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The Development of Student Key Competencies while Studying Computer Science in Secondary School

Abstract

This paper discusses the key competencies in the 21st century in the context of a transition to a new humanistic paradigm of education as well as the results of the PISA 2012 study “Creative Problem Solving.” Contradictions between traditional skills and 21st century competencies of a school graduate are analyzed. The article also discusses contradictions between social needs of a person with a highly developed intellectual, spiritual and moral potential, and an insufficient development of theoretical and methodological bases of the student’s key competence development, as well as between the traditional methods of computer science teaching and the necessity to solve problems during the educational process supported by the use of ICT. The results of the application of ICT teaching methods based on the principles of humane pedagogy are presented, and their effectiveness is confirmed.

K e y w o r d s: key competencies, reflexivity, humane pedagogy, personal development, ICT

Introduction

Research Problem

The 21st century is a time of an increasing flow of information, technologization, and automation of the society’s information space. It is a time in which

personality traits have become crucial and they determine willingness to provide an answer to new challenges of civilization; these traits include the abilities to make quick decisions, collaborate, use ICTs, think critically, take on responsibility, be proactive, and work on projects. That is why one of the priority directions of educational development is the transition to a new humanistic paradigm of education and innovation, which will ensure the growth of the intellectual, spiritual, moral, and cultural potential of a society and an individual. The keystone of the educational paradigm is the set of innovative competencies of the 21st century.

The development of population's IT literacy affects the abilities to review effectively and critically, and to create information using various digital technologies. The basic elements of computer literacy include: cultural, cognitive, constructive, communicative, confidential, creative, critical, and civil ones. According to the Institute of the Future (Tikhomirova, 2014), the skills that will be required of a person in 2020 for them to be successful may include: unusual thinking, social intelligence, computational thinking, innovative and adaptive thinking (an ability to think outside of the predetermined path), intercultural competence, the ability to process and summarize a large amount of data quickly, the ability to work with modern media, the ability to work remotely, and the possession of knowledge not limited to a narrow specialization. It is an obvious and indisputable fact that the value of computer science and academic discipline is growing in the educational process. Education needs to address more complex and creative tasks, which require critical, reflective thinking about practical problems using computer technologies.

The problem is that in the information society of today, the innovative-humanistic educational process has a number of contradictions between traditional skills and the abilities of a 21st century graduate. One of them is a societal need for a person with highly intellectual, spiritual, and moral potential versus the insufficient development of theoretical and methodological foundations for teaching students, and another one is traditional methods of teaching science versus the need to solve innovative, creative, problematic tasks of the humanities educational process when using new information and communication technologies (ICT).

Research Focus

The research hypothesis is an assumption that introducing computer science to secondary school students – via a scientifically sound methodical system based on humanistic pedagogy – will improve the quality of student knowledge and the effective formulation of their subject and key competencies. Additionally, it will promote self-realization, fulfillment of their potential, and the formation of a worldview and humanistic value orientations. It will develop reflective mechanisms of thinking and encourage the harmonious development of the younger generation, who are capable of not only a creative approach to solving specific life situations, but also integrating the acquired knowledge to further their own self-education and self-development. Thus, the relevance of this work lies in the

need to upgrade teaching methods and education to a new level. On this basis, **the aim of our work** is to explore ICT and reflective competencies: two of the key competencies of the 21st century in the innovative educational environment of the secondary school.

Research Methodology

General Background of Research

In the information society, modern education faces the key question: does the school offer the possibility to acquire the competencies necessary for the person of the 21st century? PISA 2012 presented the results of the research. The aim was to find the answer in the survey completed by more than 85,000 students from 44 countries.

It is undeniable that the current education system is built on the idea of academic achievement. The PISA 2012 researchers claim that this idea has to be corrected. The aim of the new quality of teaching is to develop metacognitive and creative skills as well as skills of effective thinking in unfamiliar situations, self-controlling skills, planning, implementation strategies to address the problems of self-identity in interaction with the unknowns, and initiative (PISA 2012).

To live, learn, and work successfully in an increasingly complex, information-rich and knowledge-based society, students and teachers must utilize technology effectively. Within an educational setting, technology can enable students to become:

- capable information technology users;
- information seekers, analyzers, and evaluators;
- problem solvers and decision makers;
- creative and effective users of productivity tools;
- communicators, collaborators, publishers, and producers; and
- informed, responsible, and contributing citizens (ICT competency standards for teachers, 2008).

According to the materials of the educational program “The partnership in support of the 21st century skills” there are three types of skills: learning skills and innovations; skills in information data, means of communication and technologies; professional and life skills. Considering that the basis of study in the 21st century is the development of critical thinking, competencies have been divided into three main groups: ICT, reflective, research (Kovalenko, 2014; Luksha, 2010; The key competences for Europe 2016, Intel: The way to success 2014).

The main characteristic of ICT **competencies** is the ability to work with information data, using them for solving problems and tasks in the professional field as

well as in everyday life, for the acquisition of new knowledge and further education, and the development of one's own capabilities. One of the main manifestations of **reflective competencies** is understanding, self-esteem, self-control and self-control activities. **Research competencies** have the following qualities: the ability to analyze, synthesize, and formalize; the ability to identify and formulate problems and tasks; the ability to forecast and model activities or experiments (Sholom, 2011; Lipman, 1998).

In addition, **the problem-solving competence** – an individual's ability for the active participation in cognitive processes of thinking and solving problematic situations (situations in which the method of solution is not is that obvious) – is classified by PISA 2012 as the most important competence of the person in the 21st century. This ability involves the willingness of the person to implement their own reflective capacity while solving non-standard interactive problems (PISA 2012).

The implementation of personality competence is based on three aspects: the nature of the problem situation, cognitive processes of problem solving and the context of the problem. It is them, as we suppose, that must serve as a modernization of educational methodological approaches (PISA 2012).

3. According to the problem's basis, it could be either an interactive (information data to be disclosed by studying the problem) or a static problem (all the necessary data for a solution to the problem disclosed in the task).
4. In the problem's context, installation has been distinguished from orientation. Installation involves the selection of targets for the peculiarities of the work with the technological device (technology or non-technology). The direction determines the environment where this problem will be solved (personal or social).
5. The cognitive processes of solving problems are as follows: study and comprehension of information data; presentation and formulation (construction of a model representation of the problem situation; formulation of hypotheses about relevant factors and the relationship between them); planning and implementation; monitoring and reflectivity (progress monitoring, reaction to feedback, reflective understanding of the decision, information data, adoption of a strategy) (PISA 2012).

Particular attention should be paid to the last process – a metacognitive superstructure, the culmination of ongoing personality cognitive processes. The researchers have shown that only 25% of the students could solve the problem tasks that required a high level of reflection (PISA 2012). A reflective competence – which is a complex structure – consists of different types of reflection: the cooperative built on the knowledge of the structure and the role of the positional organization of collective interaction; communication, based on representations of the inner world of another person and the reasons for their actions; personality, which is based on the actions, behavior and image of its own self; intellectual capacity, and the ways of working with it (Stepanov & Pokhmelkina, 1991; Mukii, 2012).

The theoretical analysis shows that the key skills of a new innovation and humanistic paradigm of the 21st century secondary education consist of two important components, which need special attention and further research. These are ICT and reflective competencies. Empirical research into personality traits has allowed us to organize innovative pedagogical methods of work, tools and training in computer science. Our aim is to prepare students for the effective ability to live in a changing world. In order to form a highly educated, creative and harmonious personality with a new type of thinking, which has the main skills and competencies of the 21st century, we have developed a **methodical system of computer science secondary school training** for the development of the personality of a potential student.

The common aim of the methodical system is the harmonious development of personality with a new type of thinking, which provides for the development of humanity, spirituality, morality, and a humane attitude to the world, humane qualities, as well as an intellectual reflective mechanism to broaden the humanistic orientation of the student. **The objectives** are to develop students' skills and abilities to perform basic operations with data objects and to achieve the key competencies of the 21st century, the reflexivity of the individual, which provides for the development of:

- reflective thinking,
- reflective abilities,
- humanism,
- humane qualities,
- values,
- formation of humanistic outlook, and
- skills of reflective and humane behavior.

The training facilities are as follows: educational software tools, object-oriented software systems, educational demonstration equipment, artificial intelligence systems, object-oriented environment and facilities developed for educational purposes (Mukii & Siurin, 2012; Mukii, 2014; Morse & Protsenko, 2012; Morze & Kuzminska, 2011; Morze, 2002).

Thus, the nature and characteristics of the methodical system of studying computer science, based on the principles of humane pedagogy, lies in the fact that the problematic reflective learning is the foundation of the whole educational process (Mukii & Siurin, 2012; Mukii, 2014). In the context of this training, the child becomes a researcher of their inner world, the values of society, fine human qualities, actions and others. Problematic tasks set by the teacher in front of their students are imbued with the ideas of humanity, humanism, kindness, and wonderful affirmation in human relations. As a consequence, the result of this educational activity is the development of IT and reflective competencies of a student (Mukii, 2013).

Features of the Methodical System of Teaching Computer Science

These theoretical assumptions were made on the basis of organizing and creating educational, computer-based teaching and learning tools for computer science with a view to the harmonious development of informative and reflective student competence.

The first sign of the methodical system is the organization of the information science lesson based on reflective and humanistic learning. An instructional design of ICT lessons in reflective humanistic educational environment should have the following elements:

- “A Reflective Card of a Student’s Success” – which is a basic thing and visualization of reflective self-humanistic educational trajectories of the student, created with the teacher at the beginning of a computer science study course, using modern ICT tools;
- special reflective methods and reflective techniques including such methods as: reflective game, modeling, reflective polylogue, reflective equilibrium, reflective inversions, semiotic method;
- “A Reflective Map of an ICT Lesson” – a spreadsheet to create and fill in, which is a reflective analysis of the teacher’s lesson for its improvement in the future; and
- training tools in a reflective and humanistic environment.

Another feature of this environment is the introduction of educational and methodical complex means for reflective-humanistic ICT teaching, which consist of two groups of special tools, namely: educational materials, information and communication environment harmonious development.

The first group includes the following:

- guidelines for the organization of lessons and project activities based on humane pedagogy using ICT;
- guidelines for the use of the Internet for harmonious development;
- a workbook called *The School of Kindness* for studying the topic *The Word Processor* – a set of practical tasks for classwork and homework; by implementing them the student not only acquires the skills to apply basic tools of the word processor, but also reveals their own humanistic outlook through a reflective analysis of texts (stories, parables, poems);
- developments of humanistic reflective competence problems – a type of technological problems, where the use of ICT is obligatory as a tool as well as the solution which promotes ICT competence, and a cognitive, reflective, spiritual, humanistic potential of the student. The main humanistic orientation of the result – to solve the problem – is a motivation and a stimulation of the student to: reflect on ways of solving social and other problems of mankind, and search for a meaning and strategy of their own life; build individual life trajectory by means of creative choice, instead of a consumer lifestyle. The advantage of such problems lies in the fact that students acquire certain skills; namely, they

- allocate various connections between components and related knowledge,
- schematize the explored ways to solve problems of the organization and methods of action, and
- produce various criteria and rules on which they can regulate and implement their own training activities.

The second group of information and communication environment of the harmonious development of the student includes the following elements:

- a designer of a reflective lesson created using ICT – a web page with hyperlinks, which is a description of reflective learning techniques and a set of Web services, making it possible to implement these techniques in the process of learning science. This element of educational and methodical tools allows the teacher to quickly and effectively solve the problem of didactic lesson design stages to develop students' ICT and reflective competencies;
- a student's magazine with a self-reflective fixing of lesson's activities ("reflective journal of the class") – an on-line questionnaire created using Google Drive forms, its aim being to examine the educational process by the teacher and by the students;
- "A reflective blog of the student's success" – a blog giving a possibility of a child's reflectivity development, published in a Word document after practical work in a computer science classroom. This blog has a table, in which the student has the possibility to continue the following sentences: I learned today... it was interesting in ... It was hard to... I realized that ... Now I can ... I felt that ... I bought ... I learned ... I got ... I could ... I try ... I was surprised ... the lesson gave me ...for my life ... I wished ...
- "The card of the student's success" ("The electronic card of the student's success") – a blog or an online-board, created with using Web-services, which shows plans and results, which were a student's academic success in computer science;
- electronic tools to diagnose the personal potential of students – tools for collection, processing, analysis, data presentation reflective and humanistic research potential of the individual, developed using modern ICT;
- a web-platform "Planet of reflective technology" (hosted by <http://planeta-reflexii.blogspot.com/http://planetareflexii.blogspot.com>) – the aims of using this online platform are: to create, to develop reflection as a key mechanism for implementing the intellectual and humanistic orientation of the individual; to place teaching materials for the development of students' reflectivity at different stages of the lesson; to systematize web services for implementing the process of teaching science to develop students' reflective capacity; and
- a web-blog "A teacher's reflective diary" – maintaining and completing the diary leads to the teacher's reflective analysis of the conducted lessons and activities, their own professional skills, information about competitions, con-

ferences, seminars. For an example of such a diary, see <http://taisiyamukii.blogspot.com/>.

Instrument and Procedures

For the psychodiagnostic complex, an empirical study of reflective spheres of students' personalities was developed. It includes:

- methods by A.V. Karpov and V.V. Ponomariova "The meaning of the degree manifestation of the personality's reflectivity" – a definition of reflectivity development levels;
- the questionnaire by A.S. Sharov "Reflexivity in a vital human activity" – a definition of the temporary measure, the characteristics of the scope of functioning and regulatory trends of reflexivity;
- the questionnaire by M. Grant "Studies of assessing the level of intensity and focus of subject's reflection" – a comparison of self-reflection and socio-reflection;
- diagnostic testing of valuable orientations by M. Rokich – a determination of significant values for the respondents;
- the diagnosis of the motivational structure of the personality by V.E. Milman – defining a leading motivational direction of the students;
- test itself-actualization – a definition of personality's capabilities for actualization;
- the self-test questionnaire by V.V. Stolin, S.R. Panteleeva;
- Cattell questionnaire "16 personal factors" – a definition of personal qualities and characteristics;
- the questionnaire "The style of self-regulation of behavior" by V.I. Morosanova – an identification of self-regulation skills relevant to students;
- the questionnaire by J. Holland – a definition of professional orientation of the person; and
- the technique to study the level of empathy trends by I.M. Yusupov – determining the presence of empathy in students.
- To study the formation of ICT competencies we used the following:
- the application for ICT teachers and class teachers: "The motivation for learning and creative activity of students with regard to ICT";
- the parents' questionnaire: "Learning motivation and creative independent activity of pupils by means of ICT";
- the survey of secondary school students: "The impact of using modern ICT tools on the development of the student's individuality";
- the method of the analysis of student achievement assessments in computer science lessons; and
- the analysis of the impact of students' participation in district, city, regional, national and international ICT competitions.

Research Results

An educational experiment was conducted in secondary schools from 2011 to 2014. The experiment involved 252 pupils at the age of 10 to 17. The aim of the experiment was to determine the level of formation of informative and key competencies of children.

1. The results of the study of the dynamics of academic success and motivation for creative activities at the control stage of the experiment are shown in Figure 1.

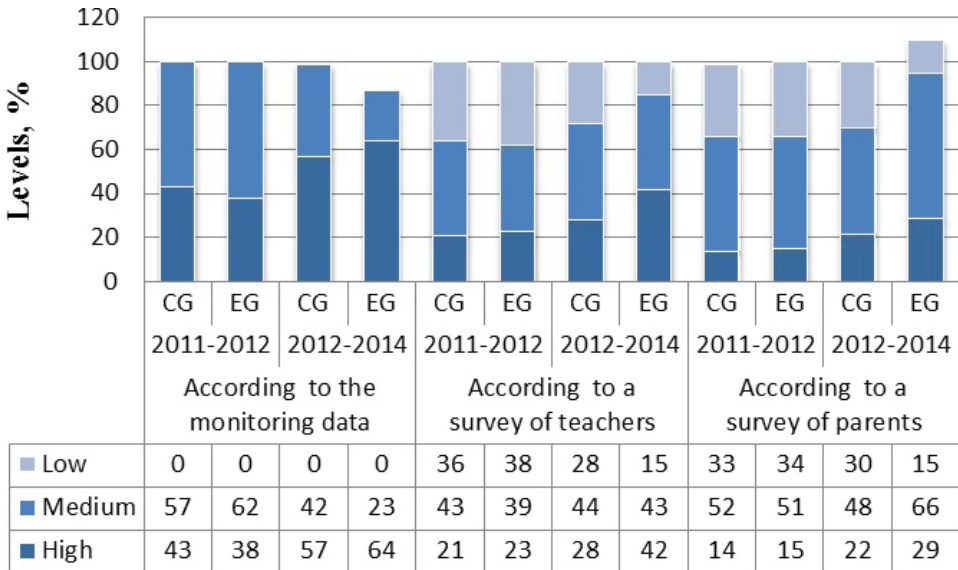


Figure 1. Level of educational achievements of high school students in computer science at various stages of the experiment.

Source: Own work.

The analysis of the data shows that during the experiment, between 2012 and 2014, the indicator of a high level of academic achievement in the experimental group increased by 26%, while the same indicator in the control group increased by 14%. Computer science learning and creativity motivation by means of ICT tools increased by 19% in the experimental group, and by 7% in the control group according to the teachers’ survey. According to the parents’ survey, it increased by 14% in the experimental group, and by 8% in the control group.

The comparative analysis of intellectual development level, including the phases of students’ diagnostic reflectivity and monitoring, was carried out using statistical criteria from the package “Teaching Statistics 6.0” including the Cramér–von Mises criterion and Welch’s t-test. The empirical value in the Cramer-

Welch test is $Temp = 2.3571$, and it is larger than the critical $T_{0,05} = 1,96$, with probability 95%. It can be argued that the differences in the results in the control and experimental groups are statistically significant.

2. The results of the students' reflective competence development after the introduction of a methodical system of teaching computer science based on humane pedagogy were higher in quality, which is clearly shown in Figure 2.

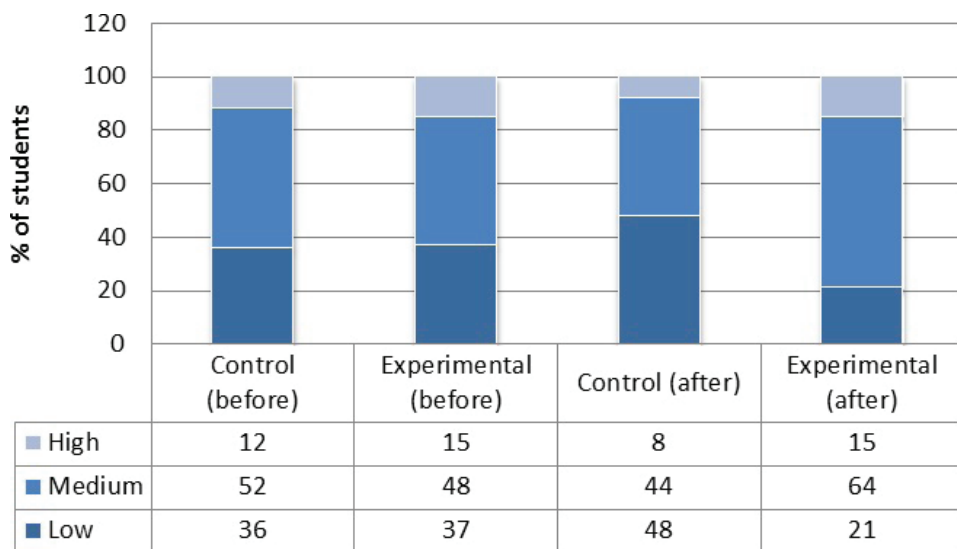


Figure 2. The level of reflective competence development at different stages of the experiment.

Source: Own work.

Apparently, the stages of reflectivity diagnostic results in the control and experimental groups are close enough. The percentage of the students who achieved a high level of reflection in the control and experimental groups are 12% and 15%, while the average value indices are 4 and 3.9 respectively.

Testing statistical hypotheses using static criteria (Wilcoxon-Mann-Whitney, Cramer-Welch) gives a reason to believe that the experimental and control groups were tailored correctly. The selection criteria were fulfilled by the algorithm (Novikov, 2004). Thus, the empirical significance criterion Wilcoxon-Mann-Whitney $W_{emp} = 0.2863$ is below the critical $W_{0,05} = 1.96$, empirical value criterion Cramer-Welch $Temp = 0.2781$ is below the critical $T_{0,05} = 1.96$, so for both of these criteria the samples are comparable and reflect the significance level of 0.05.

3. An important indicator of the level of key competencies development is the level of the child's creative abilities development. The results of the study of creative abilities of the students at the confirming and control stages are shown in Figure 3.

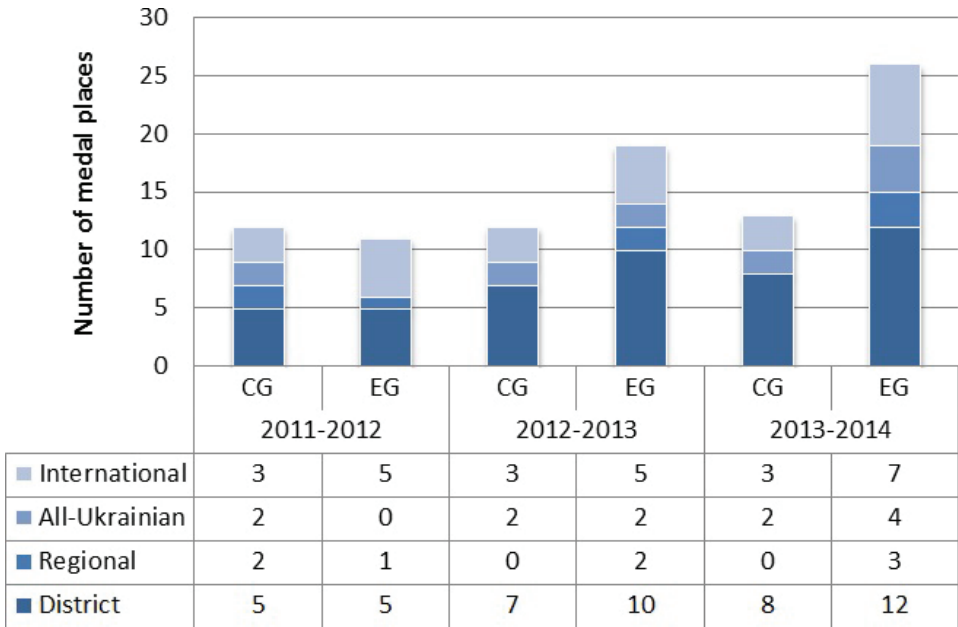


Figure 3. Dynamics of successful performance of students in computer science competitions at different stages of the experiment.

Source: Own work.

As we see from the analysis of the impact of the students’ participation in district, city, regional, national and international ICT competitions and from the analysis of applying ICT for teachers and class teachers: “The motivation for learning and creative activity of students with regard to ICT”, the number of students-winners at different levels increased significantly ($p\text{-value} < 0,05$). The number of the winners of the district competitions increased from 5 to 12 people, of the regional – from 1 to 3 students, of the all-Ukrainian – from 0 to 4, of the international ones – from 5 to 7. When comparing these data with the data from the control group, we can see that there are qualitative changes in the attitude of the students to the participation in competitions. This indicates an increase in the level of the students’ motivation for creativity and self-realization.

Basing on the results of the study, we can see that the method developed by us is effective and can be recommended for use in teaching computer science in high schools. As a result of the experiment and the implementation of the methodology described above, the hypothesis of the study was confirmed, as well as the methodical system of educating secondary school pupils was worked out and improved taking into account the principles of humane pedagogy.

Conclusions

In conditions of global informatization, the role of computer studies as a science and academic discipline is increasing significantly, helping build students' philosophy and thinking. The studies by domestic and foreign scholars have shown that computer science is a backbone subject, which is the basis of a modern learning process, becoming also the basis for educational and information industries.

The role of computer science as a school subject is to focus on the formation of key competencies and skills of the 21st century, and to teach the effective use of modern information and communication technologies, which is necessary for everyone if they want to have a successful life and work in modern society. The theoretical analysis shows that there are two important components that require special attention and further research, which are the basis of the key skills in a new innovation and humanistic paradigm for the secondary education in the 21st century. These are informative and reflective competencies. The empirical study of the personality characteristics has allowed us to create innovative pedagogical methods of work and computer science teaching tools to prepare students for an effective life in a changing world.

In order to form a highly educated, creative and harmonious personality, a new type of thinking, and skills and key competencies of the 21st century, we have developed a methodical system of teaching computer science in high schools, which results in the development of each student's personal potential. The nature and characteristics of the methodical system of studying computer science, based on the principles of humane pedagogy, lies in the fact that problematic reflective teaching becomes a foundation of the whole educational process.

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Розwój kluczowych kompetencji uczniów w trakcie nauczania informatyki w szkole średniej

Streszczenie

W artykule przedstawione zostały: kluczowe kompetencje XXI wieku w kontekście przejścia do nowego humanistycznego paradygmatu kształcenia oraz wyniki PISA 2012 w badaniu „Creative Problem Solving” (kreatywne rozwiązywanie problemów). Analizie poddano sprzeczności między tradycyjnymi umiejętnościami absolwenta szkoły i kompetencjami oczekiwanymi/potrzebnymi w XXI wieku. Omawia się także sprzeczności pomiędzy społeczną potrzebą w zakresie osób o wysoko rozwiniętym potencjale intelektualnym, duchowym i moralnym a niewystarczającym rozwojem teoretycznych i metodologicznych podstaw doskonalenia kluczowych kompetencji uczniów oraz pomiędzy tradycyjnymi metodami nauczania informatyki a potrzebą rozwiązywania problemów procesu kształcenia podczas wykorzystywania ICT (TIK). W artykule zrelacjonowano wyniki stosowania metod nauczania informatyki opartego za zasadach humanistycznej pedagogiki. W rezultacie udowodniona została jej efektywność.

Słowa kluczowe: kluczowe kompetencje, refleksyjność, humanistyczna pedagogika, rozwój osobowości, ICT (TIK)

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Развитие ключевых компетентностей учащихся в процессе изучения информатики в средней школе

Аннотация

В статье рассматриваются ключевые компетентности XXI века в контексте перехода к новой гуманистической парадигме образования, а также результатов PISA-2012 в исследовании «Creative Problem Solving». Анализируются противоречия между традиционными навыками выпускника школы и компетентностями XXI века; между традиционными методами преподавания информатики и необходимостью решения инновационных проблем образовательного процесса в условиях широкого использования ИКТ. Представлены результаты применения методической системы обучения информатике в средней школе, построенной на принципах гуманной педагогики, доказана её эффективность.

Ключевые слова: ключевые компетентности, рефлексивность, гуманная педагогика, развитие личности, ИКТ

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El desarrollo de las competencias clave de los estudiantes mientras estudian ciencias de la informática en el instituto de secundaria

R e s u m e n

Este documento discute las competencias claves del siglo XXI en el contexto de la transición hacia un nuevo paradigma humanístico de la educación, así como los resultados del estudio de 2012 de PISA: «La resolución de problemas creativos». Se analizan las contradicciones entre las habilidades tradicionales y las competencias del siglo XXI de un graduado en la escuela. También discute la contradicción entre la necesidad pública en una personalidad con un alto desarrollo intelectual, espiritual, moral y potencial y un desarrollo insuficiente de las bases teóricas y metodológicas de las competencias claves para el desarrollo de los estudiantes, entre los métodos tradicionales de la enseñanza de ciencias informáticas y la necesidad de solucionar problemas del proceso educativo en condiciones del uso de las TIC. Los resultados de la aplicación de los métodos de enseñanza informática basados en los principios de la pedagogía humana están demostrados, su efectividad está confirmada.

P a l a b r a s c l a v e: las competencias clave, reflexividad, pedagogía humana, desarrollo personal, TIC