	
Ties	72c				170c			
Total	297				297			
a. Post-test-average A3 < Pre-test-average -A3					a. Post-test-average A4 < Pre-test-average -A4			
b. Post-test-average A3 > Pre-test-average -A3					b. Post-test-average A4 > Pre-test-average -A4			
c. Post-test-average A3 = Pre-test-average -A3					c. Post-test-average A4 = Pre-test-average -A4			

Table 7. Pre-test and post-test comparative analysis regarding the five areas of digital competence.

	N	Mean rank	Sum of ranks	Asymptotic Sig. (bilateral)
Negative ranks	0a	0,00	0,00	0,000
Positive ranks	249b	125,00	31125,00	
Ties	48c			
Total	297			
Post-test-overall Average Digital Competencies < Pre-test- overall Average Digital Competencies				
Post-test- overall Average Digital Competencies > Pre-test- overall Average Digital Competencies				
Post-test- overall Average Digital Competencies = Pre-test- overall Average Digital Competencies				

In this regard, UTN professors have limitations in their competences in two of the areas that the INTEF Common Framework points out: security and digital content creation; results that partially coincide with the studies conducted by Garzón-Artacho et al. (2021), Fernández et al. (2018) and Romero et al. (2017) who found digital content creation as one the greatest weakness in university professors; contrary to this, Villarreal-Villa et al. (2019) found greater difficulties in the security area.

The results allow clarifying the limitations that teachers have regarding to creating digital content and establishing basic principles of digital security, it is inferred that they have a minimum set of skills to make instrumental use of technology, and also that they do not have the necessary skills to take advantage of the didactic potential of it; they find it complex to relate technology with pedagogy and content, affecting the development of the teaching-learning process and educational innovation.

The evidence found in this study differs with the findings from Pozo et al. (2020), where the areas of communication and information collaboration, and information literacy show the most deficient levels of competence in teachers; in contrast to Esteve-Mon et al. (2020) and Rolf et al. (2019) where these competencies predominate. Therefore, this research confirms what was stated above and it corroborates what was expressed by Rizvi et al. (2022), the design of online courses must be adapted to the diversity of focus groups by previously exploring the target population.

Ramírez-Montoya et al. (2017) recommend MOOCs to train teachers in digital competence, unfortunately this study does not show the real effectiveness of the course; contrary to Gordillo et al. (2019) who support the efficiency of this type of format in the development of digital content creation competence and point out that other training actions could be more effective. The results presented in this research, and in concordance with those obtained by Pérez-Sánchez et al. (2017), nano-MOOCs or NOOCs represent a customizable training option adapted to the teachers' needs to immediately achieve a specific competence, which later on can lead users to implement and develop techno-pedagogical innovations in the classroom and applicable to specific contexts.

The training proposal for UTN faculty was framed in the development of NOOC courses (nano-MOOC) in two areas of competence that require greater depth of knowledge and skills: security and digital content creation; this does not rule out that nano-MOOCs can be used to address other areas of competence or specific faculty training needs. For their part, Pérez-Sánchez et al. (2017) focused on the training for the areas of information and information literacy through NOOCs. These training proposals set up the re-orientation, optimization and use of ICT to improve teachers' digital competence. This appreciation is similar to other studies and TDC models (Rolf et al., 2019; Tejada and Pozos, 2018).

The university must maintain a permanent and systematic process of teaching improvement and updating; the responsibility and commitment to these actions by university actors, who are responsible for teaching, is essential, this will allow to transform the teaching-learning process (Murillo and Krichesky, 2015). These continuous training actions, in accordance with Martínez et al. (2017) will allow educators to express their positive and purposeful attitude in a concrete way to a generation familiarized with ICT, that is willing to implement radical changes in the teaching-learning process through technology.

Information and Communication Technologies in Higher Education Institutions promote innovative pedagogical practices, build new knowledge, information and other sensory-perceptual actions that initiate human educational management, production, socialization, and distribution of information through autonomous and collaborative work at the same time. Here lies the importance of developing continuous training courses in nano-MOOC format. Additionally, university professors corroborate the thesis of achieving their continuous training with nano-MOOCs in this area and with this methodology; highly positive results were achieved. This action and attitude make it possible to reduce the digital gap revealed by the teaching staff, object of this study.

The evidence of this study constitutes a contribution for the development of university professors' digital competences, nano-MOOCs are a successful alternative for training, they strengthen and update knowledge, and develop the necessary skills and abilities to integrate ICT in their work praxis. Techno-pedagogical incorporation of the contents through PACIE methodology in the different courses developed in this work allowed to transform the learning paradigm and probably its teaching model. Educators' attitude, responsibility, and commitment to their self-training play a fundamental role for the success of this continuous training format based on nano-MOOC.

6. Limitations and future lines of research

One of the limitations in this study is that the results obtained cannot be generalized or extrapolated for teacher training; it is necessary to consider the characteristics of the university professors, analyze their context, evaluate their digital competence in relation to various demographic variables such as gender, level of training, type of university, age, cultural context, among others, in order to project the nature of the use of digital technology in the teaching-learning process and plan training programs tailored to the requirements and needs of the university teaching staff.

In the same way, the comparative analysis of the digital competence of UTN faculty through the pre-test and post-test, did not consider the development of the training phase through the nano-MOOCs, a particularity that can be studied in future research in order to obtain more concrete results on the effectiveness of this format of online courses as a training tool for university professors.

In the future, researchers may address the areas of competence in which the participants of this study shown greater knowledge and mastery of: problem solving, information and information literacy, and communication and collaboration. Another line of study could be to determine whether or not nano-MOOC format online courses have instructional effectiveness to improve digital competence in relation to other substantive axes of Higher Education such as: research, management and community engagement. It would be interesting to conduct a study of the results from comparing nano-MOOC courses versus derivations of MOOCs (tMOOC, xMOOC, cMOOC).

Declarations

Author contribution statement

Andrea Basantes-Andrade: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Marcos Cabezas-González: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Sonia Casillas-Martín; Miguel Naranjo-Toro: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Andrés Benavides-Piedra: Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data associated with this study has been deposited at
GRIAL https://repositorio.grial.eu/handle/grial/2132.
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Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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References

Abad, F.M., Conde, M.J.R., Peñalvo, F.J.G., 2014. Evaluación del impacto del término “MOOC” vs “eLearning” en la literatura científica y de divulgación. Profr. Rev. Curríc. Form. Profr. 18 (1), 185–201. https://bit.ly/2QQOOK3.

Basantes, A., Naranjo, M., Ojeda, V., 2018. Metodología PACIE en la Educación Virtual: una experiencia en la Universidad Técnica del Norte. Form. Univ. 11 (2), 35–44.

Basantes-Andrade, A., Cabezas-González, M., Casillas-Martín, S., 2020a. Los nano-MOOC como herramienta de formación en competencia digital docente. Rev. Ibérica de Sistemas e Tecnol. de Inform. (E32), 202–214. https://bit.ly/3guNOpT.

Basantes-Andrade, A., Cabezas-González, M., Casillas-Martín, S., 2020b. Digital competences relationship between gender and generation of university professors. Int. J. Adv. Sci. Eng. Inf. Technol. 10 (1), 205–211.

Beltrán, J., Vota, A., 2018. Perspectivas de los estudiantes mexicanos sobre competencias en TIC, definidas por género. Rev. Lat. Comun. Soc. (RLCS) 73, 462–477.

Benavidez, P., Francés, J., Heredia-Avalos, S., Hernández, A., Rodes, J., 2019. Análisis de la primera edición del NOOC: introducción a los fundamentos físicos para las ingenierías y la arquitectura. En R. Roig (Coord.), Mem. del Prog. de REDES-I3 CE de calidad Innov. e Invest. en docencia Univ. (primera edición 1937–1943. https://bit.ly/3tHk3FX.

BERA, 2018. Ethical Guidelines for Educational Research. https://bit.ly/3seN5yk.

Cabero-Almenara, J., Martínez, A., 2019. Las Tecnologías de la Información y Comunicación y la formación inicial de los docentes. Modelos y competencias digitales. Prof.: Rev. de Currículum y Form. del Prof. 23 (3), 247–268.

Cabero-Almenara, J., Palacios-Rodríguez, A., 2020. Marco Europeo de Competencia Digital Docente «DigCompEdu». Traducción y adaptación del cuestionario «DigCompEdu Check-In. EDMETIC 9 (1), 213–234.

Cabrera, A.F., Cruz, C., Sánchez, S.P., 2019. Análisis de la competencia digital docente: factor clave en el desempeño de pedagogías activas con Realidad Aumentada. Rev. Electrón. Iberoam. sobre Calid. Efic. Cambio Educ.: Rev. Iberoam. Sobre Calidad Efic. Cambio en Educ. 17 (2), 27–42.

Caena, F., Redecker, C., 2019. Aligning teacher competence frameworks to 21st century challenges: the case for the European Digital Competence Framework for Educators (Digcompedu). Eur. J. Educ. 54 (3), 356–369.

Casillas-Martín, S., Cabezas-González, M., Ibarra-Saiz, M.S., Rodríguez-Gómez, G., 2020. El profesorado universitario en la sociedad del conocimiento: manejo y actitud hacia las TIC. Bordón 72 (3), 45–63.

Castañeda, L., Esteve, F., Adell, J., 2018. Por qué es necesario repensar la competencia docente para el mundo digital? RED: Rev. De Educ. a Dist. 18 (56), 1–20.

Esteve-Mon, F.M., Llopis, M.Á., Adell-Segura, J., 2020. Digital competence and computational thinking of student teachers. Int. J. Emerg. Technol. Learn. (iJET) 15 (2), 29–41. https://www.learntechlib.org/p/217159/.

Estévez, I., Souto-Seijo, A., González Sanmamed, M., Valle, A., 2021. Ecologías de aprendizaje y motivación del profesorado universitario de Ciencias de la Salud. Educ. XX1 24 (2), 19–42.

Fernández, F., Fernández, M., Rodríguez, J., 2018. El proceso de integración y uso pedagógico de las TIC en los centros educativos madrileños. Educ. XX1 21 (2), 395–416.

García-Peñalvo, F.J., Fidalgo-Blanco, Á., Sein-Echaluce, M.L., 2018. An adaptive hybrid MOOC model: disrupting the MOOC concept in higher education. Telematics Inf. 35, 1018–1030.

Garzón-Artacho, E., Sola-Martínez, T., Romero-Rodríguez, J.M., Gómez-García, G., 2021. Teachers' perceptions of digital competence at the lifelong learning stage. Heliyon 7 (7), e07513.

Gómez-Galán, J., Martín, A., Bernal, C., López, 2017. Los MOOC y la Educación Superior: Nuevas posibilidades para la innovación y la formación permanente. Octaedro. https://bit.ly/32H6ri4.

Gordillo, A., López-Pernas, S., Barra, E., 2019. Efectividad de los MOOC para docentes en el uso seguro de las TIC. Comunicar 27 (61), 103–112.

Habibi, A., Mukminin, A., Hadisaputra, P., 2020. Science teachers’ integration of digital resources in education: a survey in rural areas of one Indonesian province. Heliyon 6 (8), e04631.

Hernández-Sampieri, R., Torres, C., 2018. Metodología de la investigación. McGraw-Hill, México.

Instituto Nacional de Tecnologías Educativas y de Formación del Profesorado. (INTEF, 2017. Marco Común de Competencia Digital Docente. https://bit.ly/2UOi440.

Lázaro-Cantabrana, J., Usart-Rodríguez, M., Gisbert-Cervera, M., 2019. Assessing teacher digital competence: the construction of an instrument for measuring the knowledge of pre-service teachers. J. N. Appr. Educ. Res. 8 (1), 73–78.

López-Belmonte, J., Pozo-Sánchez, S., Fuentes-Cabrera, A., Trujillo-Torres, J.M., 2019. Analytical competences of teachers in big data in the era of digitalized learning. Educ. Sci. 9 (3), 177.

Luik, P., Lepp, M., 2021. Are highly motivated learners more likely to complete a computer programming MOOC? Int. Rev. Res. Open Dist. Learn. 22 (1), 41–58.

Martínez, L., Hinojo, F., Rodríguez, A., 2017. Fortalezas, debilidades y concepciones que tienen los profesores al memento de implementar las TIC en sus procesos de enseñanza. Rev. Cient. Electr. de Educ. y Comun. en la Soc. del Conocim. 17 (2), 297–316.

Maya-Jariego, I., Holgado, D., González-Tinoco, E., Castaño-Muñoz, J., Punie, Y., 2020. Typology of motivation and learning intentions of users in MOOCs: the MOOCKNOWLEDGE study. Educ. Technol. Res. Dev. 68 (1), 203–224.

Morata-Ramírez, M.Á., Tello, F.P.H., Barbero-García, M.I., Méndez, G., 2015. Confirmatory factor analysis. Recommendations for unweighted least squares method related to Chi-Square and RMSEA. Acción Psicol. 12 (1), 79–90.

Murillo, F., Krichesky, G., 2015. Mejora de la escuela: medio siglo de lecciones aprendidas. Rev. Iberoam. Sobre Calidad Efic. Cambio en Educ. 13 (1), 69–102. https://bit.ly/3dJgutE.

Nyikes, Z., 2018. Digital competence and the safety awareness base on the assessments results of the Middle East-European generations. Procedia Manuf. 22, 916–922.
Padilla-Hernández, A.L., Sánchez, V.M.G., López, M.A.R., 2019. Niveles de desarrollo de la Competencia Digital Docente: una mirada a marcos recientes del ámbito internacional. Innoeduca: Int. J. Technol. Educ. Innov. 5 (2), 140–150.
Pérez-Sánchez, L., Jordano de la Torre, M., Martín-Cuadrado, A.M., 2017. Los NOOC para la formación en competencias digitales del docente universitario. Una experiencia piloto en la Universidad Nacional de Educación a distancia (UNED). Rev. de Educ. a Dist. 55 (1), 1–35.
Posso, M., 2011. Proyectos, Tesis Y Marco Lógico. Noción.
Pozo, S., López, J., Fernández, M., López, A., 2020. Análisis correlacional de los factores incidentes en el nivel de competencia digital del profesorado. Rev. Electrón. Interuniv. Form. del Profr. 23 (1), 143–159.
Prendes, M., Gutiérrez, I., Martínez, F., 2018. Competencia digital: una necesidad del profesorado universitario en el siglo XXI. RED: Rev. de Educ. a Dist. 56, 1–22.
Ramírez-Montoya, M.S., Mena, J., Rodríguez-Arroyo, J.A., 2017. In-service teachers' self-perceptions of digital competence and OER use as determined by a xMOOC training course. Comput. Hum. Behav. 77, 356–364.
Reparaz, C., Aznárez-Sanado, M., Mendoza, G., 2020. Self-regulation of learning and MOOC retention. Comput. Hum. Behav. 111, 1–13.
Rizvi, S., Rienties, B., Rogaten, J., Kizilcec, R.F., 2022. Beyond one-size-fits-all in MOOCs: variation in learning design and persistence of learners in different cultural and socioeconomic contexts. Comput. Hum. Behav. 126, 106973.
Rodríguez-García, A., Sánchez, F., Ruiz-Palmero, J., 2019. Competencia digital, educación superior y formación del profesorado: un estudio de meta-análisis en la Web of Science. Píxel-Bit Rev. de Med. y Educ. 54 (4), 65–81.
Rolf, E., Knutsson, O., Ramberg, R., 2019. An analysis of digital competence as expressed in design patterns for technology use in teaching. Br. J. Educ. Technol. 50 (6), 2261–2275.
Romero, M., Castejón, F., López, V., Fraile, A., 2017. Evaluación formativa, competencias comunicativas y TIC en la formación del profesorado. Comunicar 25 (52), 73–82.
Ryan, R.,M., Deci, E., 2020. Intrinsic and extrinsic motivation from a self-determination theory perspective: definitions, theory, practices, and future directions. Contemp. Educ. Psychol. 61, 101860.
Sánchez-Azqueta, C., Aldea, C., Celma, S., Gimeno, C., Cascarosa, E., 2019. Intervención en el aula basada en recursos educativos de libre acceso. In: Sein-Echaluce, En M., Fidalgo, A., García-Peñalvo, F. (Eds.), V Congreso Internacional sobre Aprendizaje, Innovación y Competitividad. CINAIC Universidad de Zaragoza, pp. 647–651.
Silva, J., Lázaro, J., Miranda, P., Morales, M.J., Gisbert, M., Rivoir, A., Onetto, A., 2019. La Competencia Digital Docente en Formación Inicial: estudio a Partir de los Casos de Chile y Uruguay. Educ. Pol. Anal. Arch. 27 (93), 1–26.
Tejada, J., Pozos, K., 2018. Nuevos escenarios y competencias digitales docentes: hacia la profesionalización docente con TIC. Profesorado. Revista de currículum y formación del profesorado 22 (1), 25–51.
Tourón, J., Martín, D., Navarro, E., Pradas, S., Íñigo, V., 2018. Validación de constructo de un instrumento para medir la competencia digital docente de los profesores (CDD). Rev. Espanola Pedagog. 76 (269), 25–54.
UTN, 2012. Código de ética de la Universidad Técnica del Norte. https://bit.ly/3MW14AV.
Villarreal-Villa, S., García-Guliany, J., Hernández-Palma, H., Steffens-Sanabria, E., 2019. Competencias Docentes y Transformaciones en la Educación en la Era Digital. Form. Univ. 12 (6), 3–14.