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Theoretical foundations of professionally oriented study of physics at school

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Abstract

Relevance. The modern study of physics is focused on changes in conceptual approaches to its functioning, goals, content, methods, and results. This study examines the effectiveness of a model for training future physics teachers to design lessons in the context of variable education approaches.

Purpose. The purpose of the study is to evaluate changes in the design and modelling competence of future physics teachers after implementing an experimental training model.

Methodology. A pedagogical experiment was conducted with control and experimental groups of future physics teachers. Their design and modelling competence were assessed before and after the experimental training using surveys, tests, quasi-professional tasks, and analysis of teaching practice reports. Results were analysed statistically using Pearson's chi-squared test and Student's t-test.

Results. Three components were evaluated: motivational-axiological, cognitive-operational, and productive-creative. The experimental group showed significant increases in all components of design and modelling competence compared to the control group. Statistical analysis confirmed the differences were significant. The model improved the motivation, knowledge, skills and creative abilities related to lesson design and implementation.

Conclusions. The experimental training model was effective in developing future physics teachers' competence in designing lessons for variable educational contexts.

Keywords: teaching methods; pedagogical modelling; development of constructive skills; lesson model.

Introduction

To determine the essence of the basic concept of "preparing future teachers for modelling a lesson in the conditions of variability of education", first of all, it is necessary to reveal the meaning of the definitions "modelling", "lesson model", "professional training of future teachers for pedagogical modelling", which are the basis for understanding the relevance of the topic at hand [1]. As the study suggests, the definition of "modelling" was borrowed from technical terminology in the second

half of the 20th century, because the gradual awareness of the systematic nature of pedagogical processes required their visual demonstration [2]. The modelling, that is, the creation of a sample of an object or a future product, was designed in the field of the humanities and began to be used in pedagogy [3]. This made possible to avoid too cumbersome descriptions, where a schematic representation helped to more convincingly prove the purpose, connections and result of the main idea of a scientific problem [4]. Theoretical understanding of the

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process of lesson modelling is also impossible without considering the evolution of the development of this issue as an organisational form of teaching [5].

The first attempts to substantiate the content, teaching methods, reflections on the definition of the nature of a person's need for knowledge, the mechanisms of the perception and cognition of the environment are found in the treatises of ancient Greek and Roman philosophers (Democritus, Socrates, Plato, Aristotle, Quintilian). The works of the scholars of the Renaissance (F. Bacon, C. Helvetius, J. Locke, J. Rousseau and others) disseminated among the public the opinion about systematic and purposeful teaching and upbringing, to a certain extent revealed the content, social significance of education, its goals and values [6].

For a long time, in medieval society, individual and individual-group training prevailed, when the teacher worked with one child or several of different ages [7]. In general, it is advisable to consider such educational activities a positive phenomenon [8], however, the disadvantages were the small number of children who had the opportunity to receive education and the lack of special training of the teacher [9]. Later, with the development of industry and trade, the demand for educated people began to grow [10], the original collective forms of education began to spread (Bell-Lancaster system, Dalton Plan, brigade-laboratory method of organising training), which later turned out to be ineffective [11].

Examining in detail the process of professional training of future teachers for pedagogical modelling, special attention should be paid to its sequence [9]. At the first, preparatory stage, it is believed, the focus should be on the assimilation of special theoretical knowledge by students [12], on the basis of which the modelling of the simplest pedagogical situations of a reproductive type is carried out [13] (for example, conduct an arithmetic or vocabulary dictation in an imaginary classroom, declare homework tasks) [14]. At the second, training stage, modelling of more complex pedagogical elements is practiced [15] (for example, simulate a micro lesson, micro conversation, develop a calendar plan for a semester) [16]. At the third, behavioural stage, a creative, independent modelling by students takes place [17] (for example, simulate and conduct a fragment of the lesson, simulate a complex pedagogical situation) [18]. Such a gradual involvement of future teachers as subjects of educational activity in independent pedagogical modelling has a positive effect on the development of their professional skills [19].

Materials and Methods

Evaluation of the effectiveness of experimental training took place on the basis of investigating the dynamics of the development of teachers' ability to simulate a lesson in the conditions of variability of education, which indicates a certain level of development of their design and modelling competence, using specially designed tools. The level of development of design and modelling competence among future teachers of physics was determined according to its components: motivational and axiological, cognitive and operational, productive and creative.

The motivational and axiological component of the design and modelling competence of future teachers was assessed by the following criteria:

- focus on the modernisation of physical education in terms of its variable functioning;
- awareness of the importance of pedagogical modelling in future professional activities.

The level of development of the cognitive and operational component of the modelling competence of students was determined by:

- the formedness of the system of didactic, methodological and technological knowledge for modelling a lesson in high school;
- the ability to model a lesson (plan, select resource allocation, construct a model) and implement micro components, taking into account the specificity of the subject.

The criteria for the productive and creative component of design competence are:

- the ability to model and conduct a lesson or a system of lessons using modern educational technologies, and then analyse the consequences of its implementation (reflection on the implementation of a pedagogical concept);
- the need for self-development and self-improvement.

The motivational and axiological component of the design and modelling competence of future physics teachers in the pedagogical experiment was determined using the methods of questioning, survey, writing essays, and the like.

Let us give the content of the questions aimed at establishing whether the participants in the experiment consciously chose the profession of the teacher and whether they understand the significance of the processes of reforming the study physics at the present stage:

1. What influenced your choice of profession as a high school teacher?
2. Explain whether you consider the teaching profession a prestigious one?
3. Express your position on the expediency and timeliness of reforming physics based on the concept of an information school. How do you understand your role at the present stage of its functioning?

Analysis of the answers showed: before the start of experimental training, some of the students were not sufficiently focused on deep mastering of the profession in general and poorly understood the importance of pedagogical modelling; at a low level, they were familiar with the conceptual changes taking place in the modern system of education and only partially understood their own role in this process. According to the final assessment, the number of students motivated to pedagogical activity in general, ready to implement educational reforms and modelling modern lessons with the use of promising possibilities of high school variability has increased significantly. Let us illustrate the results obtained with the answers of the respondents. "The overwhelming majority of our society, unfortunately, does not consider the teaching profession a prestigious one and perceive a role of a high school teacher as baby-sitting while the parents are at work".

"However, I personally feel an emotional uplift for choosing this profession. I am sure that the profession of a high school teacher will remain relevant at different times. Despite the fact that the educational industry is intensively developing, a lot of methodological developments, Internet

resources and portals, educational computer games for children have been created, but all this ensures only their fragmentary unsystematic development. Only a modern teacher will be able to properly organise a child-centred environment aimed at developing key skills in high-school children, in particular the ability to learn and enjoy the realisation of their intellectual growth. So, how can such an intelligent, creative profession be considered not prestigious?" Answering the question about the awareness of the importance of reforming physical education on the principles of the school concept, they confidently assert: "The reform is simply necessary. It is impossible to prepare a child for a difficult adult life with the methods used half a century ago. The burden of theoretical knowledge in the form of information, facts, rules is also not needed. Almost all of this data is publicly available on the Internet. It is much more important to teach the child to find the necessary information, to critically comprehend it. The modern generation of children needs a new educational concept. Now the mission of the teacher is directed not at relaying facts, but at preparing students for adult life: first, to help them understand fundamental universal values; secondly, develop self-confidence, focus on success in business. This approach to the learning process is the key to the formation of students' psychological stability, psychological health, stress resistance."

"In my opinion, it is important that in high school, children should learn not to be afraid to make mistakes, but

to consider them as the starting point for their own improvement. Therefore, the goal of introducing formative assessment is to create a positive attitude of older students towards their own shortcomings, opportunities and aspirations for growth.

"To provide a new type of partnership interaction, a teacher must be sensitive, attentive to children and their parents, avoid punishment, authoritarianism in communication. For example, say: "Children, let's pay attention to ...", and not "Pay attention, children!"; "Let's all together check the results of the mathematical dictation", instead of "Check the results!"; the sentence "According to the schedule, we are going to the canteen now. Who is hungry?", is perceived and performed by children much more responsible than "Line up in pairs and go to the canteen, quietly! "It is in such simple phrases that the atmosphere of friendliness and understanding is preserved, which inspires teachers and students to creative cooperation".

Results and Discussion

Comparative analysis of the formedness of the motivational and axiological component of the design and modelling competence of future physics teachers in the control and experimental groups at the beginning and at the end of experimental training are presented in Table. 1.

Table 1. Dynamics of the formedness of the motivational and axiological component of the design and modelling competence of future physics teachers

Level of formedness	Start of the experiment				End of the experiment			
	CG		EG		CG		EG	
	Number	%	Number	%	Number	%	Number	%
High	30	17.24	27	15.70	35	20.12	53	30.81
Average	86	49.43	85	49.42	102	58.62	100	58.14
Low	58	33.33	60	34.88	37	21.26	19	11.05

The data in Table 1 indicates that the number of future physics teachers, in whom a high level of the motivational and axiological component of the studied design and modelling competence was revealed, increased in the EG (by 15.11%) compared to the CG (by 2.88%); accordingly, the number of students with a low level of formedness of this component from the EG (by 23.83%) and the CG (by 12.07%) decreased. Summing up, it should be noted that students with a high level of formedness of the motivational and axiological component of the design and modelling competence were fully aware and positively perceived the new stage of physical education functioning in terms of its variability; they were characterised by a new vision of the role of a teacher as a partner, a facilitator in the personal growth of schoolchildren. This category of respondents highlighted a strong interest and desire to model quality lessons during practice, the organisation of subject-subject interaction with all participants in the educational process (students, colleagues, parents, school administration, etc.). Future high school teachers, who had an average level of formedness of the motivational and axiological component of design competence, were mainly characterised by a conscious choice of profession, understood the importance of physics in conditions of

variability and their own role in this process [20; 21]. Usually, students in this group partially recognised that pedagogical modelling is the basis for the modernisation of the educational sector. The respondents with a low level of the motivational and axiological component of modelling competence, of whom an insignificant part was revealed according to the results of the final assessment, were not completely sure of the correctness of the chosen profession, did not attach particular importance to the readiness to model lessons in high school.

The cognitive and operational component of the design and modelling competence of future physics teachers in the pedagogical experiment was determined by the results of testing, the performance of quasi-professional tasks and the analysis of reporting documentation on pedagogical practice, which made it possible to determine the level of didactic, methodological and technological knowledge and students' abilities to model a lesson, that is, to plan subject-subject interaction at different stages, select resource support, construct a model and execute projects, taking into account the specificity of the subject. Revealing the essence of the need for the teacher to plan the organisation of the subject of subject interaction during the lesson, they noted: "The concept of the school noted the subjectivity of

the teaching of applicants for physical education. In my opinion, this means not only the teacher's planning of cognitive tasks, but also his readiness to stimulate children to express their own point of view, to take an active part in dialogue, discussion, group work, and the like. However, during the teaching practice, I observed that the teacher did not pay enough attention to this. When I was directly performing the duties of a teacher, I tried to organise a subject-subject interaction with students. Unfortunately, it was unsuccessful, which can be explained by the lack of my own experience and the unpreparedness of students for such activities. To learn how to plan a lesson correctly, I specifically attended several lessons of experienced practicing teachers”.

The answer (EG), when performing the quasi-professional assignment (Plan the organisation of the subject-subject interaction of high-school children at the lesson on the topic “Addition and subtraction within 10”), noted: “Planning this stage of the lesson should take into account its goals and expected results. I realised that a certain amount of time should be allocated for this stage, relative to the intended structure of the lesson, then the optimal forms, methods and means of teaching should be chosen in accordance with the educational achievements of the students. “During the final assessment, the ability of future teachers to model lessons in terms of variability of education was tested by analysing the performance of quasi-professional tasks, for example: “Simulate a fragment of a lesson (class, academic discipline, topic, lesson stage, choose yourself), using one or several expedient modern technologies”.

“During my internship, I was convinced that planning a modern lesson involves, on the one hand, checking homework, getting to know a new topic, working with a textbook, etc., that is, drawing up a lesson plan, and on the other hand, the ability to plan the subject-subject interaction of high-school schoolchildren, using the optimal forms, methods, means corresponding to the stage of the technology lesson, possibly even taking into account different channels of information perception. Since younger schoolchildren strive to be researchers, and not passive consumers of knowledge, a real teacher should direct professional activity towards creativity in the implementation of his pedagogical plan”. Let us give examples of students performing a number of quasi-professional tasks that were used to test their practical skills to model a fragment of a lesson. Quasi-professional task was “Simulate a fragment of the lesson, which is aimed at developing the cross-cutting skills of future physics teachers (according to the school curriculum for the first grade)”.

“While studying the topic of the 29th week of the educational programme model “The World of Animals”, I will invite the children to form a working group that will conduct a sociological survey in the class “Who lives in your house?”.

Of course, the teacher should organise the students: ask (or hint) what they need to conduct the research (a list of students in the class and a pencil for writing down answers, a Whatman paper and coloured markers for drawing bar charts, pictures of pets, etc.), help to choose the most convenient time for this work, jointly plan an action plan for its implementation and provide support and assistance

if necessary. I believe that the implementation of such tasks in the classroom contributes to the development of the communicative abilities of older students (during a survey of classmates), their thinking (analysing and summarising the results of the data obtained), the ability to work with information (processing and visualising it in the form of a diagram), which in general influences the development of cross-cutting skills of future teachers of physics”, (EG).

In order to test the ability to select the resource support of the lesson, students were also offered appropriate quasi-professional assignments. They demonstrated their readiness for this activity as follows: “During the teaching practice, which I took in 4th grade, I was instructed to prepare for a math lesson on the topic “Problems that contain finding a fraction of a number”. The class worked according to M. Struk's textbook. The teacher warned me that the topic is rather complicated. In this regard, I decided to additionally turn to the educational and methodological kit (textbook, workbook, didactic materials), in which this topic is revealed, in my opinion, in a more accessible and understandable way. This textbook was recommended to us by a teacher at the university as containing competence-oriented tasks. To explain the new educational material to schoolchildren, I created special diagrams and illustrations that are demonstrated using multimedia devices. By the way, in addition, I prepared differentiated independent tasks on Internet resources to reinforce new educational material by children, taking into account their educational achievements. “Future physics teachers with a high level of formedness of the cognitive and procedural component of design and modelling competence were able, during the modelling of a lesson or its fragment, to select the optimal resource support, apply appropriate teaching technologies and organise subject-subject interaction on the principles of cooperation pedagogy.

Students with an average level of formedness of the cognitive and operational component of design and modelling competence could not always choose effective forms, methods and means when modelling a lesson. When selecting resource support, the respondents sometimes turned to a teacher or trainer for help. During the organisation of the subject-subject interaction, the students made minor methodological errors, but in the process of analysis they were noticed and later corrected [22].

Students with a low level of the cognitive and operational component of design and modelling competence did not see significant differences between modelling a lesson and drawing up a lesson plan, since they did not attach importance to the development of new pedagogical thinking, based on the awareness of the significance of the modelling process. Future physics teachers of this level neglected the possibility of using alternative programmes, textbooks, workbooks, didactic materials, not realising that familiarity with such variable sources can increase the effectiveness of the lesson and the effectiveness of organising subject-subject interaction based on partnership pedagogy. Table 2 presents a comparative analysis of the formedness of the cognitive and operational component of the design and modelling competence of the participants in the control and experimental groups at the beginning and at the end of the experimental study.

Table 2. Dynamics of the formedness of the cognitive and operational component of the design and modelling competence of future physics teachers

Level of formedness	Start of the experiment				End of the experiment			
	CG		EG		CG		EG	
	Number	%	Number	%	Number	%	Number	%
High	27	15.52	25	14.54	33	18.97	27	15.52
Average	94	54.02	88	51.16	106	60.92	94	54.02
Low	53	30.46	59	34.30	35	20.11	53	30.46

As can be seen from Table 2, in the EG the share of students with a high level of the cognitive and operational component has significantly increased (by 15.69%) in comparison with the CG (by 3.45%). In the EG and CG the number of participants with a low level of the cognitive and operational component decreased (by 20.93% and 10.35%). Analysis of the results of the development of the cognitive and operational component of the design and modelling competence of future physics teachers allows to state that a significant part of the respondents had the high and average levels. The level of the productive and creative component of the design and modelling competence of the pedagogical experiment among future physics teachers was determined on the basis of diagnostics of their abilities to model and conduct a lesson using modern educational technologies, to reflect on the application of the pedagogical concept, self-development and self-improvement. Determination of the level of formedness of the above-mentioned component among students was carried out during the report on the pedagogical practice, analysis of the results of their research activities.

Here is a fragment of the report on the pedagogical practice of the student Aigul K. (EG), who taught a lesson in the first grade by the school programme. "During my teaching practice, I had the most successful morning meeting on the topic "Space" (14th academic week). I estimate the organisation of the general educational and cognitive atmosphere of the lesson at a sufficient level, since it was held at a stable pace, its parts were saturated with an optimal number of interesting activities and were logically interconnected. So, in the process of modelling and conducting this lesson, I created the conditions for organising the subject-subject interaction, selecting exercises for the development of critical thinking of applicants for physical education, in particular, such as "logbook", "associative bush", etc. In addition, we made a virtual journey through space, had a conversation about constellations, working on mathematical problems ("colour the cosmonaut's spacesuit by calculating mathematical expressions", "Tell us which geometric shapes the rocket is made of? Which geometric shapes are dominant?"), joined the artistic (creating a composition "Secrets of space) and language and speech (work with the letter "K") components of educational activities. While working with children, by formulating problematic questions, I tried to constantly stimulate them to dialogue, supported them in answers, and delicately corrected them if necessary. I rated everyone with only positive motivating comments. Throughout the class, I constantly tried to provide feedback to the students using signal cards".

Analysing the student's work, the teacher (Zhanar P.) commented on it as follows: "It should be noted that the

lesson was conducted at the proper methodological level. A favourable psychological climate reigned in the class, which allowed the teacher to properly organise the subject-subject interaction of students, to successfully act as a partner, a facilitator. Her dialogical speech prevailed over monological. It is important that she understood the essence of formative assessment and tried to implement it. The student was fluent in the material, presented it in an accessible form, her speech was expressive, balanced. In the lesson, an integrated approach was successfully implemented, the tasks were obtained taking into account the gradual increase in complexity. However, the student made minor mistakes of a methodological nature, which, after analysing the lesson, she was able to independently realise and plan ways to overcome them".

Within the framework of our study, the results of research activities of future physics teachers were also subject to analysis, which were presented at a meeting of the Department of Primary Education and discussed at student scientific conferences. So, Alia M. noted the influence of research work on our own professional development: "My supervisor and I decided to experimentally test the effectiveness of design technology during the development of constructive and creative skills of high-school children in labour training lessons. First of all, I got acquainted with the scientific literature, which highlights certain theoretical aspects of the problem under study: the didactic structure of modern lessons in labour training in high school, features of the use of design technology, the development of constructive and creative skills of high-schoolers. Thanks to our research, we have determined that the physical structure of the world is an important theoretical basis for the development of constructive skills of students. The main favourable pedagogical conditions are: the integration of the content of subjects, the organisation of the subject-subject interaction of the teacher and students, the use of the game method of artistic design, which significantly affects the general model of the labour training lesson. The research carried out convinced me of the importance and effectiveness of creative pedagogical experimentation, which influenced the awareness of the need for constant self-improvement". In order to identify the orientation of future physics teachers to professional self-development and self-improvement, a special quasi-professional task was proposed: "Share your experience and offer the students of your group the most optimal forms that contributed to your self-development and self-improvement. Give specific examples. "

Thus, M. Akbota said: "Last year, when a new vector of school development was proclaimed, on the advice of teachers, I discovered the possibilities of self-education

using Internet resources. This is how I got to know the online education studio. In addition to the well-known course for physics teachers, the Coursera platform contains a lot of useful information, in particular for school psychologists, educational managers, parents and persons who are associated with inclusive education for older students and the like. The advantages of such a resource for teacher education are obvious: only topical problems are considered, high-quality visualisation, accessibility (free courses, it is possible to view at any time and in any place where there is an Internet connection), pleasant and educated lecturers, a convenient modern form, the availability of materials for self-test and the like. And also, I am now automatically notified when new courses are available. “

“I often use the materials of the Internet journal “Education” and an educational project “Na Urok” to prepare for practical classes. This is a real find for teachers,

because it contains a lot of useful information: the development of lessons and activities, presentations, reports, examples of generalising pedagogical experience, interesting ideas, etc. The sites also contain the success stories of teachers and schoolchildren, news in the educational field, opinions and advice of experts, and a lot of design developments with which the teacher can diversify their lessons and improve the workplace”. Having analysed such results of future physics teachers, we can state the presence of skills to reflect on the implementation of the pedagogical concept and the desire for self-development and self-improvement.

A comparative analysis of the formedness of the productive and creative component of the design and modelling competence of the students of the control and experimental groups at the beginning and at the end of the experimental study (Table 3).

Table 3. Dynamics of the formedness of the productive and creative component of the modelling competence of future physics teachers

Level of formedness	Start of the experiment				End of the experiment			
	CG		EG		CG		EG	
	Number	%	Number	%	Number	%	Number	%
High	33	18.97	29	16.86	34	19.54	33	18.97
Average	87	50.00	85	49.42	98	56.32	87	50.00
Low	54	31.03	58	33.72	42	24.14	54	31.03

The data presented in Table 3 give grounds to assert that the number of students from the EG, who have a high level of the productive and creative component of design and modelling competence, (increased by 11.05%) in comparison with the CG (by 0.57%); accordingly, the share of respondents with a low level of development of this component decreased (by 21.51%) compared to the control group (by 6.89%). It can be stated that future physics teachers with high level of formedness of the motivational and axiological, cognitive and operational, and productive and creative components of design and modelling competence, fully realised and positively perceived the reform of physical education, in particular the variability in this process. Students showed a desire to model modern lessons during practice, select the optimal resource support, apply appropriate educational technologies in accordance with the stage, purpose and results of the lesson, organise subject-subject interaction based on cooperation pedagogy, demonstrated the ability for self-development and self-improvement. The participants in the experiment, who had indicators of the average level of design and modelling competence, consciously chose the profession of teacher, understood the peculiarities of education in conditions of variability and the importance of their own role in this process. Usually, future teachers of this group partially recognised that pedagogical modelling is the basis for the modernisation of the educational sector. Modelling fragments of lessons and lessons in general, we could not always choose the most appropriate educational technologies at one stage or another. When selecting resource support, the respondents sometimes turned to a teacher or trainer for help. During

the organisation of the subject-subject interaction, they made minor methodological errors, however, in the process of analysing the lesson, they were aware of them and in the future were able to correct them.

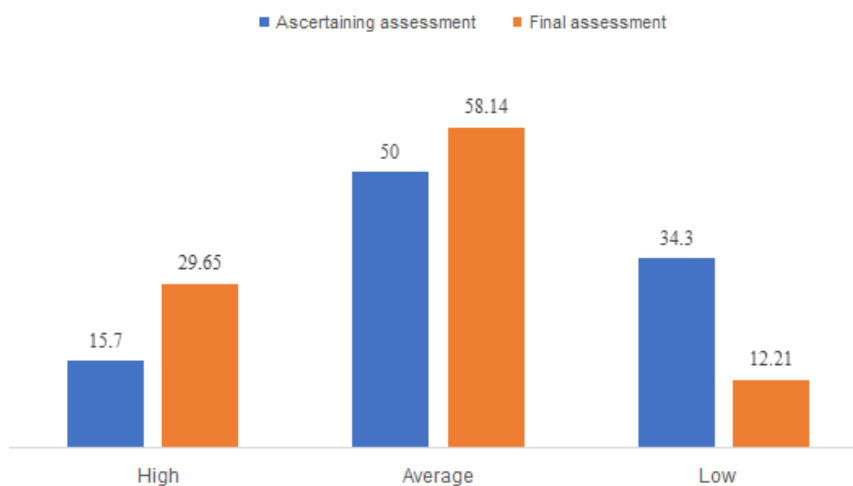
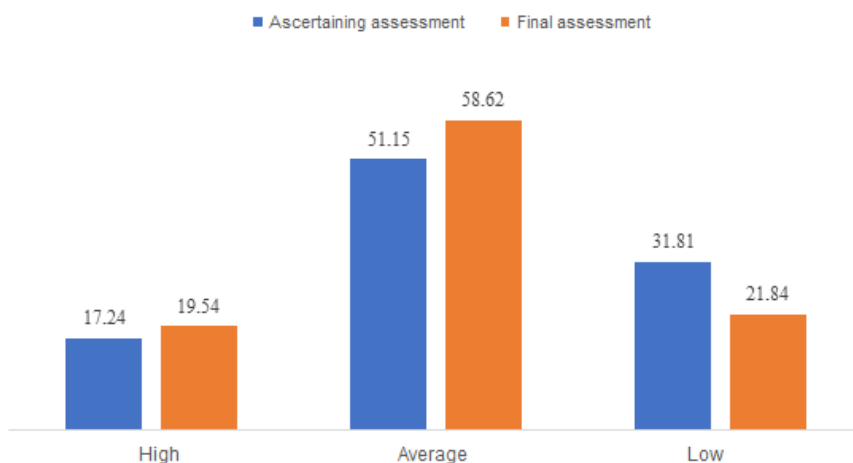
Students with a low level of development of design and modelling competence were not sufficiently confident in the correctness of their chosen profession, did not attach much importance to the ability to model a lesson in high school; they did not realise the significant differences between modelling a fragment of a lesson, a lesson as a whole, and drawing it up with a synopsis, which testified to the insufficient development of their pedagogical thinking. Future teachers of this level neglected the possibility of using alternative programmes, textbooks, workbooks, didactic materials, not realising that familiarity with such variable sources can increase the effectiveness of the lesson and the effectiveness of organising subject-subject interaction based on partnership pedagogy. The most difficult task for the students was to objectively analyse the lesson, to determine the individual trajectory of self-improvement.

Analysis and generalisation of the results of the formative experiment made it possible to identify the dynamics of quantitative and qualitative changes at all levels of the formation of the design and modelling competence of future physics teachers - high, average and low.

The results of dividing the future physics teachers of the experimental and control groups according to the levels of development of design competence are presented in Table 4 and in the form of diagrams (Figures 1-2).

Table 4. Levels of formedness of the design and modelling competence of future physics teachers

Level of formedness	Start of the experiment				End of the experiment			
	CG		EG		CG		EG	
	Number	%	Number	%	Number	%	Number	%
High	30	17.24	27	15.70	34	19.54	51	29.65
Average	89	51.15	86	50.00	102	58.62	100	58.14
Low	55	31.61	59	34.30	38	21.84	21	12.21

**Figure 1.** Diagram of the division of the EG by the levels of formedness of the design and modelling competence of future physics teachers**Figure 2.** Diagram of the division of the CG by the levels of formedness of the design and modelling competence of future physics teachers

The obtained results of the experimental study required empirical confirmation of their reliability and objectivity, which was carried out using the mathematical statistics, in particular, the calculation of the nonparametric Pearson criterion – χ^2 . For this, statistical hypotheses were formulated:

H_0 : the experimental model of training teachers for modelling a lesson in conditions of education variability does not affect the qualitative changes in the level of formation of design and modelling competence, and the results obtained are random.

H_1 : qualitative changes in the level of the design and modelling competence of future physics teachers are due to the influence of the experimental model of professional training.

The nonparametric criterion for estimating χ^2 is calculated by the equation 1:

$$\chi^2 = \sum \left(\frac{(f'_E - f'_k)^2}{f'_k} \right) \quad (1)$$

where f'_E – the relative frequency of the interval of the series of the experimental group; f'_k – the relative frequency of the interval of the series of the control group.

The relative frequency of the interval of a number of experimental and control groups at the end of the experiment is shown in Tables 2-4 and written in Table 5.

The number of degrees of freedom for χ^2 is equal to $k=(R-1)(C-1)=(3-1) \times (2-1)=2(3 - \text{the number of levels, } 2 - \text{the number of groups})$.

According to statistical tables for the value $\alpha=0.05$ and the number of degrees of freedom $k=2$, the critical value of the criterion $\chi^2_{crit}=6$ was found.

Table 5. The work table for calculating the f'_k -criterion

Levels	Output 1, %	Output Frequency 2, %	Difference	Square	Ratio
Motivational and axiological component					
H	30.81	20.12	10.69	114.2761	5.68
A	58.14	58.62	-0.48	0.2304	0.004
L	11.05	21.26	-10.21	104.2441	4.903
Criterion value:					10.579
Cognitive and operational component					
H	30.23	18.97	11.26	126.7876	6.683
A	56.40	60.92	-4.52	20.4304	0.335
L	13.37	20.11	-6.74	45.4276	2.258
Criterion value:					9.276
Productive and creative component					
H	27.91	19.54	8.37	70.0569	3.585
A	59.88	56.32	3.56	12.6736	0.225
L	12.21	24.14	-11.93	142.3249	5.895
Criterion value:					9.7
Design and modelling competence					
H	29.65	19.54	10.11	102.21	5.23
A	58.14	58.62	-0.48	0.2304	0.004
L	12.21	21.84	-9.63	92.7369	4.25
Generalised value of the criterion:					9.484

Thus, $\chi_{exp}^2 > \chi_{crit}^2$ ($9.484 > 6.0$). The experimental value of the Pearson criterion is the basis for rejecting the null hypothesis H_0 and the alternative hypothesis H_1 about the influence of the experimental model of training future teachers for modelling a lesson in the conditions of variability of education on the formation of design and modelling competence.

In addition, in order to check the heterogeneity of the experimental and control groups in terms of the level of formation of the design and modelling competence of future physics teachers, the Student's t-criterion was calculated. The calculation of the average score of the level of design competence at the end of the experiment is given in Table 6.

Table 6. Calculation of the average score of the level of formedness of modelling competence at the end of the experiment

CG				EG			
Score	Number of students	Total number of points	Average values	Score	Number of students	Total number of points	Average values
5	34	170		5	51	255	
4	102	408		4	100	400	
3	38	114		3	21	63	
Σ	174	692		3.977	Σ	172	

By calculating the t-criterion, the reliability of the coincidences and differences of the control and experimental groups was determined. Based on this, two hypotheses were formulated:

Hypothesis H_0 : the differences in the level of formedness of the modelling competence of future physics

teachers in the experimental and control groups of students are not significant.

Hypothesis H_1 : the differences in the level of formedness of the modelling competence of future physics teachers in the experimental and control groups of students are quite significant.

To calculate the t-test, the variance was determined. The calculation of the variance in the formedness of design and modelling competence is given in Table 7.

Table 7. Calculation of the variance of the formedness of the design and modelling competence of future physics teachers

Group	Score	Number of scores	Average score	Variance	Standard deviation	Variance 2	Average
EG	3	21	4.174	-1.174	1.378276	4.134828	0.0448
	4	100		-0.174	0.030276	0.121104	
	5	51		0.826	0.682276	3.41138	
CG	3	38	3.977	-0.977	0.954529	2.863587	0.0468
	4	102		0.023	0.000529	0.002116	
	5	34		1.023	1.046529	5.232645	

The variance has been obtained, and the value of the t-test has been calculated. The value of the Student's t-test is less than the calculated 1.96). (6.61). This indicates that the null hypothesis is rejected, and hypothesis H1 about the difference in the level of formedness of the design competence of future physics teachers in the experimental and control groups is accepted with the probability of 95 %.

Conclusions

The comparative analysis of the results of the final assessment of the levels of formedness in students of the motivational and axiological, cognitive and operational, and productive and creative components of design competence was conducted. This analysis revealed important findings about future physics teachers. Those who understood modern education's variable conditions performed better and recognized their crucial role in

education reform. These students showed higher levels of didactic, methodological, and technological knowledge. They demonstrated better skills in lesson planning, resource selection, and model construction. Their ability to reflect on implementing pedagogical concepts was also superior. Additionally, these students showed a stronger desire for professional self-development and self-improvement.

So, the positive dynamics of the formation of design and modelling competence among future physics teachers, in particular its qualitative and quantitative indicators, testifies to the effectiveness of the proposed model.

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Conflict of Interest

None.

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Теоретичні основи професійно спрямованого вивчення фізики в школі

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Анотація

Актуальність. Сучасне дослідження фізики орієнтоване на зміни концептуальних підходів до її функціонування, цілей, змісту, методів і результатів. У цьому дослідженні розглядається ефективність моделі підготовки майбутніх учителів фізики до проектування уроків у контексті варіативного підходу до навчання.

Мета. Мета дослідження – оцінити зміни проектно-моделюючої компетентності майбутніх учителів фізики після впровадження експериментальної моделі навчання.

Методологія. Проведено педагогічний експеримент з контрольною та експериментальною групами майбутніх учителів фізики. Їх компетентію проектування та моделювання оцінювали до та після експериментального навчання за допомогою опитувань, тестів, квазіпрофесійних завдань та аналізу звітів про педагогічну практику. Результати аналізували статистично за допомогою критерію χ^2 -квадрат Пірсона та t-критерію Стьюдента.

Результати. Оцінювали три компоненти: мотиваційно-аксіологічний, когнітивно-операційний та продуктивно-креативний. Експериментальна група показала суттєве підвищення всіх компонентів компетентності проектування та моделювання порівняно з контрольною групою. Статистичний аналіз підтвердив значущість відмінностей. Модель покращила мотивацію, знання, уміння та творчі здібності, пов'язані з розробкою та проведенням уроку.

Висновки. Експериментальна навчальна модель виявилася ефективною для розвитку компетентності майбутніх учителів фізики щодо розробки уроків для варіативного навчального контексту.

Ключові слова: методи навчання; педагогічне моделювання; розвиток конструктивних умінь; модель уроку.