Experimental Verification of the Teacher Digital Competence Formation System Effectiveness in Non-Formal Education

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http://doi.org/

Abstract. The article provides an experimental verification of the effectiveness system for forming a teacher digital competence (TDC) in non-formal education. The following research methods have been used: analysis, synthesis, comparison and matching; questionnaires, interviews, self-assessment and testing; pedagogical experiment; Fisher's angular transformation.

The work presents general scientific approaches and a model of the TDC formation system in non-formal education. The model includes the following: a block of prerequisites and organizational-pedagogical conditions; a theoretical and methodological block, a structural and content-based block, a technological and activity-based block, an evaluation and reflection block as well as a component TDC. The TDC structure is determined (its environmental, content-based, communicative and reflective components). The TDC levels (beginner, user, professional) are described according to the basic criteria: complexity, autonomy and systematic character. A strategy for forming the TDC in non-formal education is proposed.

A set of tasks is offered to prove the TDC formation system effectiveness in non-formal education, they corresponding to the authors' concept. The results of the stating stage of the pedagogical experiment (obtained through a self-assessment survey by each of the components) and the formative stages of the pedagogical experiment (based on the results of performing 25 exercises by the participants within the framework of the training course) in the context of the environmental, content-based and communicative components are presented. A statistical analysis of the obtained results using Fisher's angular transformation is performed.

Keywords: competence, teacher, digital competence, teacher digital competence (TDC), non-formal education, professional development training, adult education, pedagogical experiment.

Introduction

In modern world and in Ukraine, in particular, there has been recently observed a rapid growth of digitalization in all fields of human activity. The innovations taking place in the Ukrainian education system are directed at formation of teacher digital competence (TDC). Unfortunately, the process is rather slow and not always effective. Today, the level of TDC in Ukraine does not yet meet European standards. This indicates the need for improving teacher professional development including digital skills of teachers at all education levels in Ukraine.

Non-formal education is one of the effective ways for teachers to acquire digital competence. It

allows teachers to acquire relevant digital knowledge and skills by participating in seminars, master classes, webinars and other educational events. This approach complements traditional education, expands teachers' capabilities in the digitalized environment and contributes to making the Ukrainian education system more adaptive and competitive in today's digitalized world.

Literature Review

The following scientific research has served as the theoretical basis for the development concept of the TDC formation: specifics using the competence-based approach in education [1]; problems of forming information and communication as well as information and digital competences of a teacher [2]; issues of forming competences future teachers or other specialists [3]; models components and professional systems competence, their levels and formation criteria [4]; education digitalization and formation digital culture [5]; modern approaches to the development of digital competence [6]; methods of organizing blended and distance learning [7]; organization of adult education in non-formal education [8].

In our research we also relied on a number of classical works dealing with: the basics of synergetics, the concept of a virtual university, the formation of digital skills, the framework of digital competences, the justification of information and technological training of future teachers, the development of digital competences, the pedagogy of knowledge synthesis, the formation of transversal competences, the method of multidimensional average.

We also used the works of foreign authors: the model of five core competences [9], the DigComp framework [10], professional digital competences of a teacher [11], the formation of digital competences for non-university teacher education in special courses [12], analysis of the TDC formation [13], bibliometric analysis of the TDC [14], transition to a digital format and the importance of digital transformation for teachers [15], the framework of the DigCompEdu digital competences structure [16].

Purpose

The purpose of the study is to experimentally verify the effectiveness of the TDC formation system in non-formal education based on the developed model, indicators, and levels.

Methodology

To solve the tasks set, achieve the goal and verify the hypothesis, there was used a set of research methods: analysis, synthesis, comparison and matching to form an analytical report on the results obtained; questionnaires, surveys, self-assessment and testing to record achievements in the process of course preparation and generalization of the experience of organizing professional development training and adult education; a pedagogical experiment to assess the effectiveness of the proposed strategy and tactics for developing and supporting course training; methods of mathematical and statistical data processing (Fisher's angular transformation) to carry out a quantitative and qualitative analysis of the results of the pedagogical experiment outcomes and to find out their reliability. The participants of the experiment were 7598 educators from preschool, general secondary, vocational, pre-university and higher education institutions of various forms of ownership from all regions of Ukraine, who were taking the basic training course "Google Digital Tools for Education".

Results and Discussion

Digital education is based on information and communication technologies (ICT) and the awareness of their role in the educational process. The transition to a digital environment is advantageous for both students and teachers, contributing to the optimization of information processing and improved communication. Based on this perspective, the task of teacher training is directed at creating changes in teaching strategies and pedagogical models that comprise the teachers' competence in using the same technological devices that their students are using. Digital skills of teachers are a set of knowledge, skills and approaches that allow them to effectively use ICT in their pedagogical activities. These skills include the development and implementation of digital tools in the learning process, as well as the teachers' ability to evaluate the tools' effectiveness and adapt them to the needs of their students.

At the preparatory stages of our research, we analyzed the keywords of research (2019–2023) that refer to digital competences; studied the terms' definitions in regulatory documents; considered models and classifications created on the basis of DigCompEdu. It was clarified that non-formal education makes it possible to obtain the necessary knowledge quickly and timely, thus satisfying the current needs. Forms of non-formal education include face-to-face (trainings, master classes, seminars etc.) and distance (online courses, webinars) formats, and such education can be obtained in non-governmental institutions and on distance learning platforms. Based on general pedagogical and philosophical premises, methodological and conceptual foundations, we have identified conceptually important general scientific approaches to the formation of a teacher digital competence: synergetic, integrative, systemic, axiological, andragogical and competence-based.

The developed model of the TDC formation system in non-formal education integrates the following: a block of prerequisites (digitalization of all spheres of activity, labor market requirements, formation of the market of educational services); a theoretical and methodological block (approaches and principles, methodological, theoretical and practical concepts); a structural and content-based block (environment, resources and interaction in the process of acquiring digital competences); a technological and activity-based block (methods, forms and means of organizing adult education); an evaluative and reflective block (criteria, diagnostic tools, indicators and levels of TDC formation); a block of organizational and pedagogical conditions and a component TDC. The structure of the TDC includes:

– *environmental component*: forming a digital workplace for a teacher and a student, which involves the ability to configure and use digital devices that will protect personal data and the content; the ability to use basic software to search and evaluate the information received, store and systematize the content; ability to use the functionality of the digital environment to organize the educational process;

– *content-based component*: making a conscious and reasoned choice of digital resources to ensure the achievement of the set tasks; creating, modifying and distributing digital content to implement various learning forms and methods in the process of teaching and learning; being able to develop instructional and methodological materials for organizing active and practice-oriented learning; working in compliance with the requirements of academic integrity and maintaining confidentiality when using open educational resources;

– *communicative component*: using professional communication and interaction with other participants in the educational process within the educational environment of an educational institution and searching for ways to solve educational problems in professional social communities; organizing educational communication to implement the didactic principles of the educational process through collective and individual interactions; organizing various formats and approaches to assessment and counseling to implement the individual trajectory of development for education applicants;

– *reflective component*: self-assessing the level of digital competence and being aware of the need for constant updating of digital skills; reflecting and improving practices of using digital technologies; targeting work on the development of digital pedagogical practices in the process of professional development training; working on the formation of one's own digital brand through relevant digital services.

We have defined the levels of TDC according to basic criteria: complexity, autonomy and systematic approach:

Beginner (low level). Teachers at a low level of digital competence have limited skills in using digital tools for all aspects of educational activities. They usually use traditional methods of communication and teaching, without using digital technologies effectively. The organization of educational processes and interaction with students in an

electronic environment is difficult and confusing for them. Such teachers usually make many mistakes using digital tools for assessment, consultation or work requiring information technology knowledge and they need constant help. The teachers cannot effectively adapt to different formats and methods of teaching in a digital environment and are not aware of the advantages and opportunities that they offer. They are not able to systematically use digital resources to organize the educational process and ensure the fulfillment of the tasks set.

User (intermediate level). Teachers at an intermediate level of digital competence have basic skills in using digital tools to conduct educational and assessment processes. They usually use email, office programs and other electronic tools to communicate with students and conduct assessment. Organizing educational communication and interaction with students in an electronic environment is possible for them, but often requires some support and guidance. Such teachers use digital tools for assessment, consultation and work with information technologies with varying degrees of success and sometimes they show uncertainty. The teachers try to adapt to different formats and methods of teaching in the digital environment, but do not always fully realize their potential. They can use digital resources to support the educational process, but do not always do so systematically and effectively.

Professional (high level). Teachers at a high level of digital competence have extensive and deep skills in using digital tools for all aspects of educational activities. They effectively use a variety of digital tools and platforms to organize learning, communicate with students, conduct assessment and improve educational materials. Such teachers are able to independently develop and implement individual approaches to teaching and assessment, taking into account the needs of students and using advanced methods and practices. They realize the advantages and limitations of digital technologies in the educational process and can systematically use digital resources to achieve educational goals and ensure individualized learning. The organization of educational communication and interaction with students in the electronic environment is a common and effective daily task for teachers at this level; they have a wide arsenal of tools for communication and

collaboration with students. Their assessment and consulting are organized systematically and strategically, taking into account the latest trends in digital education.

The strategy for forming the TDC in non-formal education is implemented in the program "Google Digital Tools for Education" [17]. The uniqueness of the program lies in the following: the possibility of choosing an individual trajectory of learning and parallel learning, combined distribution of time for self-study in the context of a practice-oriented approach; the organization of safe and conflict-free work on different devices.

In order to verify the effectiveness of the developed model for TDC formation system in non-formal education, we conducted a pedagogical experiment. The full study included a set of tasks to prove the effectiveness of the system for forming the TDC in non-formal education, which corresponds to the authors' concept: clarifying the state of the research done on the problem of TDC formation; justifying the TDC structure for conducting the experiment; carrying out diagnostics of the TDC formation level (stating stage of the experiment – SS); conducting the formative stage of the experiment (FS); carrying out diagnostics of the TDC formation level at the intermediate stage of the experiment (FS-1) and after the formative stage of the experiment (FS-2); conducting the end-to-end analysis and interpretation of the experimental study outcomes.

In this publication, we will analyze the results of the stating and formative stages of the experiment, during which the components of the TDC were tested, they being grouped by modules:

1. Environmental. Digital educational environment (device settings, account settings, working in the Google Classroom environment in teacher and student mode).

2. Content-based. Digital content (creating digital content based on Google Docs and Google Jamboard, setting up access to Google Drive objects, creating workbooks based on Google Keep objects).

3. Communicative. Digital interaction (planning joint activities through Google Calendar, holding meetings using Google Meet, organizing the assessment procedure in Google Classroom).

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To diagnose the level of the TDC formation, a self-assessment survey of course participants was conducted (Table 1) regarding the existing knowledge and developed skills of working with digital tools that form the corresponding components of the TDC.

Table 1

Self-assessment questionnaire

	Digital environment	No.	Partially	Yes
1	I know how and can configure a mobile device			
2	I know how and can set up an account on the device			
3	I know and use the features of Google Classroom			
	Digital content	No.	Partially	Yes
1	I know how and can work with Google Docs			
2	I know how and can provide access to files on Google Drive			
3	I know and use the features of Google Keep			
	Digital interaction	No.	Partially	Yes
1	I know how and use Google Calendar			
2	I know how and work with Google Meet			
3	I know and use Google Classroom effectively			
Answer options are rated on a scale: No. – 1 point, partially – 2 points, yes – 3 points				

[Source – the authors' own conception]

One type of assessment questions is self-perception (self-reflection) questions. They ask respondents how confident they feel about a topic or activity, what or how much they know and/or can do, or what their actual behavior is. They play a very important role in helping a person realize their level of digital competence. The initial level of the TDC formation was determined based on the structural-componential and level characteristics presented in Table 2.

Table 2

Evaluation of TDC formation by criteria and levels

Criterion	Expression indicator	Measurement scale
Environmental	Working with devices	Low – 3–4 points
	Working with accounts	Medium – 5–7 points
	Working in the environment	High – 8–9 points
Content-based	Working with software	Low – 3–4 points
	Creating content	Medium – 5–7 points
	Setting access	High – 8–9 points
Communicative	Planning activities	Low – 3–4 points
	Conducting classes	Medium – 5–7 points
	Organizing assessments	High – 8–9 points

[Source – the authors' own conception]

In the context of the environmental component, the participants of the experiment are mainly at a low level: 56.34 % cannot cope with the maintenance of their own smart phones; 54.65 % have problems with synchronizing accounts and protecting them. The situation is somewhat better with working in the Google Classroom environment, since it has been most often used by teachers to organize distance learning. However, only 14.32 % are at a high level. Such results prove that teachers work rather superficially on organizing an effective educational environment, which in turn leads to time loss when they have to constantly solve problems with its settings (e. g. the camera does not work, the microphone has failed, you cannot take a screenshot etc.).

In the context of the content-based component, the experiment participants usually have slightly lower indicators: 46.54 % do not know how to use Google Docs to create interactive summaries; 42.35 % prefer not to work in a team mode to avoid losing information. At this, there are some participants who can make badges and conduct formative assessment, being at a high level (16.43 %). More than a quarter of teachers (26.49 %) believe that they are partially able to select digital resources to diversify the educational process. Overall, only a fifth of the respondents (22.18 %) were placed at a generalized high level in terms of the content-based component.

The situation with the communicative component is not very good at this stage of the experiment. Planning capabilities of Google Calendar are practically not used (55.02 %). The respondents do not feel much confident during video conferences via Google Meet (though we have been using it for several years). Organization of work with colleagues and parents is only at a medium level (35.07 %). It is encouraging that almost half of the respondents (48.94 %) believe that they are partially coping with setting up the assessment tools. The overall results signal that we have a lot to improve in terms of establishing digital interaction, because only 8.53% of the surveyed experiment participants are at a generalized high level.

The summarized results of the stating snapshot regarding the initial levels of the TDC formation by each component and by their generalized indicator are presented in Table 3.

Table 3

The levels of TDC formation at the stating stage of the experiment

Indicator/level	Low,%	Medium,%	High,%
Environmental	50.59	37.04	12.37
Content-based	43.47	34.35	22.18
Communicative	52.34	39.13	8.53
Generalized/average	**48.80**	**36.84**	**14.36**

[Source: the results obtained by the authors]

Analysis of the results obtained at the experiment stating stage indicates the need to introduce changes, search for and implement effective forms, methods and means of the TDC formation in the context of non-formal education.

Diagnostics of the TDC formation level after the formative stage of the experiment was carried out twice, since the course format provides an additional opportunity for the participants to complete the task within a few days after the course completion. Given the fact that the most accurate picture of the user's digital competence is reflected by answers to questions based on the results requiring users to perform certain tasks, the levels were formed not by self-assessment, but by the results of performing 25 exercises within the framework of the training (to complete the course successfully, the participants had to complete more than 80 % of the tasks and pass the test, scoring at least 80 % of the maximum number of points). To summarize the outcomes, there was used the distribution by levels: beginner (low level) – 0–

39 %; user (medium level) – 40–79 %; professional (high level) – 80–100 %.

Let's analyze the data of the first measurement at the formative stage of the experiment. Already at this stage, the participants are redistributed by levels. According to the generalized indicator of the environmental component, 45.21 % of the course participants are at a high level, which means they successfully completed the course tasks and received the corresponding certificate. A third of the participants (33.32 %) are still at a low level. These participants have not yet managed to fully cope with two-factor authentication or fulfill the requirements to a profile photo. The medium level has dropped somewhat in the context of working in the Google Classroom environment (13.61%). At the same time, more than half of the participants have completed the tasks and are at a comfortable high level (55.02%). Summarizing, it should be noted that there is positive dynamics in the context of the digital environment formation.

The generalized indicator of the content-based component shows that 55.75% of course participants are at a high level, meaning that the tasks are comprehensible and participants can cope with them. Still, a considerable number of participants remain at a low level (28.02 %), which indicates certain gaps in their competences. In particular, the problems arise when the participants create new content – 33.2 % (to some extent this is related to the reluctance to leave the comfort zone). At the same time, a significant percentage of teachers have moved to a high level in terms of working with

software – 58.82%. Almost half of the participants (20.16 % + 26.04 %) have still not coped with the exercises that involve developing such tasks as "a copy for everyone". Overall, there is a general increase in indicators for each descriptor of the content-based component.

In terms of the communicative component, we note a high level of success in activity planning exercises – 55.9 %. The distribution by descriptor regarding the organization of the assessment process looks somewhat interesting: participants showed the results at the extreme poles (41.02 % and 50.88 %), while only a tenth of respondents – 8.1 % – demonstrated the medium level. This tendency towards polarity can be noted for all indicators of the communicative component. It should be noted that the high level of organization of classes using online conferences (51.71 %) successfully crossed the 50% mark.

After conducting a component analysis of the data obtained during the first snapshot of the formative stage, let us pay attention to the dynamics demonstrated in Table 5. The situation looks like this: compared to the stating stage, 51.52 % (+36.9 %) of participants proved a high level of digital competence according to the results of training undertaken during the course; redistribution took place due to the parity transition from the medium and low levels.

Such dynamics indicates the positive effect of the proposed tactics and strategies on the formation of TDC, though it is necessary to find out how statistically significant this influence is.

Table 5

Comparison of the TDC formation levels (stating/formative, 1)

Indicator/level	Low,%		Medium,%		High,%	
	SS	FS-1	SS	FS-1	SS	FS-1
Environmental	50.59	33.32	37.04	21.47	12.37	45.21
Content-based	43.47	28.02	34.35	16.23	22.18	55.75
Communicative	52.34	31.21	39.13	15.96	8.53	52.83
Generalized/average	**48.80**	**30.85**	**36.84**	**17.89**	**14.36**	**51.26**

[Source: the results obtained by the authors]

Fisher's angular transformation was used for statistical analysis. In our case, the state of the group at the beginning of the experiment and at the time of its completion was considered. The comparison was carried out by the frequency of such studied indicators as the level of formation of each component and generalized indicators. In our case, the following statistical hypotheses were formed: H0 – the level of formation of the corresponding indicator at the end of the experiment is not higher than at the beginning of the experiment; H1 – the level of formation of the corresponding indicator at the end of the experiment is higher than at the beginning of the experiment.

As a result of the statistical verification of the results obtained at the intermediate stage of the formative experiment, it was found that according to the proposed method of forming digital competences, the levels of each of the components and their generalized indicator increased significantly, which was confirmed by the Fisher's angular transformation (Table 6).

Table 6

Calculation of Fisher criterion for the intermediate stage

Indicator	Stage		Accepting the hypothesis
	Beginning	Intermediate	
Environmental component (7598)			
Numerical value	940	3435	H1 hypothesis is accepted
The value of the fraction when "There is an effec", %,	12.37	45.21	
Angular transformation	0.7188	1.4748	
Empirical value of the criterion	46.60		
Criterion significance level	0.01		
Content-based component			
Numerical value	1685	4236	H1 hypothesis is accepted
The value of the fraction when "There is an effect", %	22.18	55.75	
Angular transformation	0.9807	1.6861	
Empirical value of the criterion	43.48		
Criterion significance level	0.01		
Communicative component			
Numerical value	648	4014	H1 hypothesis is accepted
The value of the fraction when "There is an effect", %	8.53	52.83	
Angular transformation	0.5927	1.6274	
Empirical value of the criterion	63.78		
Criterion significance level	0.01		
Generalized indicator			
Numerical value	1091	3895	H1 hypothesis is accepted
The value of the fraction when "There is an effect", %	14.36	51.26	
Angular transformation	0.7773	1.5961	
Empirical value of the criterion	50.47		
Criterion significance level	0.01		

[Source: the results obtained by the authors]

To finally verify the effectiveness of the developed mechanisms for TDC formation, there was made a final snapshot based on the results of an additional session provided for by the course conditions. In terms of the environmental component, all indicators crossed the 71% mark at a high level for each descriptor. The only indicator demonstrating that almost a quarter of the participants failed was working in the Google Classroom environment as a student (24.64 %). In fact, this is very indicative, because for successful interaction with students, teachers need to see their work through the eyes of their students. Only then teachers will be able to improve the instructions, communication style, and the form of presentation. In terms of the content-based component, the maximum indicator at a high level was achieved in the descriptor of working with software (78.55 %), which dealt with exercises on

using Google Docs. The same descriptor also recorded the lowest medium level indicator – 2.58%. At the end of the course, the participants successfully dealt with issues of working with Google Drive and providing access (only 8.33% of teachers remained at a low level). In general, the content-based component received a medium level in three indicators. In terms of the communicative component, the maximum indicator among all 9 descriptors was achieved by a high level of organization of assessment procedures in Google Classroom – 87.91 %. It is in the communicative component that the generalized low-level indicator has the lowest value – 9.37 % (in the others – 16.19 % and 14.83 %).

After conducting the component analysis of the data obtained during the second snapshot of the formative stage, let us pay attention to the dynamics, which is demonstrated in Table 7.

Table 7

Comparison of the TDC formation levels (stating/formative, 2)

Indicator/Level	Low,%		Medium,%		High,%	
	SS	FS-2	SS	FS-2	SS	FS-2
Environmental	50.59	14.83	37.04	12.07	12.37	73.10
Content-based	43.47	16.19	34.35	8.33	22.18	75.48
Communicative	52.34	9.37	39.13	12.53	8.53	78.10
Generalized	**48.80**	**13.46**	**36.84**	**10.98**	**14.36**	**75.56**

[Source: the results obtained by the authors]

Summarizing, we can state that 75 % of the course participants have achieved a high level of digital competence, as is defined by the course program. It should also be noted that among those who did not successfully complete the course there were people who took the course not aiming to obtain a certificate of completion, but sought to get free access to the course materials and get acquainted with the coaching activities of the support team.

As a result of the statistical verification of the formative experiment final stage outcomes, it was found that the application of the proposed method for forming digital competences resulted in the significant increase in the levels of each component as well as their generalized indicator, which was confirmed by the Fisher's angular transformation conducted.

Conclusions

The TDC formation in non-formal education has its own characteristics, which are reflected in the proposed model. The described TDC structure (environmental, content-based, communicative and reflective components) allowed us to determine the levels of its formation (beginner, user, professional) according to the basic criteria (complexity, autonomy and systematic character). The results obtained prove the high-quality organization of not only the pedagogical experiment, but also of the training in general, which indicates the correctly chosen strategy and tactics for designing a training program based on the developed principles of the TDC formation in non-formal education.

The promising areas of further research include: analysis of the impact of the TDC on the quality of education, student development, their motivation and academic achievements; modification of the developed system of the TDC formation to the conditions of formal education and its use for organizing the professional development of teachers; development of a universal toolkit for determining the level of digital competence using the capabilities of artificial intelligence.

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Експериментальна перевірка ефективності системи формування цифрової компетентності педагога в умовах неформальної освіти

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Анотація. У статті подано експериментальну перевірку ефективності системи формування цифрової компетентності педагога в умовах неформальної освіти, для якої використано комплекс методів дослідження: аналіз, синтез, порівняння та зіставлення; анкетування, опитування, самооцінювання та тестування; педагогічний експеримент; кутове перетворення Фішера.

У роботі наведено загальнонаукові підходи та модель системи формування цифрової компетентності педагога в умовах неформальної освіти, що містить: блоки передумов та організаційно-педагогічних умов; теоретико-методологічний, структурно-змістовий, технологічно-діяльнісний та оцінно-рефлексивний блоки; компонентну цифрову компетентність педагога. Визначено структуру цифрової компетентності педагога (середовищний, змістовий, комунікативний і рефлексивний компоненти), описано рівні цифрової компетентності педагога (початківець, користувач, професіонал) за базовими критеріями: складність, автономність та системність. Сформовано стратегію формування цифрової компетентності педагога в умовах неформальної освіти.

Запропоновано комплекс завдань для доведення ефективності системи формування цифрової компетентності педагога в умовах неформальної освіти, що відповідає авторській концепції. Наведені результати констатувального етапу педагогічного експерименту (отримані шляхом опитування-самооцінки в розрізі кожного із компонентів) та формувального етапу педагогічного експерименту (за результатами виконання 25 вправ у межах проведеного навчання) у розрізі середовищного, змістового та комунікативного компонентів. Представлено статистичний аналіз отриманих результатів за допомогою кутового перетворення Фішера.

Ключові слова: компетентність, педагог, цифрова компетентність, цифрова компетентність педагога (ЦКП), неформальна освіта, підвищення кваліфікації, освіта дорослих, педагогічний експеримент.