



TRAINING PRE-SERVICE TECHNOLOGY TEACHERS TO DEVELOP SCHOOLCHILDREN'S TECHNICAL LITERACY

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Abstract

Technical literacy is a component of professional competence of the pre-service technology teacher. However, the course content of technical disciplines in the pedagogical universities of Ukraine is not consistent with the content knowledge subsequently used in teaching practice of a technology teacher. Also, there is a need in general technical literacy of the students, yet it is developed only in its engineering design aspect. In the paper, it was proved that for the general technical literacy of pre-service technology teachers the basic concepts are the following technical phenomena: motion transmission, changes in kinematic parameters of motion, changes in force parameters of motion. Natural and scientific foundations of the machine drives were used as the basic topic-specific knowledge. It was hypothesized that effectiveness of teaching technical literacy to children would raise if the narrative about the technical phenomena is included in the content of the "Utility machinery" course for the pre-service technology teachers. The pedagogical experiment was performed in the Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (Ukraine). It included ascertaining, formative, and control stages. At the ascertaining stage of the pedagogical experiment, the students' readiness level to study technical phenomena was determined. At the formative stage, the students' readiness to develop children's technical literacy was measured. At the control stage, students' readiness level to develop technical literacy was estimated in experimental and control groups. Theoretical value of the results is in substantiating technical topic-specific content knowledge as necessary for the pre-service technology teachers. Practical significance of the results is in implementation of the narratives about technical phenomena in the learning practice of the students of pedagogical university.

Keywords: multidisciplinary approach, narrative approach, technical phenomena, technology teachers

Introduction

A part of the curricula of the Ukrainian secondary general-education institutions, the branch "Technology" is aimed to develop children's understanding of the scientific foundation of production. In Ukraine, teachers are trained for teaching this branch under the specialization "Secondary education (Handicraft and technologies)". In the core curriculum course – "Technologies" – children's learning projects are organized, which are based on the principles of congruity with nature, congruity with culture, integration, consistency, and creativity (Steshenko, 2019).

Learning technical knowledge is a didactic condition for entering a profession in the sphere of contemporary production (UNESCO, 2016). The concepts of technical education are integrity, humanization of knowledge, and sustainable development, while course content

is formed based on integrated and interdisciplinary approaches (UNESCO, 1989; UNESCO, 2016). Development of factual, procedural, conceptual and meta-cognitive knowledge in the relevant areas of technology (Barak, 2013) is a result of technical education. The content of technical knowledge is unfolded in the process of completing the learning projects by children, which are grounded in the interconnection of technical phenomena and structure and functions of technical systems (Mitcham, 1994).

In practice, however, the content of general technical training of pre-service technology teachers is selected out of the engineering theory and not out of the content of the project-based learning process. Contradiction between the need in general technical knowledge and scarce technical knowledge of the students of pedagogical universities of Ukraine raises the problem of practical use of technical knowledge in the branch “Technology”.

The drawback of technical training of the pre-service teachers in Ukraine is its orientation on engineering design for the machine-building industry (Yurzhenko & Yurzhenko, 2017). However, machine-building is not relevant for the practical activities of technology teachers.

Organization of technological activities of children is grounded in project-based learning. However, the objects of children’s learning projects usually are the household items and works of decorative and applied arts. For these objects, engineering and technical training of pre-service technology teachers is redundant and is devaluated.

Globally, in order to solve the problem of developing technical literacy of pre-service technology teachers, the researchers suggest the following methodological approaches: cultural research (Kelley & Knowles, 2016) and axiological approach (NAE & NRC, 2009). Hence, technical objects are viewed as the cultural artifacts and technical worldview—as the basic component of value orientations of students.

The basic functions of schoolchildren’s technical literacy are understanding and practical use of technical knowledge (ITEA, 1996). Technical knowledge would be acquired provided the natural and science basis of technical phenomena, and machinery operation is explained. To achieve that, traditional model making and craft projects should be complemented with informational, research, managing, game, and creative projects. Different types of learning projects broaden the sphere of practical use of technical knowledge. For instance, the senses of natural and scientific foundations of technical knowledge are the objects of research in informational and research learning projects.

Thus, at the local level, the problem is solved through shifting the accents in the informational, research, managing, creative, game projects that requires reorientation of technical training of the pre-service technology teachers from the engineering design to studying technological machine. Generalized structural and functional machine diagram was used as a formative component of general technical literacy of the pre-service technology teacher’s training (Ivanchuk, 2018). The basic components of technical knowledge of pre-service technology teacher are mechanical energy, transfer and transformation of energy. The basic technical phenomena involved in the machine drive are: motion transmission and torque, changes in kinematic and force parameters of motion, conversion of motion types. Therefore, the pre-service technology teachers’ understanding of the natural and scientific foundations of technical phenomena is the basis for their technical literacy.

Research Problem

In the study, the concept of practical knowledge (Stohlmann et al., 2012; Wang, et al., 2011), interdisciplinary didactic principle (Purzer, et al., 2015), and the concept of practice-based learning (Novoa, 2018) are considered.

Steshenko and Kilderov (2017) described the core of technical competence of the pre-service technology teacher that is rooted in activity-oriented and cultural studies methodological approaches. Putnam and Borko (2000) associated technical literacy of the technology teachers with the ability to include technical knowledge in the technological education of children. Thus,

the specifics of teaching the technical knowledge to the students of pedagogical universities requires the use of technical topic-specific content knowledge for solving practical challenges of children's education.

In defining the content of technical knowledge as a component of professional competency of the students of pedagogical universities of Ukraine, it was assumed that project-based learning is basic for the technological education of children. Hence, engineering design would be the main technical activity of technology teacher. However, the content of engineering design of an engineer radically differs from the content of engineering design of a technology teacher. There is a contradiction between machine-building engineering design training of pre-service technology teachers and their practical engineering design activities in crafts and modeling. As a result, this knowledge does not have practical application.

This problem could be solved in the context of development of scientific mindset of students. For example, Serheev et al. (2017) emphasized the worldview function of technical knowledge as a general guidance in the technological sphere. In technological education of children, this worldview function is implemented in learning projects (Serheev et al., 2018).

Yurzhenko (2019) proposed the solution of the problem of practical application of technical knowledge on the basis of the paradigm of the use of mechanical power and its transmission. Thus, mere illustration of the use and transmission of mechanical power in engineering is not sufficient. Dannyk (2012) proposed to use a generalized description of the principles of operation of technical facilities (natural and scientific knowledge and engineering implementation of these principles of operation). Varnavskiyh (2006) suggested to develop the content of students' technical training that would be rooted in generalized structural and functional machine diagram.

All mentioned approaches produce new problems to be solved. The idea to use technical worldview knowledge for developing scientific mindset of the students of pedagogical universities raises the problem of securing integrity of such mindset. The idea to illustrate the use and transmission of mechanical power in engineering requires substantiating the choice of a certain engineering object in technological education of children. The idea to use generalized description of the principles of operation of technical objects is closer to the professional activity of an engineer than to the one of technology teachers. The idea to use generalized structural diagram of a machine addresses the drawbacks of the paradigm of mechanical power use and transmission, however, it requires specification. Such specification is possible if the drive transmission mechanisms are chosen as the object of study. Accordingly, technical phenomena engaged in drive operation would become the basic concepts of the process of development of technical literacy in children that would correspond to Yurzhenko's (2019) idea about unfolding the senses of technical phenomena.

The senses of technical phenomena engaged in drives of the machines enable children to understand the practical use of natural and scientific knowledge. Considering the gaps in the fundamentals of science knowledge in schoolchildren and the need in actualization of basic natural and scientific knowledge, the narratives about technical phenomena were chosen as an effective didactic means.

Research Focus

The study was centered around raising of training of the pre-service technology teachers to the development of technical literacy of children in the process of learning "Utility machinery" course.

Research Aim

The aim of the study was to critically assess the results of including narratives in the process of training the pre-service technology teachers to develop schoolchildren's technical

literacy. The objectives of the research were the following: 1) to develop criteria and indicators for assessing technical literacy of schoolchildren; 2) to develop the narratives about the natural and scientific essence of technical phenomena and experimentally prove the effectiveness of the use of such narratives in the real-life learning process.

Research Methodology

General Background

The process of pedagogical research included ascertaining, formative, and control stages. As the basic concepts in such narratives, the following technical phenomena were used: motion transmission, changes in kinematic parameters of motion, changes in force parameters of motion. On the ascertaining experiment of the pedagogical experiment, the students' readiness level to study technical phenomena was established. On the formative experiment, the students' readiness level to develop technical literacy of children was determined. At the control stage, students' readiness level to develop technical literacy of children was compared in experimental and control groups. Eight-year (2012-2020) natural experiment in teaching and learning was realized during the "Utility machinery" course for the BA undergraduates in the Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (Ukraine).

Sample

636 students participated in the pedagogical experiment (245 at the ascertaining stage and 391 at the formative stage). Over the course of 8 years, 4 series of pedagogical experiments were conducted (two years each), and the common data set was processed with the methods of mathematical statistics in 2020. The following methods of equalizing the conditions of the experiment were used: equal composition of participants (pre-service technology teachers); permanent lecturer (Associate Professor Ivanchuk A. V.); same content of technical knowledge (drives operation); equally complicated technical problems, equal technical means of learning.

Instrument and Procedures

At the ascertaining stage, the diagnostic test for determining the students' readiness to study technical phenomena was performed. The questions of the test were assessed regarding their diagnostic value that was not over the critical value of 1.5 (Mayboroda et al., 2015) and the content of questions was validated by the experts.

The following criteria were used: value, basic features, and functional. Indicator of the value criterion – the index of the need to study technical phenomena (C_n) – was calculated based on the formula (Kyveryalg, 1980; Volovyk, 1969):

$$C_n = \frac{\sum_{i=1}^N n_i}{N}$$

where n_i is the quantity of correct answers,

N is a general number of students taking the test.

The indicator of the basic features – the index of the need to define the basic features of technical phenomena (C_b) – was calculated based on the formula (Kyveryalg, 1980; Volovyk, 1969).

The questions of the diagnostic test were divided in the following sections: the use of natural and scientific knowledge (10 questions); kinematic and power parameters of mechanical transmission (10 questions); features of the transformation of kinematic and power parameters of mechanical transmissions (10 questions). In the first section, mechanical transmission was

illustrated with the images of mechanical transmissions and description of the phenomenon of angular velocity. The students determined the technical phenomena. In the next section, combination of mechanical transmission and description of technical phenomena were used. The students determined the signs of increasing speed and decreasing torque. In the third section, the rough design of torque was used. The students determined the indicators of the increase of torque and decrease of angular velocities.

Students' readiness to study technical phenomena was evaluated under the mean value of the readiness index (C_{gi}):

$$C_{gi} = \frac{C_n + C_b + C_f}{3}$$

At the formative stage, the narratives about technical phenomena were used as an independent variable, and the readiness level of students to develop schoolchildren's technical literacy was a dependent variable. The following working hypothesis was tested: "The students' level or readiness to form schoolchildren's technical literacy would increase if the educational material about technical phenomena in drives of the machines are presented as narratives". Students were not informed about their participation in the experiment, and the course content was consistent with the curriculum of the "Utility machinery" course. The levels of students' knowledge and skills were controlled with the methods, familiar to them.

In the control groups, methodological guidance for the practical work was used; in the experimental groups, there were narratives about technical phenomena, as well as diagnostic tests. The diagnostic value of the tests was not over the critical value of 1.5 (Mayboroda et al., 2015) and the content was validated by the experts.

Students' readiness to form children's technical literacy was determined according to cognitive and processual components. For evaluating the level of development of cognitive component, the criterion of completeness of cognitive skills (C_{gc}) with the following indicators was used: index of the skill to perceive the features of technical phenomena (C_a), index of the skill to identify natural and scientific knowledge in a description (C_d), index of the skill to analyze the mechanics of the drives (C_{ch}).

Diagnostic tasks (C_a) included the following areas: figurative thinking (15 questions) and technical thinking (15 questions). Images of mechanical transmissions and their combinations were used. Students determined direction of motion transmission (5 questions), diagram of the increase of torque (5 questions), diagram of the decrease of torque (5 questions). In the technical thinking tasks, formulas of overall gear ratio were used: for power transmissions (5 questions); for speed transmissions (5 questions); for combined transmissions (5 questions). To diagnose (C_d), functional descriptions of lathe, drives were used (20 questions). Students determined natural and scientific knowledge in the functional descriptions. To diagnose (C_{ch}), the single reduction gear units (5 questions), two-stage speed reducers (5 questions), and combined reducers (5 questions) diagrams were used. The students determined gear ratio and torque. For the cognitive component, the mean value of the (C_{gc}) index was calculated.

For evaluating the level of development of processual component, the criterion of completeness of processual skills (C_{cp}) with the following indicators was used: index of the skill to analyze morphological and functional description of the drives (C_{mf}), index of the skill to define the aim of functional descriptions (C_g), index of the skill to determine the basic concepts of functional descriptions (C_i), index of the skill to prove the main point of the functional descriptions of mechanical transmissions. To diagnose (C_{mf}), the morphological descriptions of the drives (15 questions) and functional description of the drives (15 questions) were used. Students determined the elements of drives and their functions. To diagnose (C_g), descriptions of lathe, drives were used (20 questions). Students determined the aim of functional descriptions. To diagnose (C_i), the functional descriptions of mechanical transmissions were used. Students determined the basic concepts in the descriptions. To diagnose C_e , the descriptions of mechanical transmissions were used. Students established if the main point of description was well-

reasoned. For the processual component, the mean value of the (C_{cp}) index was determined.

At the control stage, the final examination was carried out. Diagnostic value of its tasks was evaluated according to the formula (Kyveryalg, 1980):

$$D = \frac{K \cdot (V_N + V_T)}{2n \cdot (k - 1)} \cdot 100\%$$

where K is overall number of tasks,

N is the number of students in the “strong” group,

V_N is the number of mistakes made by the “weak” group,

V_T is the number of mistakes made by the “strong” group.

Preliminary, a preparatory test with 52 students of experimental groups was carried out. The tasks were grouped in sections: motion transmission (6 questions), changes in kinematic parameters of motion (6 questions), changes in force parameters of motion (6 questions). At first, students determined the directions of motion transmission. In the next section, students determined gear ratios. In the third section, students calculated the torques according to the diagrams of power and speed transmissions. The results of the preliminary test were arranged in a line, with the median established. According to this median, “strong” (28 persons) and “weak” (24 persons) students were selected. They participated in final examination. The tasks were grouped in the following sections: geometric attributes of technical phenomena (6 questions), kinematic chain (6 questions), and power circuit (6 questions). At the initial stage, students determined the direction of motion transmission, geometric attributes of changes in speed and torque, force levels. In the next section, students determined gear ratios and basic geometric attributes. In the third section, students calculated the torques. The diagnostic value of the task was within the normative range between 16% and 84% (Kyveryalg, 1980).

Data Analysis

Overall database size of the pedagogical experiment was 1/17 of the total number of pre-service technology teachers in Ukraine (Vuzy Ukrainy. Dovidnyk, 2021). In the analysis, the indices of completeness of cognitive and processual skills of the students to develop children’s technical literacy were used. The obtained results of pedagogical research were checked to the extent of their randomness by means of the criterion of homogeneity χ^2 . The two statistical hypotheses: zero and alternative were compared. According to the zero hypothesis, the obtained results do not contain differences; according to the alternative hypothesis, the probability of error does not exceed 5% (significance level .05).

Research Results

The results presented in Table 1.

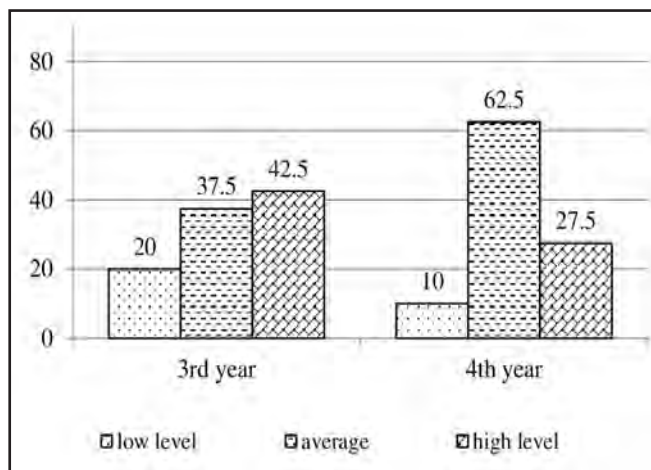
Table 1

The Results of the Final Test

Study year	Readiness level, %								
	High			Average			Low		
	C_n	C_b	C_r	C_n	C_b	C_r	C_n	C_b	C_r
1	-	-	10	50	50	20	50	50	70
2	-	55	55	55	22	-	15	23	45
3	30	90	50	80	10	30	10	-	20
4	10	50	60	100	50	20	-	-	20
5	-	50	-	50	50	80	50	-	20

Difference in (C_n) and (C_b) for the third-year and fourth-year students is caused by the impact of studying the “Utility machinery” course. Allocation of (C_p) characterizes low levels of development of figurative and operational components of students’ technical thinking. The results of the ascertaining stage of the pedagogical experiment are illustrated in the Figure 1.

Figure 1
The Results of the Ascertaining Stage of the Pedagogical Experiment



At the ascertaining stage, the third-year students were allocated to the control groups, while the fourth-year students – to the experimental groups.

The results of development of the cognitive component of students’ readiness to form schoolchildren’s technical literacy at the formative stage are presented in the Table 2.

Table 2
The Results of the Formative Stage of the Pedagogical Experiment

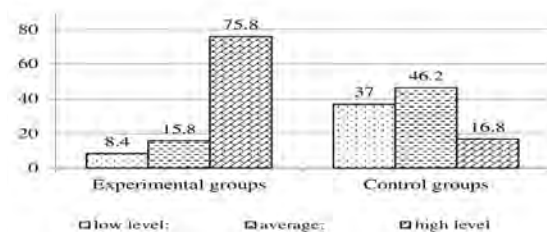
Indexes	Experimental groups	Control groups
C_a	0.92	0.84
C_d	0.96	0.51
C_{ch}	0.79	0.54

Comparison of distribution of (C_a) and (C_d) in experimental and control groups proves that impact of narratives on students’ ability to perceive the attributes of technical phenomena was not confirmed; however, their ability to identify natural and scientific knowledge was significantly influenced. Allocation of (C_{ch}) characterizes the limited potential of the narratives to learn the mechanics of the drives.

The results of the formative pedagogical experiment for the cognitive component are illustrated in the Figure 2.

Figure 2

The Results of the Formative Stage of the Pedagogical Experiment, %



The results of development of the processual component of students' readiness to form schoolchildren's technical literacy at the formative stage are presented in the Table 3.

Table 3

The Results of the Formative Stage of the Pedagogical Experiment

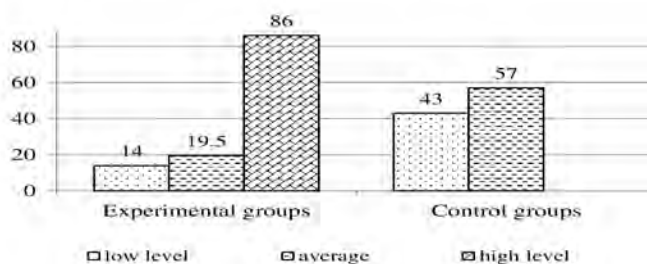
Indexes	Experimental groups	Control groups
C_{mf}	0.78	0.58
C_g	0.83	0.51
C_i	0.93	0.65
C_c	0.92	0.53

Differences in the (C_{mf}) index characterize the limited potential of the narratives to form figurative and technical thinking in students. Differences in the (C_g), (C_i), (C_c) indices give grounds to assert that the use of narratives in educational process contributes to higher level of analysis of the functional descriptions of technical objects by students.

The results of the formative pedagogical experiment for the processual component are illustrated in the Figure 3.

Figure 3

The Results of the Formative Stage of the Pedagogical Experiment, %



The results of the final test by the students of experimental and control groups are presented in the Table 4.

Table 4
The Results of the Control Stage of the Pedagogical Experiment

Scores	Frequency in experimental groups, f_e	Frequency in control groups, f_c
0 - 3	1	4
4 - 6	4	5
7 - 9	19	43
10 - 12	35	24
13 - 15	22	10
16 - 18	9	4

The results of calculation of the $\chi^2_{\text{experimental}}$ criterion are presented in the Table 5.

Table 5
Calculation - criterion

Interval	Frequency f_e	Frequency f_c	Relative frequency $f'_{e, \%}$	Relative frequency $f'_{c, \%}$	$\frac{(f'_e - f'_c)^2}{f'_c}$
0 - 6	5	9	5.6	10.0	1.93
7 - 9	19	43	21.1	47.8	14.91
10 - 12	35	24	38.9	26.7	5.57
13 - 15	22	10	24.4	11.1	15.93
16 - 18	9	4	10.0	4.4	7.12
Total	90	90	100	100	= 45.46

The results of pedagogical experiment were verified for randomness; it was found that $\chi^2_{\text{experimental}} = 45.46$ and critical value of χ^2_{critical} for $\alpha = 0.05$ and $u = 4$ is 9.49 (Kyveryalg, 1980), i.e. $\chi^2_{\text{experimental}} > \chi^2_{\text{critical}}$. Hence, the null hypothesis is not confirmed. Verification of statistical significance proved validity of the results.

Discussion

Readiness of pre-service technology teachers to form schoolchildren's technical literacy was evaluated according to their cognitive and processual components that is consistent with the idea of practical use of technical knowledge (Utesch, 2019) and dovetails with the Melezinek (1999) recommendations regarding the practical application of technical knowledge by students. For each component of the studied phenomenon, the results show the decline in the number of students with the low ability to form schoolchildren's technical literacy, while the number of students with average and high levels of this ability increased.

For the cognitive component, the lowest level of the student's ability to form schoolchildren's technical literacy in the experimental groups was identified for the index of the skill to analyze the mechanics of the drives. This reveals the lack of connection between the process of formation of the spatial thinking and graphic knowledge of students, as well as

with the narratives about the mechanics of the drives. For this component, the highest level of students' skill to form schoolchildren's technical literacy was detected for the index of the skill to identify natural and scientific knowledge in the functional description of the drives. This proves the fact that unfolding the content of natural and scientific knowledge in the plots of the narratives about the functional descriptions of machines facilitates understanding of technical knowledge by students. Students worked on practical tasks in the "Utility machinery" course, which were presented in the form of narratives.

For the processual component, the lowest level of the students' ability to form schoolchildren's technical literacy in the experimental groups was identified for the index of the skill to analyze morphological and functional descriptions of the drives. The reason for this is the multidisciplinary content of analysis of morphological and functional descriptions of the drives, with the core knowledge of natural and scientific, technical courses underlying the algorithm of actions. In this component, the highest level of students' skill to form schoolchildren's technical literacy was detected for the index of the skill to identify the basic concepts of the functional descriptions. This demonstrates that the attributes of the basic concepts in the functional descriptions could be effectively formed with the narratives.

For the cognitive component, the lowest level of students' skill to form schoolchildren's technical literacy in the control groups was detected for the index of the skill to identify natural and scientific knowledge in the functional description of the drives. This result illustrates the need to use such narratives. For this component, the highest level of students' skill to form schoolchildren's technical literacy was detected for the index of the skill to identify the attributes of technical phenomena. This proves the effectiveness of traditional technique for developing certain components of students' readiness.

For the processual component, the lowest level of the students' ability to form schoolchildren's technical literacy was identified for the index of the skill to determine the aim of the functional descriptions. This result demonstrates the need to use the narratives. For this component, the highest level of students' skill to form schoolchildren's technical literacy was detected for the index of the skill to identify the basic concepts of the functional descriptions. Such result, contrary to expectations, matches the result in experimental groups. This proves the effectiveness of traditional technique for developing certain components of students' readiness.

During the experiment, expedience of including technical phenomena as the basic concepts of schoolchildren's technical literacy into the course content was proved (Ivanchuk, 2018; Varnavskiyh, 2006). The results of the research comply with the conclusion about the positive impact of narratives on students' learning of technical knowledge (Afanasyev, 2013).

Limited potential of the narratives about technical phenomena to form consistent technical thinking of students, as Valisova (2020) and Franus (2003) previously suggested, was revealed.

Finally, the results of the pedagogical experiment show a positive impact of narratives on students' perception of technical knowledge and learning that substantiates the recommendations to widen access to knowledge as an aspect of overall modernization of the content of technical education (Levine & Marcus, 2010; Melezinek, 1999; Ruutmann & Kipper, 2016).

Conclusions and Implications

It was established that explanation of natural and scientific concepts' meaning in descriptions of technical phenomena increases the level of professional competence of pre-service technology teachers. The criteria of cognitive and processual readiness of students to develop schoolchildren's technical literacy were determined. It was confirmed that the indices of the criteria of cognitive and processual components are characteristic of the students' level of readiness to form schoolchildren's technical literacy, which is based on the conceptual type of technical thinking. In the statistically significant limits, the positive change in the level of formation of components of the readiness of pre-service technology teachers to form schoolchildren's technical literacy was established.

The main result of the research is in revealing the content of technical knowledge to the students of pedagogical universities; also, the method of narratives was tested. The change in traditional concept of formation of engineering design type of technical thinking and formation of the conceptual type of technical thinking of students creates conditions for the practical use of technical knowledge. Consequently, schools would be sufficiently stuffed and able to systemically form children's technical literacy. Well-developed technical literacy would allow the high school graduates to make an independent decision regarding their further professional education in the relevant sphere of contemporary production; and for the pre-service workers of service industry, it would be a baseline for understanding the mechanics of machines.

Further studies should be focused around the problem of integration of the narrative method and problem-based learning in the development of schoolchildren's technical literacy. The investigation regarding the use of narratives in the process of formation of the figurative component of technical thinking and development of the system of technical training tasks would also be topical.

Declaration of Interest

Authors declare no competing interest.

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