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Application of the Delphi Technique to Determine the Technological Competencies of a Faculty Member

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Abstract: The formed primary level and dynamic and sustainable development of technological competence provides quality management of teaching activities, increases the efficiency of the educational process, accelerates the achievement of pedagogical goals. Delphi expert assessment technique is increasingly used in the paradigm of pedagogy. Due to the set of advantages and objectivity of assessments, it has become the dominant method of this study. The objective of the study is to determine the current level of manifestation of technological competencies, as well as generalized prospects for development and improvement of the identified level within the selected group of freelance teachers using the technology of independent expert assessments –the Delphi method. In general, the following methods were used in the current study: Methods of data collection and coordination, anonymous brainstorming, Delphi expert assessment technique, statistical and mathematical processing of results through Delphi formulas, comparative method, generalisations. The diversified approach to the interpretation of the technological competence of faculty members allowed determining: a) the level of faculty members' knowledge of modern educational technologies at 89.1%; b) activity-practical aspect of training at 83.0%; c) dissonance between the theoretical and empirical level of teacher training and the algorithm for fulfilling the potential in practice at 21.5%; d) mastery of individual creative technologies for the organisation of an effective educational process at 55.9%; e) forecasted development of technological competencies of faculty members in the 5-year perspective under the condition of application of special control and skill trainings at 50.7%. Conclusion of the study is that according to the arithmetic mean of experts' assessments of differentiated levels of technological competence, the overall level was 75.1%. The average result of the initial student survey on the estimating of the teachers' technological competence was 69.7%. The difference of 5.4% between the data allows stating that both methods were relevant in this particular case.

Keywords: *Delphi technique, faculty members, higher education, pedagogy of higher school, technological competencies.*

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Introduction

Features of the modern era of technology affect the fundamental professional competencies of specialists in various fields. The low level of any of the basic competencies prevents high-quality professional activity of the respondent, as well as the possibility of professional self-improvement. The universal professional competencies of modern individuals include communication, civic, value, social, managerial and other competencies. One of such basic competencies, which have a pronounced temporal dependence on the realities of modern life, are integrative and interdisciplinary technological competencies (Fai & Von Tunzelmann, 2001). There are different approaches of teaching technological competences within higher school context (as integration and penetration of technologies to the other subjects or separately as an academic discipline, or in the course of pedagogical methodologies). Nevertheless, today is no doubt about its necessity for the professional development of modern pedagogical workers within pre-service or in-service trainings.

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Clearly, there is no 'one-size-fits-all' approach for preparing <…> to teach with technology. Teacher educators have often fallen short in their efforts to plan, model, and implement the right combination of technology experiences across the entire scope of a teacher preparation program (Foulger et al., 2017).

It is a mistake to identify technological competencies exclusively with information and digital ones. After all, due to its synergistic role, technological competence encompasses, launches and enables an effective mechanism of all other professional competencies, including the teacher's competence to use modern technical teaching aids for optimal organisation of the educational process.

The essence of technological competence in the field of faculty members' activity can be considered as a generalised method, a model of pedagogical actions based on theoretical knowledge, empirical skills of using standards, rules of pedagogical activity, ability to synthesise and fully implement all other basic competencies of faculty members. Technological competencies integrate the questions "What?", "How?", "When?", "Where?", "With whom?" etc. into a single whole, which is an individualised educational technology. Technological competence provides quality management of in-class and extracurricular professional situations.

Technological competence ensures high-quality performance of the teacher's functions provided by all regulatory documents concerning teaching activity. Effective organisation of interaction of subjects of educational process, correct management of educational process, creation of comfortable professional and creative space for all participants of educational process, designing and realisation of educational and professional activity, stages, sequence, system of professional and cognitive activity, as well as the subsequent guaranteed results are possible only under the condition of a high level of teacher educators' technological competencies. This is an integrative quality of professional training of teacher educators and an indicator of professional self-improvement (Segal & Heath, 2020; Uerz et al., 2018).

Technological competence is manifested in: 1) the correct definition of stages and algorithms of educational activities; 2) harmonious management of pedagogical processes; 3) ensuring mutually beneficial constructive interaction between the subjects of the educational process; 4) the desire to adhere to a range of patterns and principles of organisation of the educational process with students; 5) readiness to design and implement the initially set goals, structuring the content of teaching, methods and didactic tools (technical, verbal, etc.) to solve the problems of pragmatically organised pedagogical communication and pedagogical activities of teacher educators in general.

The requirement of a high level of technological competence of a modern faculty member in the context of the dominance of distance and mixed forms of the educational process due to the introduction of quarantine restrictions caused by the coronavirus pandemic is especially acute. The atypical situation of transition from the dominance of traditional forms of the educational process to the dominance of non-traditional forms, which involve remote interaction with students and colleagues, mediated by the use of a range of information and communication technologies (ICT), urged and diagnosed the real level of technological competence of university teachers. The high level of technological competencies of teachers is a guarantee of high adaptability to new educational and regulatory conditions, flexibility and agility of pedagogical abilities.

The dynamics of the evolution of modern educational space exacerbates the need for thorough research on diagnosing and forecasting the level of technological competencies of the faculty members and their structure in synchronous aspect and in perspective. The role of expert assessment methods is growing under the influence of, on the one hand, the topicality of the issue, and on the other hand, the need for high-quality, efficient and qualified elaboration of the problem.

The Delphi technique is considered a way to study problems based on knowledge and intuition (Al-araibi et al., 2019; Hohmann et al., 2018a, 2018b; Mohr & Shelton, 2017). It is actively used to outline the prospects for development and ongoing assessment of the effectiveness of management decisions (Gordon, 1994). This technique of forecasting and expert assessments was developed in the 50-60's of the 20th century by American researchers (Dalkey & Helmer, 1963; Helmer, 1977; Rescher, 1969). This technique has most often been used in Western scientific practice, but with a much wider range of implementation than before. In Eastern European countries, the method is less common, in particular due to the regulated mandatory range of features of its application (anonymity, multilevel and distant nature), which will be considered later and taken into account when conducting this study.

The background of the Delphi technique is formulated as the idea that in case of proper generalisation and careful processing of individual assessments of experts on a particular situation, you can get an averaged, most likely general opinion that will enclose the maximum degree of validity and scientific reliability.

A brief introductory analysis of the key concepts for our study – the technological competence of teachers of higher education and methods of expert evaluation of Delphi allows us to state and thus build a bridge to the following parts of the current study, namely:

1) there is a need to unify the content and scope of the term "technological competence";

2) the Delphi method is a relevant method among modern methods of organizing research, where a special role is played by an expert and objectively independent approach to the evaluation of issues under consideration;

3) the intersection of conceptual concepts of current research forms a plane suitable for research, which aims to categorize technological competence in the context of other competencies of teachers, as well as to expand the scope of the Delphi method usage in pedagogical research.

Literature Review

Technological competence in modern literature is outlined quite ambiguously. In our opinion, there is an urgent need to standardise this term. European policy documents address 3 Broad Areas of teacher competences, one of which is working with knowledge, technology and information, as well as the ability to effectively integrate technology into the educational process in order to stimulate teaching and learning activities (European Commission, 2005). However, what exactly the technology means is not detailed. In another European policy document (Caena, 2011) the content of technological competence is conceptualised in the paradigm of the multi-vector term "digital competencies", namely in the concept of pedagogical technological content knowledge —TPCK — that is the knowledge of new technologies applied to teaching the specific subject, cited in the document from Mishra & Koehler, 2006).

Mishra and Koehler (2006) try to arrange the basic categories of knowledge that are necessary for the integration of technologies in teaching, taking into account the complex, multifaceted and targeted nature of the category of pedagogical knowledge: thoughtful pedagogical uses of technology require the development of a complex, situated form of knowledge that we call Technological Pedagogical Content Knowledge (TPCK). The basis for an expanded interpretation of the concept of technological competence may be the apt opinion of Mishra and Koehler (2006) that merely introducing technology to the educational process is not enough. Therefore, the theoretical side of defining technological competence answers the question: What teachers need to know in order to appropriately incorporate technology into their teaching has received a great deal of attention recently. The other document, the Common European Principles for Teacher Competences & Qualifications (European Commission, 2005) uses the concept of "technology" in the pedagogical field in such contexts as: mathematical, scientific, technological literacy; working with knowledge, technology and information, use technology interactively; instrumental competences: cognitive, methodological, technological, linguistic; craft skills etc., using teaching materials and technologies.

Hunter School of Education (2021) outlines the concept as identical to ICT. This once again underscores the vagueness of the definition even within a single document. The interpretation of the term given by Mishra and Koehler (2006) obviously most accurately conveys the authentic meaning of the concept of *technological competence* as the ability to create and use a particular field of technology effectively, which is gained through extensive experimentation and learning in its research, development and employment in production (Fai & Von Tunzelmann, 2001).

Instead, Turner (2005) interprets the term in view of the semantics of technological competence — digital competence — ICT competence, which is highly undesirable from a terminological point of view. Foulger et al. (2017) generally identifies (using the Delphi technique) a set of 12 technology competencies specifically for teacher educators (faculty members). The explanatory table shows that technological competence generally utilises content-specific technologies (that is not only digital technologies) to enhance teaching and learning, and incorporate pedagogical approaches that prepare teacher candidates to effectively use technology (again the concept of pedagogical approaches/technology) is much broader than just technical skills of using ICT in the course of pedagogical activity.

That is why we propose to consider technological competence as a complex term that contains technological competence and ICT competence, but in no case is limited to them. Nessipbayeva (2012) generally qualifies a technological component, which facilitates solving different pedagogical tasks as a component of the term "pedagogical culture" (integral part of a competent teacher), and technology skills — as knowledge of when and how to use current educational technology, as well as the most appropriate type and level of technology to maximise student learning. Therefore, our understanding of technological competence is most consistent with the semantics of the integrated ability of the teacher educators acquired in the academic learning process (pre-service, in-service and individual self-development areas), which consists of knowledge, experience, values and attitudes within the content Technological pedagogical content knowledge (TPACK), which can be fully implemented in practice. In the terminological interpretation of TPACK, we rely entirely on the detailed definition given by Thohir et al. (2020).

As for the application of expert assessment in the study of pedagogy, the effectiveness of the Delphi technique for diagnosing, and especially for predicting phenomena was confirmed by the fact that most forecasts made on the basis of the Delphi technique in 1964, when it was first used, came true (Bauman, 2020). The practice of applying the Delphi technique for the diagnosis and prediction of pedagogical phenomena and personality development under the influence of pedagogical strategies is not new (Andronie et al., 2020; Mohr & Shelton, 2017; Muñiz-Rodríguez et al., 2017). Dubovicki (2019) considers the popularisation of the Delphi technique to be an important part of his scientific research, as it provides more applicable information (and suggestions) compared to conventional tests. The author qualifies the Delphi technique as futurological (aimed at the long-term definition of landmarks), and generally states the lack of involvement of the methodology of futurological research in the pedagogical field. However, the scope of the Delphi technique in pedagogical science is gradually expanding. Thus, Hsu and Chen (2019) studied the predicted set of knowledge, skills, competencies that are and will be relevant for workers in the pedagogical industry in the era of cloud

pedagogy through the Delphi technique. Thohir et al. (2020) chose the modern vector for the application of the Delphi technique, exploring Technological Pedagogical Content Knowledge (TPACK) as a special competence that is conceptualised under the influence of 21st century trends, and appears as a condition for successful pedagogical activity of a modern teacher.

It is interesting that, in both cases, Dubovicki (2019) and Hsu and Chen (2019) used not only the Delphi technique, but also surveyed and tested respondents, or based on the obtained results of the application of the Delphi technique. This mix of traditional pedagogy research methods and innovative Delphi technique (RAND's now-famous Delphi method — Bauman (2020) allows obtaining more substantive empirical data, adds objectivity, scientific depth to research (Irvine, 2021).

Janer and Úcar (2017) used the Delphi technique to outline a modern vision of the role, structure, content of social pedagogy from an international perspective. Ismoilova (2020) notes the relevance of the Delphi method for multimodal forecasting purposes in education. Thus, today there is a successful practice of applying the Delphi technique for both narrow, specific research in the pedagogical field, as well as generalized and conceptual. In addition, the above scientific papers confirm the universality of the Delphi technique and its winning compatibility with other research models. Another interesting conclusion from the review of current scientific works is the tendency to use the Delphi technique in pedagogy to determine the content and level of different pedagogical competencies, as well as their development prospects in the paradigm of projected future changes (especially deepening of technologization of the areas of human activity) (Muñiz-Rodríguez et al., 2017; Swank & Houseknecht, 2019).

For the most part, the applied purpose of the Delphi technique is to obtain empirical data from a group of experts, which are later summarised by a group of analysts in the form of recommendations, directives, identified trends in pedagogical phenomena (Millican & Forrester, 2018).

Depending on the case of using the Delphi technique, the algorithm of its application differs. The number of experts involved varies significantly from 7 (Dubovicki, 2019) to 30 (Ruiter et al., 2020; Thohir et al., 2020). There are very few cases of involving several dozen people as experts (for example, 82 in Pavlova et al., 2021). This greatly complicates the calculation of results and usually increases the number of rounds of survey required to reach a consensus among independent experts — the only possible evidence of successful completion of the test using Delphi technique. In the classic version, the number of experts is ≤10 (Helmer, 1977). In the study Cateté and Barnes (2017), two variants of the Delphi technique were used at once to obtain data on the creation of thematic curricula for the purpose of training well-qualified and well-supported computing teachers.

Thus, the analysis of the literature on the topic allowed identifying the tendency towards modern adaptations of the Delphi method and its composition with other diagnostic techniques. This contributes to the universalisation of the Delphi technique, expanding the scope of its application. However, there is still little research that would involve the Delphi technique in the diagnosis and prediction of results within the pedagogical field. This is the second topical area of our research. The first is the need for close scientific attention to the definition and improvement of technological competencies of a faculty member. This is the key to a harmoniously and effectively organized educational process, taking into account the classic triad of educational and developmental goals.

Aims

The aim of the study is to determine the current level of technological competencies, as well as generalised prospects for development and improvement of the identified level in the selected group of faculty members using the method of independent expert assessments — the Delphi technique. The aim involves fulfilment of the following research objectives:

1) find out the levels of expert assessments for different structural components (levels) and criteria for the manifestation of technological competence;
2) determine the prospects of improving the technological competence of teachers with the help of expert assessments, taking into account that this competence also depends on the level of technological optimisation of the higher educational institutions (HEIs), in particular its material and technical resources, partner programmes in which the university participates, and in general, the established links that can help the teacher to: a) fully implement the existing level of technological competence: b) constantly develop and update the existing level;
3) summarizing the obtained data, determine the main ontological trends of technological competencies as a fundamentally important component in the professional training of a faculty member.

Methodology

Study Design

This study involved the following methods: methods of data collection and coordination (questionnaires; Gmail, Telegram, Zoom platforms); anonymous brainstorming; Delphi technique of expert assessments; statistical and mathematical processing of results using the formulas of the Delphi technique; comparative; generalizations. The choice

of methods was partially predicted by other successful and profound studies where Delphi method was used as a central one (i.e. Swank & Houseknecht, 2019; Thohir et al., 2020; Pavlova et al., 2021).

Background of the Study

The study using the Delphi technique was preceded by an open questionnaire conducted at the Department of Pedagogy and Innovative Education, Lviv Polytechnic National University with the involvement of 68 fourth-year students majoring in Computer Technology. Bachelor's graduates were intentionally selected as a group of respondents in order to obtain a more conscious and generalised feedback to the organisation of pedagogical activities by faculty members with an emphasis on the technological side of the process of educational interaction between students and teachers. The aim of the open questionnaire was to identify the attitude to the problem from the student community's point of view. The survey showed quite heterogeneous results: the overall assessment of the effectiveness of teachers' use of technological competencies to organise work with students on a 100-point scale ranged from 45 to 97 within the group of respondents. The average score was 69.7%. However, significant fluctuations in the assessment of the technological side of teacher activity have urged the need to clarify the issue within the expert group with the involvement of a wider range of experts on technological competencies, as well as prospects and ways to improve them under the influence of traditional and innovative forms of learning. It was the requirement of an expert approach to assessing the problem that initially prompted the idea of applying the Delphi technique of its elaboration.

The entire period of preparation, implementation and final interpretation of the study data covered 5 months (October 2020 — February 2021 academic year). Thus, the whole process was relatively dynamic. This is due to the requirement of the classical Delphi technique that the interval between the conducted rounds of surveys cover the time of ≤1 month.

Two groups of participants were involved to apply the Delphi technique:

1) Expert group (10 people). The task is to provide qualified assessments on the issues under study. The composition of the group of experts is kept strictly confidential. This moment is documented in advance, guarantees of anonymity are taken;

2) Analytical group (6 people). The task of analysts is to reduce the answers of experts to a single denominator, summarising them and performing all the necessary mathematical calculations.

At the previous stage of the study with the use of the Delphi technique, the organiser of the study, Head of the Educational and Research Institute of Pedagogy and Psychology, selected a group of experts. Each expert received his or her own code (for example, Expert A), which he/she retained throughout the study. However, it was allowed to disclose the area of the expert's interests.

Experts Selection Criteria

The selection of experts was based on the criterion of involvement in the educational environment of the Faculty of Pedagogy. The next idea in the selection of experts was their affiliation to different areas of activity (teachers, top executives, heads of departments, representatives of the student community). Two representatives of the partner HEIs were also involved in the study for the purpose of maximum objectivity. This corresponds to the position that interdisciplinary judgments contribute to a better understanding of the issues (Vrcelj & Mušanović, 2001).

In addition, the very concept of the Delphi technique is that some group of independent experts can much better assess the existing and predict the future outcome within the studied phenomenon than a structured group of people. The independence of the experts' opinion guaranteed by their anonymity allows avoiding a direct clash of different positions, eliminates the factor of fear of responsibility for a truthful, in the opinion of the expert, but inconvenient in terms of formalities, answer. The format of study through Delphi technique also precludes collective influence due to collaboration and conformist tendencies.

Table 1. List of experts involved in the Delphi technique

No.	Expert Identification	Sphere of interest and professional activity
1.	Expert A	Teacher, General pedagogy, innovations in education
2.	Expert B	Teacher, General pedagogy, inclusive education
3.	Expert C	Head of Department
4.	Expert D	Head of Department
5.	Expert E	Representative of the partner HEI
6.	Expert F	Representative of the partner HEI
7.	Expert G	Administrative executive
8.	Expert H	Administrative executive
9.	Expert I	Student community representative
10.	Expert G	Student community representative*

*Note: The applicant for the Master's degree and one of the graduate students were taken from the student community. Both are preparing for teaching and are interested in the latest pedagogical technologies.

Preliminary Preparation for the Study and Research Ethics

Two conferences were previously held using video communication technology — Zoom — in order to avoid discrepancies of opinion on the essence of the problem of technological competence and, as a consequence, deepened contradictions in the responses of the expert group. The results of the initial survey among a group of students were reported, in particular, the heterogeneity of respondents' answers was emphasised. Attention was also focused on the Delphi procedure. The cameras as well as the microphones of all the experts were turned off. Special consent forms were sent to the experts via Gmail.

The organisers of the study decided that further collection of answers, as well as all working communication would be conducted through specially created and also coded (even before the introductory conference) e-mail box.

Stages of Application of the Delphi Technique

STAGE 1. The group of experts faced a common problem — measurement of technological competencies of faculty members. At this stage, the experts had to differentiate this general issue into narrower ones at their own discretion. This is how the microthemes of the general problem were singled out.

STAGE 2. Analysts formed a prototype of the questionnaire and sent it to each of the experts for prior approval.

STAGE 3. Based on the generalisation of the experts' responses, the most common ones were taken into account and the primary questionnaire with all the questions included in the general questionnaire was modified — Table 2 (combined questionnaire: With open and closed questions). The requirements of the Delphi technique were taken into account when compiling the questionnaire: the wording of the questions should be clear and the questions themselves provide only the possibility of an unambiguous answer. Each question must allow the possibility of numerical expression of the answer (for the mandatory subsequent calculation of points using the formulas of the Delphi technique). It was envisaged that the answer to each question (numerical assessment) should be substantiated by an expert in the form of comments, the essence of which is summarised in the table (Appendix A).

Table 2. The relationship between the structural components of technological competence and the relevant question of the Delphi survey technique.

Levels	**Technological competence of a faculty member**		
	Description of the component	**Assessment criteria**	**Question of the questionnaire**
1. Theoretical	Theoretical knowledge about pedagogical technologies as such and about particular technologies. Steady interest in the pedagogical techniques, effective technologies of the educational process.	Cognitive-search activity of teachers for professional self-development	Assess the level of faculty members' knowledge of modern educational technologies on average. Short: knowledge level. *Scale 0-100%*
2. Empirical	Focus on successful pedagogical experience of colleagues. Reproduction of actions of colleagues on a pattern with gradual working off of own pedagogical techniques. Formation of holistic and system ideas about the organisation and management of educational activities of students of higher educational institutions.	Optimal structure of pedagogical activity to achieve the planned results.	Assess the activity-practical aspect of the training of faculty members on average. Short: practical level. *Scale 0-100%*
3. Algorithmic	Ability to embody theoretical knowledge about theories of pedagogical technologies, as well as adopted and independently acquired empirical experience of teaching in a sequence of coordinated actions that in the long run should lead to the result predicted at the design stage. A holistic and systemic approach to the implementation of pedagogical technologies. Teacher's ability to creatively transform and situationally adjust the algorithm of activity, determine cause-and-effect relations, describe interdependencies; adequately evaluate the results.	Accuracy and specifics of the formulation of objectives. Adequacy of applied methods, techniques, ways to fulfil the planned objectives.	How would you assess the dissonance between the theoretical and empirical level of teacher training and the algorithm for realising the potential in practice. Short: dissonance level. *Scale 0-100%*

Table 2. Continued

Levels	Technological competence of a faculty member		
	Description of the component	**Assessment criteria**	**Question of the questionnaire**
4. Creative	Ability to creatively transform the basic structural components of technology, creatively apply certain techniques and methods, the ability to create an author's teaching technology (pedagogical system), the ability to analyse and evaluate the external and internal relationships of process and result in the complex; predict the development of situations and manage force majeure situations.	Innovative activity of a teacher on the organisation of an effective educational space. Correspondence of visible results to the desirable purposes of training, development, education.	Do teachers know individual creative technologies for organising an effective educational process? Short: creativity level. *Scale 0-100%*
5. Prospective	Ability to be critically concern one's professional skills, consistently plan activities for the development of "superiority zones" and minimization/elimination of "problem zones". Defining long-term and short-term prospects for professional development. Methods of institutionalised and self-control over the teacher's professional development, especially the practical side of teacher's work, due to: a) lack of practical skills of young teachers; b) stagnant phenomena, stereotyping of the teaching style of teachers of older generations.	It was recommended to make decisions in the triad paradigm: 1) Mechanisms of motivation and stimulus 2) Prospective development zone 3) Current development zone	Give a forecast of the development of technological competencies of faculty members in a 5-year perspective, subject to the use of special control and skill training in this area. Short: prospects level. *Scale 0-100%*

STAGE 4. The questionnaire with the relevant comment on the technical side of its completion was sent by e-mail to all involved experts. The task of the experts was to assess the questions proposed for consideration on a 10-point scale.

The available assessments and ideas expressed in the comments, if they contradicted the opinion of the majority, were read to all experts while preserving anonymity. After a consultation phase, the experts had the opportunity to adjust their previous assessments and positions. Stages *diagnostics 1 → consultation/discussion → diagnostics 2* are cyclically repeated until the stage of reaching consensus between the members of the expert group. Achieving the desired consensus was objectively determined by analysts according to the Delphi procedure. They will be listed in the Results section.

Therefore, at the stage of the study through the Delphi technique, all the standard application requirements were taken into account (Cuhls et al., 2012), in particular:

- the group of experts is provided with all the necessary information to provide an assessment of the studied concepts and their actual empirical manifestations;

- a sufficient number of experts, and a constant composition of experts within the study is provided;

- the number of rounds, as well as the time interval between rounds is sufficient to ensure the optimal pace of work of both groups of experts and groups of analysts;

- the ethical side of the study is ensured.

Data Analyses

In the formal processing of data, in accordance with the requirements of the Delphi technique, the self-assessment criteria of each of the experts are taken into account. Classically, the range of self-esteem was proposed to be set in the range of 0-10 points. The length of the confidence interval (CI) of 15% was taken as the basis.

The self-assessment coefficient was designated as x_i, the expert's assessment is identified as y_i. Number of experts — n. On the basis of the obtained data, the corresponding calculations were performed and given in the table under each question: average group self-assessment, average value of assessment on questions 1-5, weighted average assessments. All calculations were performed by the following formulas:

1) Average group self-assessment (*SAav.gr. — average group self-assessment*) —the ratio of the sum of self-assessment coefficients to the number of experts involved in the study:

$$SA_{av.gr.} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (1)$$

2) The average score of the assessment of the question (*Aav.s.*) — the ratio of the sum of assessments of services by experts to the number of experts:

$$A_{av.s.} = \frac{\sum_{i=1}^{n} y_i}{n} \quad (2)$$

3) Average weighted score of the questionnaire (*ASws.q.*) — the ratio of the sum of the products of self-assessment coefficients to the level of assessment of the questionnaire to the sum of self-assessment coefficients:

$$AS_{ws.q.} \frac{\sum_{i=1}^{n} x_i\, y_i}{\sum_{y=1}^{n} x_i} \quad (3)$$

Results

The Results of the First Round of the Delphi survey

After the first round of the expert survey, the following data were obtained (Table 3).

Table 3. Calculation of results through the Delphi technique in the first round of the survey

Expert	Self-assessment	1. Knowledge level	2. Practice level	3. Dissonance level	4. Creativity level	5. Prospects level
A	9.5	90%	79%	20%	34%	45%
B	8	87%	82%	21%	31%	28%
C	8.5	91%	84%	34%	29%	21%
D	9	94%	63%	18%	52%	37%
E	9.5	71%	85%	23%	50%	89%
F	8.5	90%	88%	19%	59%	42%
G	10	91%	90%	29%	98%	38%
H	8	95%	93%	19%	91%	29%
I	7.5	92%	85%	15%	41%	92%
G	6.5	94%	81%	17%	62%	81%
$SA_{av.gr.}$	8.5	-	-	-	-	-
	$A_{av.s.}$	89.5%	83.0%	21.5%	54.7%	66.1%
	$AS_{ws.q.}$	89.1	83.0%	21.5%	52.87%	49.3%
	*Me**	91%	84.5%	19.5%	51%	40%
	Quartile	6	7.5	12.3	17.3	17.8
	The lower confidence limit	77%	70.5%	27.3%	46.3	38.8
	The upper confidence limit	89%	85.5%	21.7%	80.7	74.2
	Difference	12%	15%	5.6%	34.4%	35.4%
	Correspondence to the set interval, ≥15%	Corresponds	Corresponds	Corresponds	Does not correspond	Does not correspond
			Can be accepted		Require repeated round	

*Me = median

On the example of Question 1, the *average weighted score of the question* assessment is equal to (9.5x90 + 8x87 +… + 6.5x94): (9.5 + 8 +… + 6.5) = 89.1. The median in the case of an even number of experts is calculated as the arithmetic mean between the mean assessments and will be equal to the first question: Me=(91+91):2=84.5 (the assessments of experts were arranged in ascending order to find the median). Quartile was calculated by the formula:

$$\text{Quartile} = \frac{max_{(yi)} - min_{(yi)}}{4} \quad (4)$$

Accordingly, the quartile on the first question will be $\frac{95-71}{4} = 6$. The lower confidence limit will be equal to 71+6=77%, upper confidence limit: 95-6=89%.

As expected above, the experts had to justify the scores given for each question: 1) first succinctly (in one sentence); 2) in more detail. A matrix of the generalised comments is provided in Appendix A.

Thus, according to the results of the first round of survey, it was possible to give an average acceptable answer to 3/5 of the questions, which corresponds to the maximum acceptable range of fluctuations of 15% set at the beginning in the opinions of experts on the questions. At the same time, on the following questions: 4) Do teachers know individual creative technologies for organising an effective educational process? 5) Give a forecast of the development of technological competencies of faculty members in a 5-year perspective with special control and skill training in this

direction — they failed to reach a consensus in the first round, so these two questions are transferred to the next round, where they will be given more attention.

The Results of the Second Round of the Delphi Survey

At the end of the first round of the survey, in order to speed up consensus decisions and optimally find common solutions to the criteria that remained unmet, the following was conducted:

1) a matrix of generalised comments was previously sent to all experts for review (Table 4);

2) after that, an Incognito chat was initiated in Telegram for simultaneous and anonymous exchange of the following comments on the issues under discussion, expression of ideas (anonymous brainstorming), etc.

The results of the second round are shown in Table 4.

Table 4. Calculation of results according to the Delphi technique in the second round of the survey (questions 4-5)

Expert	Self-assessment	4. Creativity level	5. Prospects level
A	9.5	44% (+10%)	45%
B	8	39% (+8%)	38% (+10%)
C	8.5	44% (+15%)	34% (+13%)
D	9	52%	37%
E	9.5	50%	89%
F	8.5	59%	42%
G	10	86% (-12%)	38%
H	8	81% (-10%)	34% (+5%)
I	7.5	41% (+7%)	81% (-11%)
G	6.5	62%	71% (-10%)
$SA_{av.gr.}$	8.5	-	-
	$A_{av.s.}$	55.8%	50.9%
	$AS_{ws.q.}$	56.1%	50.3%
	Me	51%	40%
	Quartile	11.8	13.8
	The lower confidence limit	50.8%	47.8%
	The upper confidence limit	74.2%	75.2%
	Difference	23.4%	27.4%
	Correspondence to the set interval	Does not correspond	Does not correspond

As Table 4 shows, 6 experts in the fourth question and 5 experts in the fifth question adjusted their assessments, but this still did not allow them to agree and accept the results because they do not fit into the established 15 percent confidence interval. Therefore, the decision was made to hold the third round.

The Results of the Third Round of the Delphi Survey

In the course of preparation, anonymous communication between experts and organisers also took place via Gmail and Telegram Incognito chat. The results of the third round of the Delphi survey are provided in Table 5.

Table 5. Calculation of results according to the Delphi technique in the third round of the survey (questions 4-5)

Expert	Self-assessment	4. Creativity level	5. Prospects level
A	9.5	44%	45%
B	8	44% (+5%)	38%
C	8.5	46% (+2%)	40% (+6%)
D	9	52%	37%
E	9.5	50%	89%
F	8.5	59%	42%
G	10	79% (-7%)	38%
H	8	81%	34%
I	7.5	41%	79% (-2%)
G	6.5	62%	71%
$SA_{av.gr.}$	8.5	-	-

Table 5. Continued

$A_{av.s.}$	55.8%	51.3%
$AS_{ws.q.}$	55.9%	50.7%
Me	51%	40%
Quartile	12.8%	13.8
The lower confidence limit	53.8	53.8%
The upper confidence limit	66.2	65.2%
Difference	12.4	11.4
Correspondence to the set interval	Corresponds	Corresponds

Thus, based on the results of the third round of the survey, the experts managed to make a jointly acceptable decision. Agreement was reached on all five levels of assessment of the technological competencies. We summarise the results in Table 6, taking into account the final weighted score of the questionnaire (*ASws.q.*) for each of the assessed levels.

Table 6. Generalised results of assessment by structural components of technological competence using the Delphi technique

	1. Knowledge level	**2. Practice level**	**3. Dissonance level**	**4. Creativity level**	**5. Prospects level**
Average weighted score of the question $AS_{ws.q.}$	89.1%	83.0%	21.5%	55.9%	50.7%

The data of Table 6 show that the levels of theoretical training and practical manifestation of technological competence by all experts is assessed as quite high. In fact, this is partly reflected by the third indicator — the level of dissonance between theoretical knowledge and practical representation of the theoretical background. The criteria were discussed within the concept of a well-established and efficient teaching algorithm. If the desired zone of development for criteria 1-2 and 4-5 is the maximum indicator, just the minimum level is positive for criterion 3. The result of 21.5% can be considered acceptable, but it still requires work to minimise it. The levels of creativity and prospects for the development of technological competencies, which proved to be the most problematic in terms of reaching a consensus among experts, were still averaged at 55.9% and 50.7%, respectively. This is evidence that special measures need to be taken to stimulate them. According to the arithmetic mean of 1-2 and 4-5, we can find the level of manifestation of technological competence, determined by the answers of the expert group. It is 75.1%. It will be recalled that the average result of the initial student survey was 69.7%. The difference between the data is (5.4%), but it is not critically large.

To sum up the idea of technological competence we would like to provide the final version of technological competence that the current study allowed to develop or rather confirm based on both our findings and literature review (especially TPACK concept by interpretation of Thohir et al. (2020)). Thus, technological competence is an important component in the professional training of teacher educators (faculty members), which includes not only a system of knowledge, skills, norms and values, but also the possibility of technological means for the professional and personal development of future teachers of vocational training. Being a component of a holistic professional and personal structure, it is defined as a complex of cognitive, operational-activity, didactic-design and reflexive-analytical skills, mediated by value-semantic attitudes and motives for the implementation of the teacher's professional activity, to implement the pedagogical process at school with guaranteed results.

Discussion

The application of the Delphi technique for the assessment of pedagogical phenomena has a number of features outlined above. In particular, this applies to the stage of selection of experts (Foulger et al., 2017). Since the pedagogical process is always at least two-way, it is necessary to take into account not only the opinion of specialists in the field of pedagogy, but also to take into account the opinion of the student community. This is confirmed by slight differences between the levels of assessment of technological competencies provided by students, with the level that was determined by applying the expert assessment method, which is the Delphi technique. This hybridised way of organising research on pedagogical phenomena is particularly acceptable in the niche of pedagogy (Andronie et al., 2020).

Our study showed the following classic features of the application of the Delphi expert assessment technique:

1) at least some of the experts change their answers after group feedback and discussions (Khodyakov & Chen, 2020);

2) iterative data collection and careful discussion of issues, while maintaining the anonymity of experts, helps to reach consensus, even if there were no visible steps towards unification of opinion between experts in the course of discussion (Mulder, 2017);

3) the extreme opposition opinions revealed at the initial stage of the survey were most correlated from one stage to another;

4) insignificant changes in participants' responses between the upper and lower limits may also affect the final results of the study (Khodyakov & Chen, 2020).

However, despite the classic slight fluctuations in the answers of experts, the current study found fluctuations in the range of +15 points per round. Such fluctuations are considered acceptable, but they are still quite high (Andronie et al., 2020). As the experts who admitted such a difference in their answers later explained, the previously given too high or too low scores were caused by ignorance of some points, preconditions, which, in their opinion, significantly influenced the expert's final conclusions. Thus, the establishment of partnerships with foreign universities, the prospects of receiving funds from private investors, new internship programs for faculty members, information about which was provided but not detailed at the initial stage, became key to correcting extremely low scores in the second and third rounds of the survey.

The Delphi technique for determining technological competencies was fully implemented with the use of other auxiliary techniques, including preliminary survey, which revealed some dissonance in views on the overall problem, thus urging the need for further studies (Hsu & Chen, 2019).

The study also showed that the greatest contradictions among experts arose during the assessment of the creative and prognostic aspects of the manifestation of technological competence. This is due to the very relativity of the concept of the teacher's innovative and creative activity, the contradictions of determining the optimal correlation, on the one hand, between theoretical and practical activities, which allows students to achieve desired learning outcomes quickly and with high probability. On the other hand, the frequency and nature of the use of innovative and experimental forms of organisation of educational activities by the teacher with a fairly dynamic curriculum.

Regarding the prognostic criterion, the ambiguity is caused by many of all primary and secondary and n^{th} factors (Gordon, 1994), which in the long run may contribute to or hinder the process of in-service training of faculty members, determining the levels of technological competence. The more information was provided on possible influences, the faster consensus was reached.

Paradigmically, the closest to our study is the work of Thohir et al. (2020), which: 1) is also based on the study of the concept of TPACK, but without emphasizing the competence of this concept in pedagogical activities, although, of course, related to the competence functioning; 2) is also based on the application of the Delphi method, but not relatively. In contrast to the work of Thohir et al. (2020), in our study the goal was not purely ascertaining, but ascertaining and prognostic: determining the current level of manifestation of technological competencies, as well as generalized prospects for development and improvement of the identified level within the selected group of freelance teachers. Respondents were also high school teachers, which also has its own characteristics compared to the perspective of the study Thohir et al. (2020), which focused on pre-service science teachers. In addition, our study used an empirical two-level experiment, which allowed us to approach the problem from two sides (the method of assessing the technological competencies of faculty members by students and the method of independent expert evaluation of Delphi), but to reach homogeneous conclusions, which confirms the effectiveness of our model.

The theoretical value of the results lies in the actualization of issues of technological competence of teachers of higher education institutions and in the experimentally confirmed effectiveness of the Delphi method in the field of pedagogical research.

The practical value of the results lies in the possibility of reusing the developed methodology for similar research in other educational institutions. It is also possible to adapt this model in order to study other relevant issues of pedagogy, especially those where there is a need for expert forecasting of phenomena and processes.

Further research on the topic may relate to the use of other methods of measuring technological competencies, elaboration of optimal programmes for the development of technological competencies, and so on. It is also interesting to study the correctness of the forecasts made on the development of teacher educators' technological competencies, checking the correctness and practical value of the obtained forecasts in 5 years. Terminological unification of technological competence as a complex concept, and its distinction with the terms of digital competence and ICT are also topical.

Conclusion

Technological competence ensures high-quality performance of the teacher's functions provided by all regulatory documents concerning teaching activity. Effective organisation of interaction of subjects of educational process, correct management of educational process, creation of comfortable professional and creative space for all participants of educational process, designing and realisation of educational and professional activity, stages, sequence, system of professional and cognitive activity, as well as the subsequent guaranteed results are possible only under the condition of a high level of faculty members' technological competencies. This is an integrative quality of professional training of faculty members and an indicator of professional self-improvement.

Technological competence is manifested in: 1) the correct definition of stages and algorithms of educational activities; 2) harmonious management of pedagogical processes; 3) ensuring mutually beneficial constructive interaction between the

subjects of the educational process; 4) the desire to adhere to a range of patterns and principles of organisation of the educational process with students; 5) readiness to design and implement the initially set goals, structuring the content of teaching, methods and didactic tools (technical, verbal, etc.) to solve the problems of pragmatically organised pedagogical communication and pedagogical activities of faculty members in general.

The application of the Delphi technique allowed not only to expertly measure the level of technological competencies on the example of the community of teachers according to the given parameters, but also to check the correctness of other diagnostic methods (previously conducted surveys among students). The diversified approach to the interpretation of the technological competence of faculty members allowed establishing: the level of faculty members' knowledge of modern educational technologies at 89.1%; activity-practical aspect of faculty members' training — 83.0%; dissonance between the theoretical and empirical level of teacher training and the algorithm for realising the potential in practice — 21.5%; teachers' knowledge of individual creative technologies for the organisation of an effective educational process — at the level of 55.9%; forecast of development of technological competencies of faculty members in the 5-year perspective under the condition of application of special control and skill-trainings in this direction — at 50.7%.

The average result of the primary student survey for measuring technological competencies of teachers was at the level of 69.7%. The difference between the data of 5.4% allows stating that both methods were relevant in this case. Due to the practical importance of technological competence, this aspect of professional development and self-improvement of teachers requires close attention and also the use of mechanisms of external control and stimulation.

Recommendations

Further research on the topic may relate to the use of other methods of measuring technological competencies, elaboration of optimal programmes for the development of technological competencies, and so on. It is also interesting to study the correctness of the forecasts made on the development of faculty members' technological competencies, checking the correctness and practical value of the obtained forecasts in 5 years. Terminological unification of technological competence as a complex concept, and its distinction with the terms of digital competence and ICT are also topical.

Limitations

The Delphi technique, despite a number of advantages outlined above, has a number of disadvantages that require its use with extreme vigilance and sometimes caution in assessing the phenomena of the pedagogical process. The process is very time consuming and requires vigilance from a group of analysts to correctly calculate the results. It should also be borne in mind that the collective is not in all cases correct. Because of this, the role of the stage of selection of experts and special preparation of the group of experts for the application of the Delphi technique is growing. Focusing on the search for medial solutions leads to the fact that analysts reject creative solutions to problems in the course of data processing. However, these solutions can be the most effective and offer innovative ways to reflect research issues. The Delphi's technique requires careful informing of the expert group about any factors that may have even the slightest impact on the correction of opinion.

Authorship Contribution Statement

Sosnytskyi: Conceptualization, design, supervision, final approval. Sikorskyi: Analysis, drafting manuscript. Bezborodykh: Data acquisition, data analysis / interpretation, drafting manuscript. Morozova: Data acquisition, data analysis / interpretation, drafting manuscript. Moroz: Conceptualization, critical revision of manuscript, supervision.

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Appendix

Generalized comments of experts in the first round of the survey

Expert	1. Knowledge level	2. Practice level	3. Dissonance level	4. Creativity level	5. Prospects level
A	They have a high level of theoretical aspects of high school pedagogy	The level of practical activity is rather high, however, the forms of organisation of classes need to be diversified	The process of realisation of ideas lacks a clear algorithm of actions	Creativity is manifested only indirectly	Correction is needed by the management of the institution
B	Analytical approach to theoretical problems of educational technologies	The level of practice can be improved even more	Sometimes the inconsistency of teachers' actions is noticeable	Methods of work are often outdated, especially for older teachers	Low motivation of teachers
C	Knowledge of educational technologies of high school and knowledge of technologies, methods, means, forms of activity and conditions of their application	High level of design skills	Often the results do not meet expectations	The activity is partly standard	Due to the lack of funding for the material and technical resources, one should not expect very significant changes
D	Even young teachers have thorough theoretical training	Compared to the theoretical background, practical skills of interaction with students are not so high yet	Methods and techniques of working with students are sometimes outdated	Excessive use of technical means of obtaining information	Additional financial incentives are needed to improve the motivation of teachers, but the resources do not allow
E	Sufficient theoretical background, lack of knowledge about innovative technologies	Highly productive teaching technologies of the vast majority of faculty members teachers	Despite the stated subjective teaching, the process lacks democracy	Students' creative activity is indirectly stimulated	The prospects are good enough provided the implementation of all the prerequisites described in this level
F	Teachers regularly publish high-quality scientific works from their own pedagogical experience	Take into account the age specifics of students, select interesting methods of working with ICTs	The activity of the whole teaching staff is well coordinated	Creative methods of work are used only occasionally	Prospects are mediocre
G	Participate in trainings and conferences	Demonstrate the unity of theoretical and practical training	Teachers' actions often lack integrity	Most teachers regularly introduce innovations in their teaching activities	It is difficult to say unequivocally because of the uncertainty of the conditions
H	Teachers have a high level of theoretical training	Effective, productive activity of teachers	Dissonance within the acceptable norm	Optimal alternation of traditional and innovative methods	Significant progress is not to be expected
I	Teachers interestingly present theoretical material	More stimulation of students' research is desirable	Theoretical and practical aspects of the activity look quite coherent	Classes are often boring	Under conditions of favourable state regulation of higher education, the incentives for teachers will also increase
G	Teachers are interested in innovations in pedagogy	Sometimes there is a noticeable inability to organise interpersonal communication	Practice usually completes the theory effectively The activity of the whole teaching staff is well coordinated Teachers' actions often lack integrity Dissonance within the acceptable norm Theoretical and practical aspects of the activity look quite coherent Practice mostly effectively complements the theory	Lectures do not activate students' attention and motivation	Perspectives are good enough