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Developing Cognitive Independence of Future Informatics Teachers by Multimedia Tools

Nataliya V. Yakymchuk [a, *], Victor V. Kazachenok [b]

[a] I. Zhansugurov Zhetysu State University, Taldykorgan, Kazakhstan
[b] Belarus State University, Minsk, Belarus

Abstract

Future Informatics teachers need to have skills and abilities to continuously improve their knowledge in the field of both modern Information Technologies and modern methods of teaching Informatics. Specialists should constantly self-study because of the rapid pace in development of Informatics and Information Technologies. Thus, the high level of cognitive independence gives students real opportunities to integrate into the world information space, operating information resources presented in various forms. A new learning technology based on subject- and problem-oriented computer training programs and, in particular, multimedia programs is one of the ways to train highly qualified specialists. The programs help to improve the efficiency of learning technology, to intensify educational process, to improve the quality of training. At the same time, it is the role of an Informatics teacher that is significantly increasing. However, modern courses of Informatics do not adequately reflect the issues related to the theoretical and practical aspects of multimedia technology. This article describes our experiment on developing the components of cognitive independence of future Informatics teachers through learning, development and practical use of multimedia tools and gives the details of the used diagnostic material.

Keywords: cognitive independence, multimedia, diagnostics, Informatics teacher, motivation, experiment.

1. Introduction

Pedagogical education is modernized in order to provide high professionalism, pedagogical and professional culture of a specialist who receives a bachelor's degree in accordance with the modern requirements of information society and the demands of pedagogical practice (Ministry of Education et al., 2010). Rapid constant changes in the content of the subject "Informatics" determine changes in professional university training of a future Informatics teacher.

* Corresponding author
E-mail addresses: jakim79@mail.ru (N.V. Yakymchuk)

At the same time, not just a well-educated specialist is in demand in the labour market, but a specialist who has qualities necessary for continuous improvement of knowledge in addition to professional skills (Abrami et al., 2015; Delen, Liew, 2016). Future Informatics teacher needs knowledge both in the field of modern Information Technologies and methods of their pedagogical application (Novković-Cvetković, Stanojević, 2017). A future teacher needs to adapt to a rapidly changing environment because of the limited possibility of mastering the new content of the subject at a faster pace in the university (Torabi et al., 2013). It means that it is necessary to master the skills of continuous self-learning (Arsić, 2014; Zanden et al., 2018).

Thus, the high level of cognitive independence gives students real opportunities to integrate into the world information space and participate in professional information processes, operating information resources presented in various forms, and use multimedia tools of presenting information for self-expression (Kazachenok, 2017; Milková, 2012; Rusakov et al., 2017).

The powerful computer multimedia systems and interactive computer programs have become the basis for intensive development of the content and principles of creating electronic textbooks, training programs, their usage on the basis of mobile devices (Sakibayev, Yakimchuk, 2017; Folley, 2010), tablets (Duran, Aytaç, 2016; Chen, Sager, 2011) for self-education of students, as well as their use in blended (Dalal, 2014; Yap et al., 2016) and distance learning (Kazachenok, Mandrik, 2011; Kazachonak, Mandrik, 2009).

Simultaneously, a number of researchers develop some issues related to a cognitive load in multimedia education (Mayer et al., 2004; Sorden, 2005; *Davies*, *Cormican*, 2013; Kalyuga, 2013), principles of multimedia education (Mayer, Moreno, 2003), as well as the use of multimedia technologies in the university pedagogical process (Kalyuga, 2013; Schnotz, Rasch, 2005) and their impact on formation and development of learning motivation (Folley, 2010; Vanslambrouck et al., 2018) and individualization of learning (Schnotz, Rasch, 2005; Casillas et al., 2016).

In these circumstances, it is of paramount importance for future specialists to develop the need in constant renewal and updating of knowledge in Informatics, and skills to meet this need (Milková, 2015; Dalal, 2014). Mastering new content of the subject area "Informatics" is possible only when all components of cognitive independence develop as a whole. Therefore, in the experimental part of our study we tested the process when future Informatics teachers were developing the components of cognitive independence, and the level of the education content that students were acquiring. We identified informative, operational, motivational, emotional-volitional and reflexive components in the structure of cognitive independence.

2. Materials and methods

To diagnose the levels of cognitive independence, we have developed a set of indicators, control and ascertaining materials (tasks, tests).

The indicator is considered as a component of a criterion, i.e. a specific indicator of qualities of a process or phenomenon (Borodin et al., 2015). For example, we chose the indicators of the operational component for measurements based on the skills of creative activity listed by the authors N.V. Bordovskaya and S.I. Rozum (Bordovskaya, Rozum, 2011) in combination with the features of creative achievement of the goals by a teacher, distinguished by V. Ye. Peshkova (Peshkova, 2015).

Table 1 shows the totality of all indicators on the informative, operational, motivational, emotional-volitional and reflexive components of cognitive independence of future Informatics teachers.

Table 1. Indicators of the selected components of cognitive independence of future Informatics teachers

Components	Indicators
Informative component	General professional knowledge (psychological, pedagogical, methodological).
	The amount of knowledge acquired by students in Information Technologies and Informatics (general, special).
	The system of knowledge acquired by a student about the ways and methods of using multimedia tools for cognition, self-education.

Operational component	The ability to form a problem, set a goal, suggest a rational, original solution in professional activity.
	The ability to transfer the acquired knowledge and methods of activity to different situations (analogous, partially modified, completely new ones).
	Operative and independent reproduction of knowledge.
	The ability to effectively use multimedia learning tools.
Motivational component	Cognitive interest in the object of professional activity.
	The need for self-improvement and self-education in the field of multimedia tools.
	The need to overcome difficulties in learning.
Emotional-volitional component	Strong-willed efforts to complete educational and cognitive activity.
	Striving to overcome difficulties in learning.
	Willingness to adopt and implement independent solutions.
	Making independent decisions in both standard and non-standard pedagogical situations.
Reflexive component	Self-assessment of the level of professional competence.
	Analysis and correction of cognitive activity.
	The ability to change oneself for achieving success in independent cognitive activity (analysis and improvement of the relationship between goals, means and consequences of actions).
	Self-monitoring of the use of multimedia tools and the result of his/her cognitive activity

To measure each indicator, diagnostic materials (tests and tasks for execution) have been developed.

We have identified three levels of cognitive independence of future Informatics teachers: high, medium, low for each of the components.

When characterizing each level, we used such a concept as the degree of acquirement (V.N. Bespalko gives the term – the level of assimilation in his work (Bespalko, 1995), which implied the student's ability to perform certain purposeful actions for solving a certain class of problems associated with the use of the object of study.

In our study, the method of expert assessments was used to determine the completeness, consistency, awareness of knowledge (Dneprov et al., 2017). Experts, measuring the degree of development of the studied quality, assessed in accordance with three levels. The experts were teachers-methodologists of the Informatics and Methods of Teaching Informatics Department, the Department of Information Technologies and the Department of Pedagogy and Psychology, I. Zhansugurov Zhetysu State University (ZhSU) (http://zhgu.edu.kz/).

When carrying out the differential analysis, we used a "biparadigmatic" approach, which allows combining quantitative test results with survey data, study of activity products, as well as with the results of oral questioning and interviews. We used statistical methods to empirically confirm the validity of the study results.

During the courses "Introduction to pedagogical profession", 'Informatics", etc., students were tested to check the development of cognitive independence on the first and second indicators of **the informative component**, questioned on availability (absence) of additional knowledge in the field of multimedia tools.

To achieve the greatest objectivity and reliability of information, we offered test tasks from each section of the courses. 500 test questions were developed and proposed covering all the topics studied for control and experimental groups for each course. 40 test questions to diagnose each student were selected by random sampling with the help of the software developed by us.

We divided into the levels in accordance with the assessment policy adopted in I. Zhansugurov Zhetysu State University in terms of the credit education system (Table 2). According to the grading scale, the following quantitative indicators were determined for the low, medium and high levels: the high level is 90-100 points (excellent); the medium level is 75-89 points (good); the low level is up to 75 points (unsatisfactory, satisfactory).

Table 2. Grading scale

Letter scale grade	Numerical scale grade	Points	Traditional Grade System
A	4.0	95-100	**Excellent**
A-	3.67	90-94	
B+	3.33	85-89	**Good**
B	3.0	80-84	
B-	2.67	75-79	
C+	2.33	70-74	**Satisfactory**
C	2.0	65-69	
C-	1.67	60-64	
D+	1.33	55-59	
D	1.0	50-54	
F	0	0-49	**Unsatisfactory**

To determine the level of development of **the operational component**, we used:

- a method for analyzing the products of respondents' activity;
- a questionnaire to identify students' abilities to use the multimedia tools in education;
- the methodology for compiling a test material by students.

We were able to identify the level of *the fourth indicator* using the questions of the questionnaire "Multimedia tools in Education". Here are some of the questions in this questionnaire:

- Are you familiar with training computer programs? (A lot and constantly, insufficiently, no)
- Do you have any application programs, information technologies? (Sufficiently, only the simplest ones, insufficiently)
- Could you optimally combine traditional and innovative (active methods of teaching, the newest models in organization of educational process) methods and means of teaching during the period of pedagogical internship? (A lot and constantly, differently, insufficiently)
- Do you know how to use the Power Point program capabilities when completing SIS assignments (students' independent study) and in preparation for other forms of study? (To a high degree, sometimes, very rarely)
- Do you use the capabilities of other, not listed above, various software products when completing SIS assignments (students' independent study) and in preparation for other forms of study? (to a high degree, sometimes, very rarely)

We evaluated each answer as follows: to a high degree – 2 points; sometimes – 1 point; very rarely – 0 points. The levels of the fourth indicator were distributed according to the points scored (the high level is 16-22 points, the medium level is 11-16 points, the low level is less than 11 points).

The boundary levels of all the studied indicators were selected in accordance with the recommendations of Ye. Sidorenko to identify differences in the level of the feature studied (Sidorenko, 2002, chapter 2).

We used the assessment based on the analysis of the students' project products (presentations, thematic booklets, sites) according to the requirements for multimedia projects to determine the levels of the *second and first indicators* of the operational component of students' cognitive independence.

Project-oriented tasks were developed and proposed for students in each course (Programming, Programming C ++, Computer Architecture, Computer Graphics, Modeling Basics in 3D MAX, Non-traditional methods of teaching Informatics). Here are some of the tasks:

1. Demonstrate how the inkjet printer devices function using the capabilities of 3D MAX program.

2. Develop and simulate animation materials on the topic "The principles of building local computer networks" by the tools of PowerPoint 2010.

3. Using C ++ language, develop and write a program that displays an animated model of the map of the Republic of Kazakhstan.

4. Record a mini-video lecture on the topic: "Basic methods of array sort".

Moreover, we adhered to the requirements proposed by the authors N.K. Solopova and O.V. Vyazovova (Solopova, Vyazova, 2010), which included an assessment of the technological, informative and ergonomic levels of the project (20 points, 50 points, 15 points according to each level).

Quantitative indicators for the low, medium and high levels are selected as follows: the high level is 57-85 points; the medium level is 29-56 points; the low level is up to 28 points.

To determine the levels of *the third indicator* (operational and independent reproduction of knowledge), we used the diagnosis of students by compiling tasks in a test form for each unit of educational material. The methodology of students' participation in test compilation encouraged them to independence and self-development. At the same time, the student's learning success was evaluated without comparison with others. It gave an opportunity to self-evaluate the learning success (Maltseva, 2002). Table 3 presents criteria evaluation for compiling test tasks. The quantitative indicators for the low, medium and high levels are as follows: (based on criteria evaluation according to a 10-point scale) the high level is 9-10 points; the medium level is 7-8 points; the low level is up to 6 points inclusively.

Table 3. Criteria evaluation for compiling test tasks

Criteria	**Maximum number of points**
Completeness of the task performed (15-20 questions on the topic covered)	1
Compliance of the test material with the topic studied	1
Coverage of all the concepts and definitions of the topic studied	1
Identical plausibility of answers to the test task, i.e. incorrect answers should be plausible	1
Maximum clarity of the text (no discrepancy)	1
Brevity (up to 12 words)	1
Simple stylistic layout	1
All answers, correct and incorrect, should have approximately the same number of words	1
Associations facilitating selection of the right answer are excluded	1
The extra words ("in the figure above", 'from the examples listed") are excluded	1
Total	**10**

Also, to determine the levels of *the third indicator*, SIS assignments were analyzed and evaluated in accordance with the grading scale of the credit education system (Table 2).

We used questionnaires "Diagnostics of the level of partial readiness for professional and pedagogical self-development" (Fetiskin et al., 2002) and "The demand for self-improvement and self-education in Information Technologies and multimedia tools" to evaluate **the motivational component** of cognitive independence and to determine the levels of the component's indicators. Here are some of the questions from this questionnaire:

1. Does the learning process at a university have a significant influence on formation of your demand to acquire knowledge in the field of multimedia tools?

2. What role in training future teachers do you assign to new information technologies?

3. Do you use new information technologies independently in your learning process?
4. Do you need to acquire new knowledge in multimedia tools?

We evaluated each answer as follows: highly is 2 points; sometimes – 1 point; very rarely – 0 points).

To measure the level of indicators of the **emotional-volitional component**, we used the questionnaires "Diagnostics of the level of partial readiness for professional and pedagogical self-development" (Fetiskin et al., 2002) and the methodology "Diagnosis of communicative and organizational inclinations (COI-2)" (Fetiskin et al., 2002: 184). This method is designed to identify communicative and organizational inclinations of an individual (the ability to clearly and quickly establish business and friendly contacts with people, the desire to expand contacts, participate in group activities, the ability to influence people, etc.). The tools that diagnose the indicators of the emotional-volitional component were chosen due to the fact that these techniques, developed specifically to identify the indicators we are considering, have the full scope of their content.

To measure the level of indicators of **the reflective component**, we used the test "Reflection on self-development" according to diagnostics of the level of self-development and professional-pedagogical activity by L.N. Berezhnova (Fetiskin et al., 2002). Quantitative indicators for low, medium and high levels were determined according to the processing and interpretation of results on the scales "Level of aspiration for self-development", "Self-evaluation of one's personality", "Self-assessment of the level of ontogenetic reflection", "Diagnostics of implementation of needs for self-development", proposed by the authors of the test.

We used the presented diagnostic materials and methods to measure the level of the studied quality development both at the stating stage of the experiment and at all stages of the forming experiment with small adjustments.

Students majoring in Informatics, who were studying at the Faculty of Physics and Mathematics from 2011 to 2017, participated in the experiment. In total, there were 150 participants including 76 students in the control group, where the traditional teaching method was practiced, and 74 students in the experimental group, where experimental methods were used in teaching. 30.7 % of male and 69.3 % of female students participated in the experiment.

The students were divided into experimental and control groups in two stages.

At the initial stage, first year students, who participated in the experiment (more than 95 % of them enrolled the university right after school or college), were divided into three clusters: 1) graduates of privileged educational institutions (lyceums); 2) graduates of urban secondary schools and secondary schools-gymnasiums; 3) graduates of colleges and rural schools.

At the second stage, students were distributed to the experimental and control groups for each cluster, if possible, evenly, by random selection, and separately for boys and girls. The name of each applicant was recorded into a private card. After mixing the cards, we randomly took the necessary number of cards. The students, whose names were on the selected cards, were distributed to the experimental group, the rest – to the control group.

Identification of the initial conditions was based on the following parameters: the students of the experimental and control groups studied at the same university (identity of technical support), the subject was taught by one teacher according to a single program approved by the ZhSU Academic and Methodological Council. In addition, initial teaching of Informatics students was identified by preventive activities that took place in the course of studying the courses "Informatics", "Introduction to the pedagogical profession" before the experiment began.

Before the beginning of the experiment, the characteristics of the initial training state for these courses in the experimental and control groups coincided with the significance level of 0.05 according to Fisher's statistical criterion (a detailed description of the methodology for applying the criterion is described below).

In particular, the number of students with a high and average score in the control group was 35 (46.1 %), in the experimental group – 34 (46.0 %).

We proposed the introduction of an appropriate methodology for developing cognitive independence of future Informatics teachers by multimedia tools to improve the quality of their teaching in the field of modern Informatics.

To determine the most effective forms and methods of teaching, taking into account the specifics of multimedia tools (Mayer et al., 2004; Mayer, Moreno, 2003) and the specifics of the major "Informatics" (Dalal, 2014, Majherová, Králík, 2017), a forming experiment was conducted with these groups of students. The experiment was conducted on the premises of I. Zhansugurov Zhetysu State University.

The purpose of the forming experiment was to test the effectiveness of the developed methodology described below.

To achieve this goal, the following tasks had to be solved:

- to compare the results of the initial state analysis and the results of the forming experiment;
- to reveal dynamics of results of developing students' cognitive independence by multimedia tools;
- to conduct a differential analysis on effectiveness of formation of the studied quality by statistical methods;
- to draw conclusions and make recommendations on the further use of the developed methodology.

Next, we briefly outline the content of the appropriate methodology, implemented in the teaching and educational process of the university by stages (**theoretical, integrating, practical ones**). The first stage (theoretical) lasted two semesters (3, 4 semesters) of the second year, the second stage (integrating) lasted two semesters of the third year (5, 6 semesters), the third stage (practical) lasted two semesters of the fourth year of study (7, 8 semesters).

The purpose of the methodology is to develop cognitive independence of future Informatics teachers by multimedia tools: to deepen and systematize students' knowledge base in the field of multimedia; to shape a positive attitude to the use of multimedia, to develop skills to create multimedia tools with the help of computer programs and it is advisable to apply various types of multimedia products in their future teaching activities.

At **the theoretical stage** of the methodology, conscious motivation is developing to use multimedia in the process of students' independent cognitive activity by using various types of multimedia support. The main task of the **integrating stage** is to give knowledge and develop skills by major subjects by developing multimedia tools. The final stage in developing cognitive independence of future Informatics teachers is the **practical stage**, when students can apply multimedia technologies in pedagogical activities.

The experimental group students used updated academic programs of basic and major courses, as well as a special course and a program of pedagogical internship. The renewed topics of the courses under study did not break the logics of main topics, harmoniously merged into their content; in addition, the titles of main topics and the total number of hours according to the curriculum were not changed. Details of each innovation will be described below by the implementation stages. The control group was taught using traditional forms, methods and techniques of teaching; the topics of subjects were not changed in academic programs.

When choosing methods and means for the purposeful developing cognitive independence of future Informatics teachers, we used the experience of applying blended learning technology to improve the quality of teaching (Folley, 2010; Yap et al., 2016; Vanslambrouck et al., 2018). In contrast to the control groups, in addition to the traditional means, forms and methods of teaching, students of experimental groups did SIS assignments using different multimedia tools that we developed and tested (electronic textbooks on the subjects studied, lessons for interactive whiteboard, interactive schemes, etc.). In particular, multimedia educational and methodical complex (MEMC) "Multimedia in education", as well as renewed teaching methods and techniques. We will give their description and clarify the peculiarities of their application at different stages of developing cognitive independence of future Informatics teacher. The control group was provided only with traditional data storage media (methodological aids, textbooks, problem books, etc.).

Theoretical stage of developing cognitive independence of future Informatics teachers.

Teachers who taught the experimental group had a seminar "Multimedia support for SIS assignments" at the first year of study. The topics of the academic programs on the courses Programming (2nd year, 3rd semester) and Programming C ++ (elective course) (2nd year, 4th semester) were updated. For example, the following topics of the course "Programming" are supplemented with multimedia content: “Graphics in Pascal language”, "Graphic and multimedia information display”, etc.

***Multimedia tools*:** At this stage we used electronic multimedia textbooks “Programming”, “Programming C ++” intended for students to independently master theoretical and practical units of courses using up-to-date computer visualization tools that contain various level practical tasks. The text material of each topic is supplemented by video and audio materials.

Besides textbooks and problem books on traditional media, students of experimental groups used 7 independent lessons developed for an interactive whiteboard in order to support practical and laboratory lessons (Molina, Sampietro, 2015; Yakimchuk, 2009). Each lesson concerns a certain topic on programming.

In addition to these textbooks for additional multimedia support of lecture classes, we developed a set of mini-lectures on the above course s (Folley, 2010; Whatley, Ahmad, 2007). Each video file lasting 10-15 minutes is a “screencast” for studying the most difficult for understanding parts of the theoretical material of course s, for example, on the topics "Recursion", "Sorting arrays", etc.

***Methods and techniques of the theoretical stage*:** Along with traditional methods and techniques, we actively used associative methods at various stages of classes: actualization of knowledge, independent study of new material, checking the studied material in the form of SIS (students’ independent study) assignment. The methodological purpose to apply associative methods (intelligence maps, associograms, etc.) was students' independent application of complex knowledge in their interrelationship, development of the skills of graphical representation and structuring of knowledge.

The integrating stage of developing cognitive independence of a future Informatics teacher.

The topics of academic programs on the courses “Computer Architecture” (3rd year, 5th semester), “Computer Graphics” (3rd year, 6th semester) were updated. For example, the topic “Multimedia systems” was included in the unit “Specialized computers” of the standard program of the course “Computer architecture”, and the topic “Adobe Photoshop tools for creating animations” was included in the academic program of the course “Computer graphics”.

***Multimedia tools*:** we used the electronic multimedia textbook “Computer Graphics”, designed for students to self-study such units of the course as “Raster Editor Adobe Photoshop” and “Vector Editor CorelDRAW”. The textbook includes materials in video, audio, and text formats.

The set of mini-lectures or screencasts lasting 10-15 minutes was developed as an supplementary tool for studying the most difficult practical techniques of working with computer graphics editors, for example, “Creating lines in Corel DRAW object model”, “Masks of complex Adobe Photoshop objects”, and so on.

Taking into account the necessity and importance of gaming activities in learning (Veličković, 2013; Gómez, Barujel, 2017), during studying the course “Computer Architecture”, we used a multimedia teaching game developed in the Delphi programming environment (Yakimchuk, 2011). This is a full-fledged computer game, which has its own storyline, script and game world.

Methods and techniques of the integrating stage: at this stage we used the method of the thematic multimedia portfolio. At the beginning of the semester students received the topic and, during the course, collected multimedia materials that they were developing (screencasts, flash animations of various directions, presentations, etc.). Using this method, students could apply knowledge and skills acquired in previously studied courses, such as, for example, web technologies and Internet programming. They could finalize the portfolio at the end of the semester and present interconnected web pages with multimedia content.

The practical stage of developing cognitive independence of a future Informatics teacher of computer science.

At this stage, the topics of the academic program on the course “Fundamentals of Modeling in 3D MAX” (4th year, 7th semester) were updated; a specialized course “Non-traditional methods of teaching Informatics” and a program of pedagogical internship (4th year, 8th semester) were developed and tested.

Multimedia tools: We used the electronic textbook "Fundamentals of Modeling in 3D Max" at all types of lessons, along with full (50 minutes) video lectures on study of lecture material (tools and program commands). The textbook contains screencasts for performing thematic laboratory tasks, and a set of ready-made three-dimensional models.

The specialized course "Non-traditional methods of teaching Informatics" was supported by MEMC "Multimedia tools in teaching". The MEMC gave opportunities for students to acquire professional knowledge both under teachers' supervision and independently, so it was used both in a classroom and for SIS and TSIS (students' independent study and students' independent study with teacher) as required by the credit education system. When developing multimedia tools, we made an emphasis on students' independent study, their team work, mini-research of various levels, activation of cognitive activity. It should be noted that the developed MEMC combined the properties of an ordinary textbook, reference book, laboratory manual and an expert of the acquired information.

Methods and techniques: We used an innovative Case study method in teaching Informatics combining it with other methods. The Case study method perfectly complements traditional methods at seminars and TSIS in developing independent cognitive activity skills of future Informatics teachers in study of multimedia technologies for their future pedagogical activity.

At the preliminary stage, the teacher distributed case studies describing the mechanism for further work, clearly defined goals, tasks and the rules of work for each stage; the questions to be answered, the criteria and principles of evaluation were called.

The Case study method was based on students' independent study. Firstly, students received information on the case (specific learning "problem", which is described in a specific period of time, revealed and clearly formulated with the aim of diagnosing and self-decision), its analysis and interpretation, and then they searched for possible solutions to the situation. After students formed an independent view of the situation and found solutions, they were united in small groups and shared the results of independent work, received feedback, developed the optimal solution to the problem, presented their results to other small groups. At the end of this work the teacher summed up with a few comments and remarks directly on the content of the situation (solutions, key provisions of the pedagogical situation, problems) and on other aspects (e.g., interesting points of presentations, creative findings, and analytical thinking). At the end of the lesson, each member of the group was evaluated, their grades were explained.

The method of projects was the leading method of performing independent work at this stage (Fernández et al., *2013*). The choice of the educational project topic and the beginning of its implementation were organized in parallel with the laboratory and practical classes. The project was implemented in parallel with study of the course: at the current lesson students studied the material on implementation of a certain stage of the corresponding project. In the course of the experiment, on the basis of the analysis of the curriculum for the major "Informatics", variants were developed for the content of projects from different subject areas, taking into account interdisciplinary connections, in which elements of the fundamentals of multimedia technologies can be studied.

At this stage of experimental work with students, during pedagogical internship, one of the main and most effective forms of work on developing the motivational component of students' cognitive independence was the interest group' program for schoolchildren "The World of Multimedia." Students supervised the sections of the interest group: "Web-masters", "Researcher", "Computer graphics and animation".

3. Findings

Thus, the method of developing informative independence of future Informatics teachers by multimedia tools has the following **unique features**: firstly, we relied on the use of different types of multimedia support as a source of training materials, learning tools, and so on; secondly, the use of multimedia tools as the teaching method indirectly – as a final product of students' work in acquiring knowledge and skills in various courses.

The role of multimedia as a means of teaching is expanding at each subsequent stage in developing the cognitive independence of future Informatics teacher. At *the initial stage* it is a means of visual presentation of educational material. At the *integrating stage* students learn the technology of creating various multimedia tools (including interactive ones) in addition to using multimedia as a means of visual representation. At *the practical stage*, future Informatics teachers carry out creative multimedia projects, both group and individual ones, during the course "Non-traditional methods of teaching Informatics". The projects were later used in teaching practice in classrooms and supervising schoolchildren's interest groups. For this, students use all the knowledge and practical skills acquired at the previous stages.

This distribution of the role of multimedia tools in the process of training the future specialist allows us to achieve the goal of each stage of the methodology for the formation of the desired personal education.

Table 4 indicates the results of the final assessment after three stages of the experiment (where IS is initial state, E is the results of experimental groups, C is the results of control groups). The integrative indicator shows the arithmetical average of the numerical values of all five components of cognitive independence.

Table 4. The results of developing components of cognitive independence of future Informatics teachers by multimedia tools (in %).

Components	**High level**			**Medium level**			**Low level**		
	IS	**E**	**C**	**IS**	**E**	**C**	**IS**	**E**	**C**
		3	3		3	3		3	3
Motivational	14,0	24,3	17,11	35,2	63,5	40,79	50,8	12,2	42,11
Informative	15,4	33,8	26,32	40,1	58,1	47,37	44,5	8,1	26,32
Emotional-volitional	4,1	12,16	6,58	44,9	78,38	50,00	51,0	9,46	43,42
Operational	9,9	27,03	18,42	21,5	60,81	30,24	68,6	12,16	51,32
Reflexive	3,1	12,16	6,58	44,9	78,38	51,32	52,0	9,46	42,11
Integrative indicator	**9,30**	**21,89**	**15,00**	**37,32**	**67,84**	**43,94**	**53,38**	**10,27**	**41,06**

According to the analysis, the results of developing cognitive independence components are interdependent in the experimental group using the Pearson correlation coefficient (Grabar, Krasnyanskaya, 1977). The analysis showed their statistically significant pair correlation (significance level 0.05). Such a result was not observed in the control group.

Let us consider the results of effectiveness analysis in developing *the motivational component* of the future Informatics teachers' cognitive independence. The results of effectiveness analysis in developing emotional-volitional and reflexive components, as well as the third indicator of the informative component and the fourth indicator of the operational component are similar.

In order to determine the significance level of differences in the effectiveness of training students in the control and experimental groups, we carried out research and statistically processed the results of observations. We assumed as a null hypothesis (H^0) that the offered method of developing components of cognitive independence of future Informatics by multimedia tools does not give advantages in comparison with the traditional method of teaching future Informatics teachers at university. An alternative hypothesis (H^1) corresponded to the assumption that the offered method of developing components of cognitive independence of future Informatics by multimedia tools has advantages in comparison with the traditional method of teaching future Informatics teachers at university.

To compare the results of the final assessment we used the Fisher criterion φ, designed to compare two samples according to the frequency of the occurring effect (Novikov, 2004). The criterion estimates reliability of the differences between the percentages of the two samples in which the feature of interest is registered. To obtain quantitative estimates, let us specify the hypotheses formulated above:

H^0: studies in the experimental group do not help achieve the high and medium levels, that is, the quality of knowledge is not higher than in the control group.

H^1: studies in the experimental group help to achieve the high and medium levels, that is, the quality of knowledge is higher than in the control group. The data are given in Table 5.

Table 5. The results of the experiment

Group	The number of students tested (n)	High and medium level (the number)	Percentage share
E	74	65	87,8
C	76	44	57,9

Using statistical tables, we determine the values of φ, corresponding to the percentage of each group: φ1 (87.8) = 2.43, φ2 (57.9) = 1.73. We calculate the empirical value of φ^0 by the formula 1:

$$\varphi^0 = |\varphi_1 - \varphi_2| \cdot \sqrt{\frac{n_1 \cdot n_2}{n_1 + n_2}}. \tag{1}$$

In this case we receive $\varphi^0 = 4.27$. To assess the significance of psychological and pedagogical effects, a level of statistical significance was used, $p \le 0.05$, at which φ^0 (min) = 1.64. As a result, we receive $\varphi^0 > \varphi^0$ (min) with a significance level of $p \le 0.05$.

Thus, reliability of the differences in the characteristics of the compared samples is 95 %. It allows us to state that hypothesis H^1 is proved: studies in the experimental group help to achieve the high and medium levels of the integrative indicator.

The dynamics of developing the first two indicators of the *informative component* of the future Informatics teachers' cognitive independence was checked by comparing the results of the final assessments at the end of each stage of the forming experiment.

The coefficient's average value of complete mastering the content of knowledge in Informatics and multimedia (q^*) was used as a measurement tool. This coefficient was determined at each mid-year assessment on the basis of the operational analysis developed by A.V. Usova. We adapted it to teaching in ICT (Menchinskaya, 1989):

$$q^* = \frac{\sum_{i=1}^{n} q_i}{nq} \cdot 100, \tag{2}$$

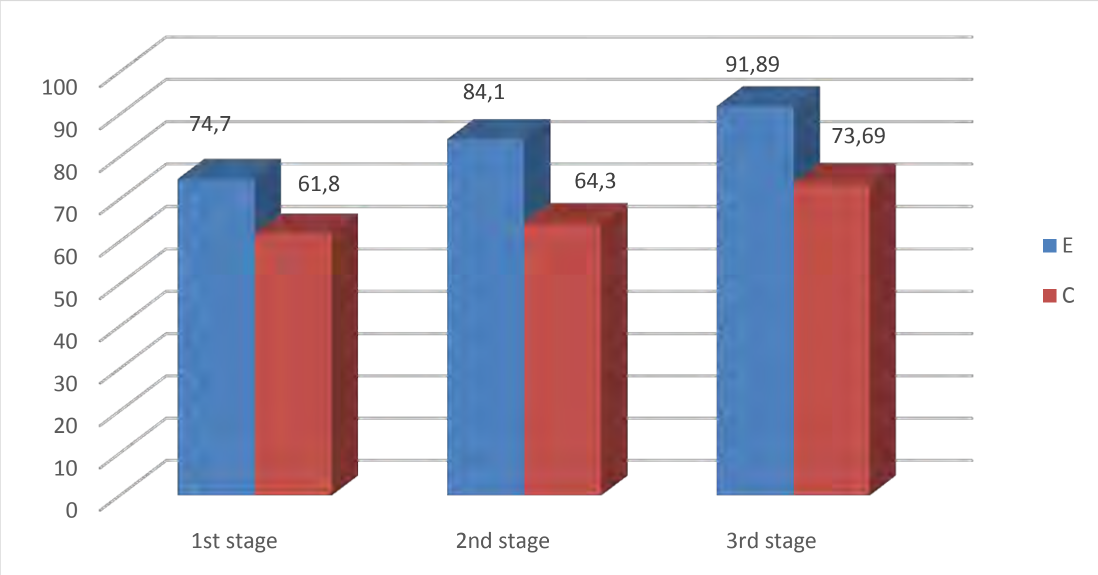
where n is the number of students performing work,

q_i is the number of correctly performed tasks by the i -th student at the corresponding stage of the experiment,

q is the maximum number of the tasks that must be performed.

Figure 1 shows the results of a comparative analysis.

The presented results visually testify to positive changes in a level of indicators of the *informative component* of future Informatics teachers' cognitive independence, which is much higher in the experimental groups, than in the control groups.



E is the experimental groups; C is the control groups

Fig. 1. Comparative characteristics of indicators of the informative component of future Informatics teachers' cognitive independence in the experimental and control groups (%)

In order to confirm the significance of differences in the effectiveness of teaching students in the control and experimental groups, a study was carried out and the results of observations were statistically processed.

To compare the results, we used Student's *t*-test (Klochko, 2003). The experimental data are given in Table 6. Here, the standard deviation was calculated according to the formula 3:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{q_i}{q}\cdot 100 - q^*\right)^2}. \quad (3)$$

Table 6. The results of the experiment for indicators of the informative component of cognitive independence

Group	The number of students tested (n)	The coefficient's value q^*			Standard deviation σ		
		1st stage	2nd stage	3rd stage	1st stage	2nd stage	3rd stage
EG	74	53	63	72	12	13	16
CG	76	52	57	59	12	15	19

The significance criterion for testing the null hypothesis was based on computing sample statistics

$$t = \frac{q_1^* - q_2^*}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}, \quad (4)$$

where q_1^*, σ_1, n_1 correspond to the experimental group, and q_2^*, σ_2, n_2 – to the control group;

$\nu = n_1 + n_2 - 2 = 148$ is the number of degrees of freedom.

As a result of the calculations using the cognitive independence indicators for the first stage, we obtained $t = 0.51$. In this case, the table value t (tab) = 1.97 with a significance level of 0.05. For the second stage, we received $t = 2.62$, and for the third stage, $t = 4.54$

Comparison of the calculated values of t with the tabulated value at the corresponding significance level shows that if knowledge was approximately the same at the first stage in the experimental and control groups, then it was significantly different at the second and third stages.

It is worth noting that the preliminary verification of the null hypothesis about the normal distribution of values $\frac{q_i}{q} \cdot 100$ at the significance level $\alpha = 0.05$ was carried out using Pearson's agreement criterion χ^2 according to the formula:

$$\chi^2 = \sum_{i=1}^{k} \frac{(m_i - np_i)^2}{np_i}, \qquad (5)$$

Where m_i are frequencies,

p_i are theoretical probabilities,

$n = n_1$ or $n = n_2$, $k = 10$.

Similar results were achieved for the second and third indicators of the *operational component* of cognitive independence.

4. Discussion

The findings of the ascertaining experiment showed a fairly low initial level of development of students' cognitive independence. The teaching methods used earlier did not allow to provide a high level of the desired personal education.

Thus, the components of students' cognitive independence had to be purposefully developed through the use of specialized forms, methods and means of teaching used in study of basic and major disciplines and in pedagogical internship.

We developed and tested multimedia tools: interactive multimedia programming lessons for interactive whiteboards, a multimedia game, short video clips and animations in subjects (10-15 minutes), full video lectures (50 min) on topics, interactive schemes and multimedia textbooks on the above disciplines.

It should be noted that multimedia textbooks have proved to be the most effective means for studying subjects within practical classes and SIS. The textbooks have full-scale (50 min) video materials that provided methodological support to students when they did practical assignments. However, using video to support lectures, short animation fragments and "screencasts" (10-15 min) turned out to be more effective. We used them when studying material at various stages of classes.

We used the results of a study by Janice Whatley and Amrey Ahmad (Whatley, Ahmad, 2007) who experimented with different types of video lectures. When developing video fragments, the authors found out that eye contact with the lecturer should be encouraged during video recording by providing a direct view of the lecturer to the camera for most of the time. According to the results of their experiment, lectures recorded in a separate room exceeded those recorded in a classroom directly at the lecture due to the possibility to rehearse, improve the sound and remove extraneous noise.

In accordance with this, we used video fragments that were recorded both with the help of video capture programs from the screen, and with the help of a video camera with the possibility of rewriting and editing. In addition, using Adobe Flash software, we developed short (5-7 min) animation clips where some abstract notions of disciplines were visualized. These clips also proved their effectiveness.

In particular, we used such animation to visualize the programming techniques: "Sorting arrays", "The Tower of Hanoi problem", etc. Various authors have experimentally proved the effectiveness of using multimedia software to develop students' algorithmic thinking (Milková, 2015; Milková, 2012), to use robotic virtual environments in teaching future Informatics scientists programming (Majherová, Králík, 2017), etc. Also our experiment justified and proved the efficiency of multimedia software for study of the courses "Programming", "Programming C ++ ", "Fundamentals of programming for Robotics" (Yakimchuk, 2008; Yakimchuk, 2017).

A multimedia training game for the discipline "Computer Architecture", which was programmed in the Delphi environment, was the most laborious in terms of software development. Researchers (Veličković, 2013; Gómez, Barujel, 2017) emphasize that effective learning takes into account various psychological processes, such as attention, memory, motivation, emotions, etc. Educational games stimulate critical thinking, creative approach to problem solving and teamwork (Sampedro, McMullin, 2015). Thus, educational video games become an effective tool if applied to achieve the ultimate goal of the learning process. Due to the fact that our multimedia game had its own storyline (script, characters) and the game world, it had a significant impact on developing the motivational component of the future Informatics scientists' cognitive independence when studying in combination with other multimedia and scientific and methodological support.

Thus, we proved the effectiveness of the developed methodology by analyzing the process of forming components of future Informatics teachers' cognitive independence to improve the quality of their teaching in modern Informatics.

5. Conclusion

The positive dynamics of the experiment's results allows us to state that students systematically, completely and consciously acquire theoretical knowledge and develop their pedagogical skills due to the purposeful consistent work on teaching future Informatics teachers.

To effectively **implement** the methodology for developing cognitive independence of future Informatics teachers in terms of the credit system of education, we have identified the following **pedagogical conditions**:

- scientific and methodological support, development of a new content of education, taking into account the use of multimedia tools;
- development of future Informatics teachers' cognitive independence on the basis of modular technology, which allows students to independently achieve the goals of educational and cognitive activity;
- development and implementation of multimedia support for developing the cognitive independence of future Informatics teachers, which allows to provide an individual trajectory of its development.

Students could form the whole picture of new information technologies and multimedia thanks to a seminar for teachers and introduction of educational, methodological and multimedia support. Also they could improve necessary knowledge and skills to use them independently in professional activities.

The tests, questionnaires, and other methods for diagnosing the levels of cognitive independence of future Informatics teachers listed in the article were used to measure the individual components of the quality in question: informative, operational, motivational, emotional-volitional, and reflexive ones. The proposed tools are adapted as a whole to train future Informatics teachers to use multimedia in their activities. Currently, the specialized course that we developed and multimedia support of disciplines are widely used in the learning process of the university. The materials of the article can be useful to researchers involved in improving the quality of university education, as well as practicing teachers as a tool for determining the level of cognitive independence of future teachers in the learning process.

Thus, the experiment's results prove the effectiveness of the methodology that we developed. The received results of the research testify to the positive dynamics of improving the quality of their training in modern Informatics on the basis of developing components of cognitive independence, which proves the expediency of introducing the methodology that we developed s into the university learning process.

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