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Formation of Skills to Visualize of Future Physics Teacher: Results of the Pedagogical Experiment

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Abstract: It is relevant for teachers of science to get visualization skills for explaining abstract concepts, showing the logic of processes, and explaining the natural phenomena at the micro and macro levels.
For research conducting, authors used theoretical and empirical methods such as analysis of specialized for physics visualization software; survey for determining the needs of physics teachers; analysis of the curricula content for the training of future physics teachers; performing of the pedagogical experiment to determine the effectiveness of the developed model, statistical evaluation is provided by using Student's criterion.
The developed model of visualization skills formation of future physics teachers is based on cognitive-visual approaches and provides the modernization of the content of teachers' training by including a special course.
The analysis of software that supports the teaching of physics makes it possible to divide it into three classes: virtual and digital physics laboratories, mathematical and simulation software, office applications with Smart-Art-objects, and animation software. Analysis of the visualization studying material needs of physics teachers, based on a survey, showed the priority of skills in the office suite programs and skills of creating simulation models (static and dynamic). The introduction of a model of visualization skills formation of future physics teachers ensures the achievement of the goal. Further research is directed to the study of the problem of forming future science teachers' skills to use augmented reality in the educational process.

Keywords: *future physics teachers, ability to visualize, computer visualization tools, forming visualization skills.*

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1. Introduction

Modern education is now characterized by an intensification of the learning process, which is due to various factors, including the development of information technology and the exponential increase in information flow, which is often ignored in the text format by the subjects of studying. The latter not only actualizes the need for visualization of textual information, but also the problem of teachers' willingness to visualize study material with a cognitive approach.

Among the possible solutions to this problem, we will note the formation and development of future teachers' skills to use computer visualization tools (CVT), which means computer programs, in which developers provide the ability to visualize on the computer screen abstract objects or processes, their models in compact form (if necessary from different angles or dynamically) with the ability to demonstrate the internal interconnections of components, including those hidden in the real world (Semenikhina & Biloshapka, 2018).

We will note the results, which describe: methodological, cultural and didactic aspects of mathematical training of future specialists in the pedagogical field (Perminov et al., 2019); the importance of changing the paradigm of technology teacher training in the face of fast implementation of digital technologies and tools (Nekrasova & Novikova, 2019); educational projects designed for future teachers, who study physics, chemistry or mathematics, which are devoted to establishing students' skills of creating physical models and to representation them by mathematical methods (Miranda & Koyama, 2017); the general teachers' position on using software protocols in the pedagogical process of various sciences (biology, chemistry, physics, and geography) (Zupanec et al., 2017); development features and outcomes of a course that integrates different STEM disciplines (De Meester et al., 2015); changes in methods and technologies that have taken place over almost 50 years from traditional lectures to the modern techniques based on electronic educational resources (Haugen, 2015)

The analysis of scientific publications has confirmed the expediency of using CVT by biology teachers (Osadchyi, 2014) for increasing the effectiveness of educational material in biology; chemistry teachers (Kelly & Akaygun, 2019) to develop abstract thinking and enhance students' cognitive activity in conducting chemical experiments.

Among the works devoted to the problems of professional training of physics teachers, including using information technologies and tools, we note the works that describe:

- general problems of professional training of physics teachers, in particular: results of the analysis of practical works on natural sciences, performed by future physics teachers, to improve their professional training (Zorrilla et al., 2019); peculiarities and problems of continuous training of physics teachers, which focused on the assessment of students' academic achievement (Breganha et al., 2019); presenting future physics teachers about their role in the educational process and the submission of teaching material (da Silva & de Almeida, 2018); analyzing opinions and views on innovation and modernization of teaching procedures, methods and forms of learning, supported by an appropriately and didactically well-prepared digital educational resource (Karolcic et al., 2014);

- the study of specific topics in physics, in particular: the peculiarities of studying the topic "Magnetic forces" using multimedia tools (Onorato & De Ambrosis, 2014); the study through the integration of the case-method and digital technologies to develop students' creative abilities on the example of "Optics" course (Ramankulov et al., 2020);

- features of organizing and conducting a physical experiment based on virtual laboratories, in particular: performing in a virtual physical laboratory in order to form metacognitive skills of future specialists (Yusuf & Widyaningsih, 2020); the problem of choosing a virtual laboratory and mastering the process of training in it (Kassenova, 2017); the use of virtual physics laboratories to conduct physics training experiments for future engineers (Mircik & Saka, 2018); the use of an innovative 3D virtual reality learning environment designed to assist students in studying and teachers in explaining the various physical processes (Grivokostopoulou et al., 2017); the impact of the using of virtual laboratories on enhancing the creative abilities of future physics teachers (Gunawan et al., 2017); the using of visual models to accompany the training in optics from the standpoint of the quantum nature of light with consistent analysis of classical and modern experiments (Malgieri et al., 2014);

- usage of different technologies, forms, and methods of teaching, in particular: features of the usage of interactive forms of teaching in the preparation of physics teachers (Garnaeva et al., 2019); blended learning features for future physicists and physics teachers using the Moodle platform (Krasnova & Shurygin, 2019); features of implementing active ICT-based training with millisecond resolution to support physical learning (movement, momentum, etc.) (Kobayashi & Okiharu, 2009);

- the usage of electronic educational resources in the training of physics teachers, in particular: the possibility and feasibility of studying the online course "Methods and innovative technologies of teaching physics", dedicated to the development of ICT competence of the future physics teachers (Garnaeva et al., 2018); distance learning as a computer simulator for the usage of ICT in the future professional work of physics teachers (Mahdi et al., 2018); peculiarities of preparing physics teachers to use online learning tools and electronic educational resources (Kulikova et al., 2015); experience in developing computer-based analytical assignments to prepare students for the physics exam (Kravets et al., 2013);

- features of computer simulation training, in particular: features of teaching future physics teachers computer simulation that develops their intellectual ability to perform mental operations (Khazina et al., 2016); stages of designing training activities based on the 7E training model developed in the virtual laboratory on the topic of "Electric current" (Karagoz & Saka, 2015); peculiarities of the influence of atomic 3D models on the educational achievements of students in physics (Akilli & Seven, 2012).

Among the works of Ukrainian scientists-educators, we note the works, which describe the problems of improving the school experiment in physics by ICT tools (Zabolotnyi & Lavrova, 2013).

At the same time, it remains an open problem for future physics teachers to become able to use visualization through their professional training.

Objective: To describe the results of the pedagogical experiment on the formation of visualization skills of future physics teachers.

Investigating the problem of the formation of future skills in the use of CVT by physics teachers consistently required five tasks: 1) specification of software specialized in the field of physics, which can be attributed to the CVT; 2) analysis of the needs of physics teachers for visualization teaching material; 3) analysis of the content of the curricula focused on the training of future physics teachers to visualize the educational material; 4) development of a model of forming the ability to visualize educational material by future physics teachers; 5) checking the effectiveness of the developed model.

2. Materials and methods

The theoretical and empirical methods were used to perform the research tasks: analysis of specialized software in the field of physics software for visualization of concepts, phenomena, processes (task 1); a survey to determine the needs of physics teachers to visualize the course material (task 2); analysis of the content of the curricula for the training of future physics teachers (task 3); pedagogical design of a model of visualization skills formation of future physics teachers (task 4); performing of the pedagogical experiment to determine the effectiveness of the developed model with Student's criterion for statistical evaluation of averages to confirm the reliability of the obtained results.

A pedagogical experiment to test the effectiveness of the model of visualization educational material skills formation of future physics teachers was conducted based on educational institutions of the Sumy and Vinnytsia regions (Ukraine). 48 physics teachers, 103 students (future physics teachers) were involved in the experiment.

The choice of participants was caused by educational institution's orientation on training and retraining of future and currently working teachers, particularly teachers of physics, with the annual organization of natural science festivals, training, workshops, and experimental classes for this purpose.

All participants were aware of the purpose of the experiment and gave their consent to participate.

Initially, current working teachers were surveyed about their needs in the visualization of educational material, and after that authors confirmed the importance of visualization skills developing for future physics teachers. Also, it was confirmed the expediency of developing an appropriate model of visualization skills forming, which would be introduced by the special course within the range of elective courses.

47 students were involved in the experimental training (experimental group), and 56 students were involved in the control group. The experimental groups were formed as follows: students of both groups studied in the same educational institution and according to the same training plans, the only difference was that the experimental group chose a special course among elective disciplines, while the control group studied traditional computer mathematics course. Additionally authors provided the ascertaining experiment in purpose to confirm the same level of academic achievements of students in control and experimental groups at the beginning of the study, which was confirmed statistically by the analysis of averages according to the Student's criterion. In this way authors confirmed the equality in conditions at the start of the experiment.

During the pedagogical experiment, the training of experimental and control groups differed only in one special course, which involved activity-based and cognitive-visualizational approaches and project-study methods of education. All other conditions remained the same.

To test the effectiveness of the model, a diagnostic toolkit was developed in the form of indicators that tracked positive shifts in the ability of future physics teachers to visualize teaching material.

Such indicators were: 1) knowledge of the CVT and their tools; 2) knowledge of the school course of physics; 3) knowledge about educational material forms and methods; 4) the ability to use the CVT toolkit to build static models; 5) the ability to use CVT toolkit for designing interactive models; 6) the ability to analyze developed models (own and colleagues').

These indicators made possible the characterization of the three levels of future physics teachers' ability to visualize teaching material:

low (characterized by low motivation to use visualization technologies in professional activity and creative self-realization; lack of the ability to model educational material; elementary theoretical and technological training in the introduction to computer visualization tools for the learning process; fragmentary ability to analyze and self-analyze educational activity; lack of desire to introduce computer visualization tools into own professional activity);

average (characterized by a limited interest in visualization technologies and the usage of computer visualization tools, partial ability to use simulations, situational desire to implement computer visualization tools in professional activities, and the need of additional motivation, sufficient theoretical and technological training in computer visualization, uncertainty about the expediency of the interactive models, unreliably identified pedagogical self-evaluation);

high (characterized by conscious and reasoned motivation for the usage of visual models and computer visualization tools in professional activity or creative self-realization, thorough theoretical and technological training in the fields of physics and CVT, ability to critically evaluate willingness to use CVT and create own visual models of knowledge, awareness of the need for constant evaluation of the development of such tools and technologies).

Methods for determining achievements by selected indicators were as follows.

1. Knowledge of CVT and its instrumentation was checked by the tests offered by (Bezuhlyi et al., 2018).

An example of one of the tasks:

Match the specific CVT to the visualization form that it supports:

1) XMind	a) Flash animation
2) MS PowerPoint	b) Cognitive maps
3) PowToon	c) Presentations
4) Adobe Animate	d) Video
	f) Scribing

2. Knowledge of the school physics course was checked by tests based on “External independent evaluation” in physics. The test included 40 questions, the correct answer of which was rated as 1 point. Testing questions were as follows:

During the uniform movement of the body in a circle it’s acceleration:

a) is zero
b) is constant in modulus and direction
c) is constant in modulus and varies in direction
d) changes continuously in modulus and direction

How does a capacitor represent the circuit diagram?

a) b) c) d)

3. Knowledge about the forms and methods of identification of educational material was checked by the tests developed by (Bezuhlyi et al., 2018). The questions were as follows:

Among the diagrams are:

a) Histogram;
b) Sectoral and circular diagram;
c) Bubble diagram;
d) Ishikawa Scheme;
e) Flowchart.

4. The ability to use the CVT for constructing static models was tested by an individual task (for example, to construct an electrical diagram of a given laboratory installation), which evaluated: the appropriate choice of the CVT (5 points), compliance with physical laws (10 points), the presence of all the necessary elements in the scheme (10 points), the correctness of elements’ connection (5 points), the expediency of using the tools of the selected software (10 points).

5. The ability to use the CVT for constructing interactive models was tested by executing a project (for example, developing an interactive visualization model of the phenomenon of lunar eclipse), which assessed: compliance with physical laws (10 points), interactivity of the model

(10 points), the presence of shadows on intermediate one's stages of motion of the Earth (5 points), completeness and correctness of images (5 points), step-by-step detailing of the phenomenon (5 points), the expediency of using the tools of the selected software (10 points), clarity of animation (5 points).

6. The ability to reflect on the author's development was determined based on an adapted test by L. Berezhnova (Karpov, 2003), containing 18 questions with three options for each answer. The maximum number of points that can be scored on the test is 54 points.

The distribution of levels for each indicator was as follows (Table 1)

Table 1. Score distribution to determine levels of learning achievement by each of the indicators

Level / *Indicators*	*Low*	*Average*	*High*
1. Knowledge of CVT and their tools	0-8	9-15	16-20
2. Knowledge of physics school course	0-14	15-29	30-40
3. Knowledge of the visualization of educational material forms and methods	0-8	9-15	16-20
4. Ability to use the CVT to build static models	0-14	15-29	30-40
5. Ability to use the CVT to build interactive models	0-19	20-39	40-50
6. The ability to evaluate the developed models (own and colleagues')	0-24	25-39	40-54

Personal contribution of each co-author: O. Semenikhina – idea, research design, manuscript writing; A. Yurchenko – data statistical evaluation and statistical analise; O. Udovychenko – collecting empirical data from Sumy city; V. Petruk – collecting empirical data from Vinnitsya city; N. Borozenetz – collecting empirical data from Romenskiy district of Sumy region; K. Nekislih – collecting empirical data from Nedrighayliv district of Sumy region.

3. Research results

Task 1. According to the analysis of software, which supports the teaching of physics from the standpoint of cognitive imaging, we have identified specialized software in physics (virtual physical laboratories, digital physical laboratories), software for modeling physical processes (mathematical and simulation modeling), as well as general-purpose software (office programs with Smart-Art objects, programs for creating animations) (Fig. 1).

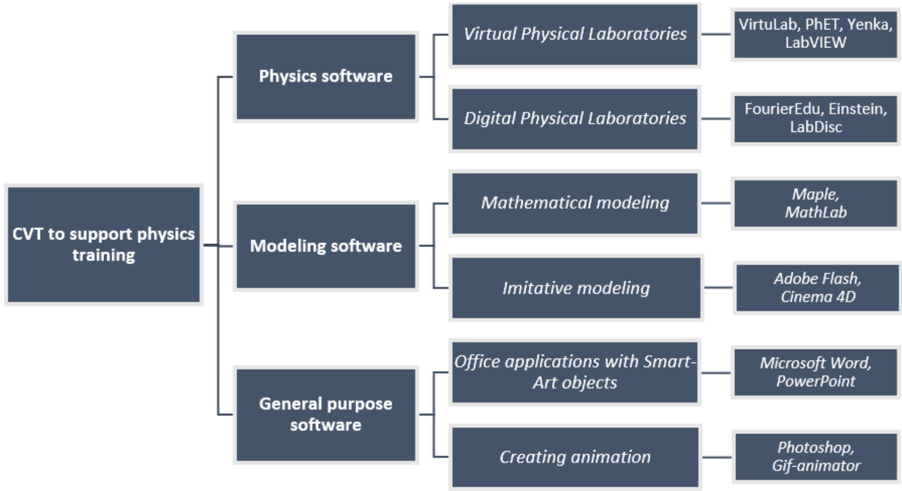

Fig. 1. Classification of CVT to support education in physics

Physics software includes virtual and digital physical labs.

Virtual labs are computer environments that allow you to organize experimental research using computer tools in virtual space. Virtual laboratories provide the possibility to design simulation models of the phenomena or processes in which quantitative characteristics make it possible to predict the results and validate mathematically their probabilities. Virtual laboratories in the field of physics include VirtuLab, PhET Interactive Simulations, Yenka, Electronics Workbench, LabVIEW, NI Multisim, and others.

Digital labs are a collection of special digital equipment and related software. Digital physical labs are a real part of the physical installation of a real physical phenomenon. They allow real-time measurements of characteristics to explore a particular phenomenon or process. Among such laboratories in the field of physics are the FourierEdu, Einstein, LabDisc, Pasco, Relab, L-micro, and others.

Modeling software includes programs that can be used to construct a computer model of a studied object or phenomenon. The computer model can be mathematical, so the studied object is described (mathematically and graphically) and investigated based on mathematical formulas, dependencies, and physical laws, as well as it can be a simulation (static or interactive), then it is possible to demonstrate ideas, dependencies, consequences of physical phenomena and laws by simplifying them with a focus on their important characteristics. Usually, mathematical software programs (symbolic computer environments such as Maple, MathLab, or interactive applications like GeoGebra, etc.) are used for mathematical modeling of physical processes. At the same time for imitative modeling are used computer graphics systems graphics (Adobe Photoshop, CorelDraw, 3D Max, etc.), as well as animation environments, (Adobe Flash, Adobe After Effect, Cinema 4D, and others), are used for simulation.

General software includes 1) a suite of office applications that have Smart-Art objects; 2) programs for creating elementary time-lapse animation.

A suite of office applications (text and spreadsheets, presentation software) is available with the function of building Smart objects, which help to identify algorithms, processes, dependencies, influences, etc. Their usage in physics lessons is convenient for organizing or repeating topics while mastering new material submitted step by step (algorithm of action), etc. Also, these applications are useful for presentations during lessons or the preparation of didactic materials, including the creation of tables, diagrams, booths for the classroom, etc.

Simple time-lapse animation programs provide the ability to create elementary dynamic images with minimal frame changes to capture simple ideas, phenomena, or processes. Usually, these animations have a *.gif extension and are small in size. These include Adobe Photoshop, Microsoft Gif Animator, Easy Gif Animator, and more.

Task 2. Studying the opinion of physics teachers (48 teachers who work as teachers of physics in Sumy region) regarding the usage of specialized software, including CVT, in the lessons of physics revealed the following:

1) access to computer classes is limited (100% of respondents) and therefore it is impossible to organize a physics lesson on a personal computer;

2) digital physical laboratories (98% of respondents) are not available in every general secondary education institution in Sumy region, what on the one hand confirms the importance of pre-mastering their tools, and on the other, focuses on using of other software in physics lessons;

3) virtual physical laboratories such as Virtulab, Prometeus are

difficult to perceive by students (71% of respondents) and therefore their usage in non-specialized classes is debatable;

4) the package of office programs, in particular, the presentation programs (67% of respondents) is actively used which confirms the need to master them to support the educational process;

5) didactic materials presented on the Internet are actively used: presentations (83% of respondents), video materials (73% of respondents), animations (73% of respondents), but teachers say that they often refined the material or borrowed an idea with reworking it under the peculiarities of the educational process (100% of respondents);

6) visual models and animation videos (94%) are actively used to support physics education by teachers, however, teachers indicate their ability to independently develop a computer visual static model (48%) and an animation movie related to physics training (23%).

Thus, thanks to a survey of current teachers, authors concluded that future physics teachers must master a package of office programs and the environments in which it is possible to create visual models (static and dynamic).

Besides, the authors explored the priorities of using CVT by future physics teachers in their future professional activities. In particular, according to the survey results (103 students, future teachers of physics and mathematics), the answers were distributed as follows (Table 2).

Table 2. Questionnaire

№	*Question*	*Answer*
1.	Have you ever created visual models using: a) virtual physical laboratories; b) digital physical laboratories; c) mathematical modeling software; d) simulation software; e) office applications with Smart-Art objects; f) software for creating animations.	 a) Yes / No b) Yes / No c) Yes / No d) Yes / No e) Yes / No f) Yes / No
2.	Due to your opinion, mark the necessary CVT for your future professional activity, scoring 1 to 6,	a) virtual physical laboratories; b) digital physical laboratories; c) mathematical modeling software;

	respectively.	d) simulation software; e) office applications with Smart-Art objects; f) software for creating animations.
3.	Choose, due to your opinion, the types of CVT required for the professional activities of a physics teacher.	a) physics software; b) modeling software; c) general-purpose software.
4.	Underline, due to your opinion, which CVT is needed for the professional activities of a physics teacher.	VirtuLab; Electronics Workbench; Prometeus; Yenka; LabView; NI Multisim; FourierEdu; Einstein; LabDisc; L-мікро; Adobe Flash; CorelDraw; Photoshop; 3D Max; Cinema 4D; Maple; Mathematica; MathCad; Maxima; MathLab; Microsoft Excel; Microsoft Word; Microsoft PowerPoint; Microsoft Publisher

Survey results show that 67% of future physics teachers have skills in working with Smart-Art objects; only 33% can create static visual models using computer graphics programs; only 12% know how to create simple animations. At the same time, few students can create interactive models, and there are no students at all able to develop three-dimensional models of the processes under study.

The results of the experiment also showed the following:

1) 100% of students wish to use CTV in future professional activity;

2) most of our future physics teachers put office programs with Smart-Art objects in the first place, programs for imitation modeling - in the second place, software for modeling of physical processes (mathematical packages and virtual physical laboratories) - in the third place, and software to visualize the results of a real physical experiment were on the fourth place.

3) among virtual physical laboratories, future physics teachers preferred VirtuLab (47%), Electronics Workbench (34%), Prometeus (15%), Yenka (9%), LabView (6%), NI Multisim (3%);

4) among the digital physical laboratories, students identified desirable descriptions, characteristics, and capabilities - FourierEdu (85%),

Einstein (24%), LabDisc (9%), L-micro (3%);

5) future physics teachers will use Adobe Flash (57%), CorelDraw (58%), Photoshop (54%), 3D Max (12%), Cinema 4D (5%) to create complex animations, interactive models or 3D visualizations;

6) among the computer simulation systems, students identified Maple (37%), Mathematica (20%), MathCad (54%), Maxima (24%), MathLab (13%);

7) in the office suite with the ability to develop Smart-Art objects, the percentage was divided as follows: Excel (57%), Word (44%), PowerPoint (78%), Publisher (3%).

Thus, an analysis of the needs of physics teachers (current and future) to visualize educational material based on the survey confirmed the priority of the ability to operate the office suite tools and the ability to create simulation models (static and dynamic) to explain physical phenomena and processes.

Task 3. To accomplish task 3, the authors have analyzed the content of the curriculum and work programs of the disciplines of professional training of future teachers of physics at Makarenko Sumy State Pedagogical University. The analysis confirmed the presence of educational components designed to build the ability to use a suite of office applications ("ICT", 3 credits, 1 year) and skills to use a computer in physics lessons (special course "Using a computer in physics lessons", 4 credits, 4th year). At the same time, syllabus analysis confirmed the lack of discipline aimed at developing the ability to create visual computer models to support physics education.

The results of Tasks 1-3 gave the basis for the development and experimental verification of the model of formation by future teachers of physics skills to visualize the educational material.

Task 4. The developed model of visualization teaching material skills formation by future physics teachers (Fig. 2) is based on activity and cognitive-visual approaches and provides the modernization of the content of professional training by including in it a special course aimed at the formation of such skills.

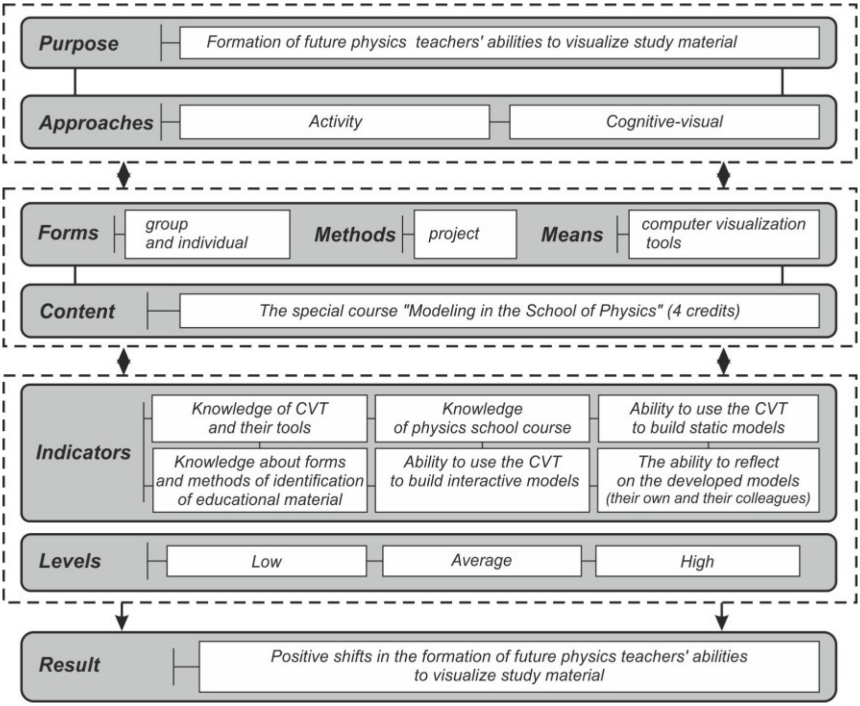

Fig. 2. Model formation of future teachers of physics skills to visualize teaching material

We consider the activity approach as a priority of active action in the formation of skills to visualize teaching material for future teachers of physics. The cognitive-visual approach is necessary because of the importance of qualitative visualization of educational material taking into account the laws of visual perception, psychological peculiarities of the perception of colors and forms, and due to the importance of forming by future physics teachers the ability to predict the activity of visualization of visual activity.

The special course " Physics Modeling in the Secondary School Course " is designed for 4 credits. It contains two modules: "Computer Visualization Tools for Simulation" and "Physical Process Modeling in Adobe Flash". The first is devoted to giving an idea of the CVT toolkit for creating static and interactive objects. The second is devoted to a dual purpose: to teach how to create unique interactive applications to support the educational process and to test the ability of future physics teachers to correctly identify physical phenomena and processes.

During the special course, such topics are offered for students: "Simulation modeling", "Computer simulation tools", "Motion animation", "Form animation", "Animation of graphics, text, and colors of objects", "Complex animation", "Animation of physical processes and phenomena."

Laboratory classes solve typical tasks (for example, tasks for developing a body motion demonstration with a given trajectory) and professionally oriented tasks (for example, visualization of the process of changing the aggregate state of water (water-ice-steam) according to the instruction, and offer similar tasks for independent work. The special course program provides for the implementation in individual projects the development of an interactive application to visualize a particular physical phenomenon, law, or process.

The specified special course stipulated the use of group and individual forms of training, project methods of teaching, CVT (Adobe Flash, Adobe Photoshop, and CorelDraw) as learning tools.

The developed model required verification of its effectiveness.

Task 5. 47 students were involved in experimental training (they formed an experimental group). The control group enrolled 56 students.

At the beginning of the experiment (the third year of study) and the end of the experiment (the end of the fourth year of study), EG and CG students were asked to take tests and complete tasks to determine the levels of academic achievement by each of the indicators.

The results obtained (Table 3) were additionally subjected to statistical analysis.

Table 3. The dynamics of the ability to visualize teaching material in future physics teachers (%)

Indicator and method of it's evaluation		*Levels*	*EG*	*CG*
Knowledge of CVT (tests)	I1	Low	-23,4%	-17,9%
		Average	-8,5%	3,6%
		High	31,9%	14,3%
Knowledge of school physics course (EIT based tests)	I2	Low	-12,8%	-12,5%
		Average	-6,4%	1,8%
		High	19,1%	10,7%
Knowledge about forms and methods of refining training material (tests)	I3	Low	-42,6%	-50,0%
		Average	14,9%	26,8%
		High	27,7%	23,2%

Indicator and method of it's evaluation		*Levels*	*EG*	*CG*
Ability to use the CVT to build static models (individual task)	I4	Low Average High	-19,1% -2,1% 21,3%	-19,6% 8,9% 10,7%
Ability to use the CVT to build interactive models (individual project)	I5	Low Average High	-36,2% 10,6% 25,5%	-17,9% 5,4% 12,5%
The ability to reflect (tests based on L. Berezhnova)	I6	Low Average High	-27,7% 4,3% 23,4%	-19,6% 10,7% 8,9%

To compare the statistical significance of the results of the experiment, the Student's t-test was used (MS Excel spreadsheet analysis package).

Zero hypothesis: the difference between the means in the control and experimental groups is insignificant and equal to zero)

Alternative hypothesis: the means in the control and experimental groups differ.

Statistical analysis of the results confirms the effectiveness of the study of the special course for the formation of visualization educational material skills: at the significance level of 0.05, the null hypothesis about the equality of averages at the beginning of the experiment is accepted and rejected after its conduct for each of the indicators (Table 4).

Table 4. The results of the statistical analysis according to Student's criteria (for a significance level of 0.05 critical T = 1.96)

Indicator	*Average*				*The value of statistics*	
	CG (before)	*EG (before)*	*CG after)*	*EG (after)*	*|T| (before)*	*|T| (after)*
I1	9.77	9.13	11.36	13.19	1.5	2.27
I2	19.92	18.23	23.68	27.3	0.97	2.02
I3	8.01	8.85	12.89	14.28	1.33	2.07
I4	17.71	19.15	25.2	28.45	0.77	2.33
I5	21.8	23.47	24.71	29.85	1.24	2.62
I6	27.21	24.85	36.63	39.87	1.32	2.09

4. Conclusions

The informatization of society influences the younger generation who refuses to read texts but quickly adopts visual images. This necessitates the usage of visualizations of educational material in the educational process and the need for advanced training of teachers, in particular, and physics teachers.

Analysis of software that supports the teaching of physics from the standpoint of cognitive imaging makes it possible to divide these applications into three classes: software in physics (virtual and digital physical laboratories), modeling software (mathematical and simulation), general-purpose software (office software programs, Smart-Art objects, and animation software).

An analysis of the needs of physics teachers in visualization training material based on a survey showed the priority of using the tools of the office suite programs and the ability to create simulation models (static and dynamic) to explain physical phenomena and processes.

An analysis of the content of the curriculum and work programs of the training courses for future physics teachers confirmed the lack of disciplines aimed at developing the ability to create visual computer models.

The developed model of visualization teaching material skills formation by future physics teachers is based on activity and cognitive-visual approaches and provides the modernization of the content of professional training by including in it a special course, which is studied before professional traineeship and used group and individual methods. (Adobe Flash, Adobe Photoshop, and CorelDraw).

Experimental verification of the developed model confirmed its effectiveness. Based on Student's criterion comparison in terms "Knowledge about CVT and their tools", "Knowledge of the school course of physics", "Knowledge about forms and methods of refinement of educational material", "Ability to use the CVT for building static models", "Ability to use the CVT for Interactive Model Building, "Self-evaluation ability" confirmed the statistical difference between control and experimental groups. “Knowledge of CVT” was the most dynamic indicator, which explains students' interest in modern information visualization technologies and the usage of CVT in their activities (31.9% versus 14.3% in EG and CG, respectively).

Further research will be directed to the study of problem formation skills of future teachers of natural and mathematical disciplines to use augmented reality in the educational process.

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