Methodology for Teachers' Digital Competence Developing through the Use of the STEAM-oriented Learning Environment

Nataliia V. Soroko [0000-0002-9189-6564]

Institute of Information Technologies and Learning Tools of NAES of Ukraine, Kyiv, Ukraine
nvsoroko@gmail.com

Abstract. The article focuses on analyzing the experience in using information and communication technologies for professional communication, collaboration and the teachers' digital competence development. The article defines a content, forms, methods and tools as parts of the methodology of using the STEAM-oriented learning environment for the teachers' digital competence development. The teachers' digital competence development is one of the important factors for the establishment and support the STEAM-oriented learning environment in schools. The specialized course "Creation and use of the STEAM-oriented learning environment for the teachers' digital competence development" may contribute to implementing STEAM education in schools. The suggested course on STEAM education for teachers will provide a content, forms, methods and tools as parts of the methodologies of using the STEAM- oriented learning environment for the teachers' digital competence development. Such methodical support of the teachers' training course as instructions and guidance notes on how to use and create e-Learning resources. The specialized course "Creation and use of the STEAM-oriented learning environment for the teachers' digital competence development" is supposed to contribute to the teachers' digital competence development by their acquiring knowledge on implementing STEAM education into the school learning environment.

Keywords: Teachers' Digital Competence Development, STEAM-oriented Learning Environment, STEAM Education.

Introduction

The so-called "Inquiry-based science education" (IBSE) is of particular importance for the information society development. One approach to developing inquiry-based science education is the STEAM-approach, based on a project-based teaching method, focused on the development of skills to solve problems creatively, critically and systematically, by using scientific knowledge within STEAM (Science, Technology, Engineering, Arts, and Mathematics). The main issue is the creation of conditions for the teachers' professional competences development in STEAM education fields, which should influence on the improvement of quality and modernization of education following world trends in science and education. We can state the particular importance

of the teachers' digital competence development and the design of the STEAM-oriented learning environment, which can contribute to continuing teachers' professional competence development. At the same time, it is important to select the necessary Methodology for the teachers' digital competence development.

The article's goal is to define a content, forms, methods and tools as parts of the methodology of using the STEAM-oriented learning environment for the teachers' digital competence development.

Methods of research

To achieve the goal of the study, we used methods of systematic and comparative analysis of pedagogical, philosophical, sociological works, methodological and specialized literature to clarify the problem of creating the STEAM-oriented learning environment, to identify the main ways of using open e-learning resources for STEAM-education support; analysis experience of using the STEAM-oriented learning environment in schools; synthesis and generalization of research literature to clarify the concept of STEAM-oriented learning environment, interpretation of research results within the topic of the article; method of analysis of teachers' questionnaire results.

The Theoretical Backgrounds

1.1 The teachers' digital competence

According to the European Framework for the Digital Competence of Educators (Christine Redecker, 2017) [1], six Digital Competences' areas that focus on different aspects of teachers' professional work: using information and communication technologies (ICTs) for professional communication, collaboration and development; searching, creating and sharing e-learning resources; teaching, managing and organizing the use of ICTs in teaching and learning; assessing the use of ICTs and strategies to improve them; increasing students' opportunities through the use of ICTs, encouraging their learning through research work; promoting students' digital competence, in particular, by enabling students to use ICTs creatively and responsibly, to find information, communicate, create a content and solve problems.

It is important to note, that "educators' digital competence is expressed in their ability to use digital technologies not only to enhance teaching but also for their professional interactions with colleagues, learners, parents and other interested parties, for their individual professional development and the collective good and continuing innovation in the organization and the teaching profession".

The personality's digital competence is the confident, critical and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion and participation in society (Anusca Ferrari, 2012) [2].

Taking into account the above mentioned, in our opinion, the digital competence of teachers is their readiness, ability and skills to use information and communication

technologies autonomously and responsibly in their professional activities for solving individual problems and learning throughout their life.

At the same time, it is important to ensure the continued development of teachers' digital competence, which can be supported by ICT and the creation of specialized environments such as, for example, the STEAM-oriented learning environment.

1.2 The STEAM-oriented Learning Environment

The STEAM-oriented learning environment is one of the main trends in the world education, which is defined by the scientists as follows:

- an environment that should provide its users with tools for research in STEM fields involving, where appropriate, the arts, such as music, dance, the visual arts, literature, theatrical arts, humour, or any activity related to the use of art, including visiting museums, listening to lectures, observing various processes, scientific problems or reading scientific literature (Mark E. Rabalais, 2014) [3];
- an environment that should cover such components as object templates according to the learning requests and the students' educational research in STEM fields; software, platforms and other ICTs to provide visualization of educational and scientific materials; training laboratories; study contract – an interactive tool for maintaining a social network that allows students to execute study contracts and connect with other students' communities for logical purposes; training based on the use of blogs by teachers, scholars, students; a system of on-line monitoring and assessment of teachers' professional competencies and students' STEAM competencies (Maïté Debry and Dr. Agueda Gras-Velazquez, 2016) [4];
- an environment that should provide strategies for improving the engineering and technological education of students (Connor, A.M., Karmokar, S. & Whittington, C., 2015 [5]; Dr. Agueda Gras-Velazquez, 2016 [6]);
- an environment that should encompass online teacher communication services with students and colleagues to address learning problems; applications for exchanging information on STEAM training activities and for the ICT participants' hands-on activities; platforms for providing on-line learning and teaching; tools for creating questionnaires and tests; open online libraries and more (Jacina Leong, 2017 [7]; Vimala Judy Kamalodeen, Sandra Figaro-Henry, Nalini Ramsawak-Jodha and Zhanna Dedovets, 2017 [8]); Elaine Perignat & Jennifer Katz-Buonincontro, 2018 [9]).

O. V. Barna, N. R. Balyk (2017) offered the following interpretation of STEAM education: STEAM education provides the study of Science and Technology through the application of technical creativity and Engineering, based on Mathematics, modelling and integrating the use of various tools of other sciences (All) [10]. Analyzing the situation in Ukraine within 2017, the scientists note that the implementation of this approach is very slow, generally in the framework of non-formal learning through meetings with experts, browsing educational scientific channels, sites, developments, participation in competitions, festivals, workshops, picnics, days of science, etc.

1.3 The Results and Discussion

The STEAM-oriented learning environment, in our opinion, should be such an environment that performs the functions of a computer-oriented, mobile-oriented, cloud-oriented, open learning environment through practically-oriented, interdisciplinary and project-based approaches in the study of natural and mathematical cycle disciplines by students; it should develop student's creative thinking through the use of different branches of the arts in the educational process and promote the development of teachers' digital competence for students to acquire key competencies and to get them motivated to study these disciplines, to explore various problems in science and be effective in integrating the subjects of primary and secondary education at the national and international levels.

The teachers' digital competence development is one of the main goals for the creation and using the STEAM-oriented learning environment in schools.

We conducted a survey to study their need to use ICT for the STEAM training in the school curriculum.

We suggested that, by using the service Word Cloud (https://www.mentimeter.com/), teachers choose five important tools that can help them develop their creativity and use the STEAM-oriented learning environment in schools (2019). A total of 1542 respondents answered the question "What information and communication technologies are needed to introduce STEAM education into the learning process in schools?" (Fig. 1).

Fig. 1. The map of important tools that can help develop teachers' creativity and use the STEAM-oriented learning environment in schools according to the answers.

The obtained answers show that 3% of the respondents have chosen Padlet, 1% of them have chosen Kahoot ! and YouTube Scratch; all other tools have been repeated not more than twice, namely: TinyTap, Quizizz, Socrative, Quizlet, Europeana, Tuva Lab, Google Apps for Education, MindMeister, Freemind, Bubble, MindMup, Tinybop, Google Earth, Enercities, BlueBot, Root Coding, Robo Code, Robot Factory by Tinybop, Cyber Robotics Coding Competition, KQED Education, HighAdventure

Science, Education Closet, ArtsEdge, NOVA Labs, GoLab, GeoGebra, PhET Interactive Simulations project, Interactive PhysicsTM and others.

The same question was also put to the teachers who took part in the webinar "Information and communication technologies for the STEAM-oriented learning environment in schools" (2019). One hundred and twenty-seven respondents reported on which information and communication technologies (tools) they would prefer for the creation and using the STEAM-oriented learning environment in schools. The participants evaluated the proposed ICT by using a five Likert scale ranging from very undesirable (1) to very desirable (5).

Table 1. The survey results regarding teachers' attitudes to the most relevant ICTs for the STEAM-oriented learning environment in schools.

The most important information and communication technologies as educational resources for creating and supporting the STEAM-oriented learning environment in schools are:	Mean values
Google Drive	4,9
LinoIt	2,55
Padlet	4,9
Thinglink	2,7
TinyTap	2,7
Word Cloud	1
Kahoot!	4,5
Quizizz	2,5
GoLab	1,3
Moodle	3,7
Cyber Robotics Coding Competition	0
Surveyanyplace	2,3
Scratch	4,5
KQED Education	1
I don't know how to use information and communication technologies for the STEAM-oriented learning environment at school	-
Suggest tools	GeoGebra
Total (N= 127)	

Table 1 demonstrates that teachers usually use information and communication technologies for creating and supporting the STEAM-oriented learning environment at school when performing general class activities, as team work and collaborative communication (Google Drive – 4.9; Padlet – 4.9; Moodle – 3.7), also, they use ICTs for assessment (Kahoot! – 4,5; Quizizz – 2,5), but rarely for specific purposes (GoLab – 1,3; Cyber Robotics Coding Competition – 0; KQED Education – 1). It should be noted that five respondents added such tool as GeoGebra.

The mean values in Table 2 indicate what kind of teachers' skills are important for implementing the STEAM-approach in schools and creating the STEAM-oriented learning environment.

Table 2. The survey results regarding teachers' attitudes to the most relevant skills for creating and supporting the STEAM-oriented learning environment.

The most important skills for creating and supporting the STEAM-oriented learning environment are acquired through:	Mean values
online tools to create and manage training projects	4,9
online tools for conducting seminar, forums and others	4,9
opening educational resources	4,9
programming languages	2,7
online security tools	3,7
online games	3,5
online tools for creating tests and quizzes	4,5
Total (N= 127)	

Table 2 demonstrates that teachers should develop such skills as using online tools to create and manage training projects; opening educational resources; online tools for conducting the seminar, forums and more; online security tools; online tools for creating tests and quizzes; online games.

The teachers' answers to the question "What information and communication technologies are needed to introduce STEAM education into the school learning process?" show that it is becoming highly important to use the following ICTs: online tools to create and manage training projects (4,9); opening educational resources (4,9); online tools for conducting seminar, forums and others (4,9); online tools for creating tests and quizzes (4,5); online security tools (3,7); online games (3,5).

According to the results of the questionnaire, we have identified the current problems and issues regarding teachers' using ICTs to improve the quality of their school STEAM-projects and creation and using the STEAM-oriented learning environment schools. For the first time, we have defined the content, forms, methods and tools as constituents of the methodology for using the STEAM-oriented learning environment for the development of teachers' digital competence.

The content as a component of the methodology for using the STEAM-oriented learning environment for the teachers' digital competence development includes the following modules "Creation and use the STEAM-oriented learning environment for the teachers' digital competence development":

- Module 1 "The STEAM-oriented learning environment in schools" consisting of the following topics: theoretical principles of creation and use of the STEAM-oriented learning environment in schools; creation and use of strategies for the STEAM-oriented learning environment in schools;
- Module 2 "The use of information and communication technologies to organize and support the STEAM approach in schools" consisting of the following topics: e-Learning resources as the means of teacher's digital competency development to support the STEAM-oriented learning environment in schools; electronic Platform for organizing the STEAM-oriented learning environment in schools;
- Module 3 "Electronic learning resources on self-assessment and evaluation of teachers' digital competence to support the STEAM-oriented learning environment in schools" comprising such topics as requirements for assessing a teacher's digital

competence for creation and support the STEAM-oriented learning environment; self-assessment of digital competence and its importance for teachers' professional development and support the STEAM-oriented learning environment in schools; planning training activities (lesson plans, learning projects, etc.) to support the STEAM-oriented learning environment in schools. The purpose of the course "Creation and use of the STEAM-oriented learning environment for the teachers' digital competence development" is to develop teachers' digital competence, to create, use and support the STEAM-oriented learning environment.

The main tasks of learning are as follows: organizing practical and theoretical activity of the participants of the educational process, which is conditioned by the regularities and peculiarities of the content for pedagogical activity in the conditions of the STEAM-oriented learning environment in schools; introducing theoretical and organizational basics of the STEAM-oriented learning environment in schools to students; enabling students to acquire the necessary skills to create and use the STEAM-oriented learning environment in schools through the planning and organization of educational activities (lessons, educational projects, weeks on certain sectors for STEAM, etc.) using ICTs; raising the level for teachers' digital competence.

According to The Law of Ukraine on Education (2017) [11] the forms for the organization of the suggested course and training participants may be different: institutional (internal, correspondence, remote, network); individual (external, family, pedagogical patronage, on workplace (on production); dual, that involves the combination of training of persons in educational institutions with on-the-job training at enterprises, institutions and organizations for the acquisition or upgrading of certain qualifications, usually on a contractual basis.

The basic types of classes in the course can be offered in the following ways: workshops, practical seminars, webinars, trainings, computer practical lessons and consultations. At the same time, as for the teaching methods are concerned, we suggest: discussions, exchange of experience, peer-to-peer (equal participation of all participants of the educational process), problematic, story, conversation, explanatory-illustrative, "case-method" (research by participants of the course of different situations concerning the organization of the STEAM-oriented learning environment and determining ways to solve them), demonstration, written survey (questioning), testing, self-assessment, peer-to-peer assessing (mutual evaluation of participants in the educational process of the end products of the course, such as lesson plans, study projects, etc.).

The training process in the course is accompanied by such tools as personal computers, software, e-learning resources that include:

- general educational resources: Flash Cards and Quizzes Apps and Websites (for example, TinyTap, Kahoot!, Quizizz, Socrative, Quizlet, Albert); electronic libraries (for example, Europeana (https://www.europeana.eu/portal/en), Ukrainian Center (http://www.ukrcenter.com), Tuva Lab (https://tuvalabs.com/); Web services for teamwork (for example, Google Apps for Education, Microsoft Office 365 online, Padlet); tools for creating mental maps (for example, MindMeister, Freemind, Bubble, MindMup); search engines (for example, Google, Yahoo!, Baidu);

- resources for specific purposes of the STEAM-oriented learning environment: to review and study various scientific concepts by using models and simulations (for example, Tinybop is for students to work individually or in pairs, to study a particular system as a human body, water cycle, Solar system, etc.; Google Earth VR is designed to explore the Earth and its three-dimensional structures, topography, important historical sites or geographical areas; Enercities is for pupils' modeling of cities, buildings, etc.), programs and websites of Robotics (for example, Blue-Bot, Root Coding, Blockly for Dash & Dot Robots, Robo Code, The Robot Factory by Tinybop, Sphero Edu, Microsoft MakeCode (micro:bit, Circuit Playground Express, Minecraft), Cyber Robotics Coding Competition), online resource centers (for example, KQED Education (https://ww2.kqed.org/education/stem-resources/), High-Adventure Science (https://has.concord.org/), Education Closet (https://educationcloset.com), ArtsEdge (https://artsedge.kennedy-center.org/educators.aspx); labs (for example, NOVA Labs, GoLab, GeoGebra); simulators (for example, PhET Interactive Simulations project (https://phet.colorado.edu/), Interactive PhysicsTM (http://www.design-simulation.com/ip/), OnlineLabs.in (http://onlinelabs.in/physics). It is important to note that course participants choose e-learning resources, depending on their STEAM-project goals, the form of education chosen for this project (formal, non-formal, informal) and the students' level of education;
- Educational Electronic Platform (E-Platform) for the STEAM-oriented educational environment, which should facilitate the implementation of practical-oriented, interdisciplinary and project approaches in the study of natural-mathematical disciplines and robotics, the formation of students' creative thinking through the use of various arts in the educational process.

One of the requirements for the Educational E-Platform in school is, above all, the selection of software that will meet the needs of teachers to deploy, use and create electronic educational resources, cooperate with all participants in this process and motivate them to teach students.

Among them, Online Learning Platforms users distinguish ten most popular ones in 2019, which are presented on the site "g2.com": Udemy, Infosec Flex, TalentLMS, McGraw-Hill, WebAssign, MyLab, Cloud Guru, LearnWords, WebAssign, Skillshare.

The Educational E-Platform in schools is "specifically known information and telecommunication system work", the goals of which include: technological support for secondary education reform; providing participants with up-to-date educational process, electronic educational resources and services; providing electronic textbooks in open access for students, who completed secondary general education, and competent pedagogical staff; providing and creating the environment for the development of national e-learning resources, services and e-textbooks; development of e-learning and formation of digital competence of participants in the educational process in our country.

The data show that the educational E-Platform for supporting the STEAM-oriented educational environment should host:

- open electronic educational resources, which include resources for students and teachers and can be distributed through e-textbooks, e-libraries, blogs for teachers and teaching staff, Ministry of Education and Science websites, distance courses, etc.;
- tools (ICTs) that provide communication and collaboration between students; between teachers; between students and teachers; between professionals, employers, students, teachers, etc., that can be implemented, for example, throughout open forums, webinars, Internet conferences, etc.;
- online assessment and self-assessment, which can be conducted through contests, competitions, quests, tests, projects, etc., that motivate students to study STEAM and develop teachers' digital competence, to ensure the modernization of education in accordance with demands of the society;
- laboratories covering simulators, games, imitation models, etc.;
- individual profiles of participants of the STEAM-oriented educational environment, where there can be placed the data about participants, their achievements in training, participation in STEAM projects or various forums; certificates, electronic educational resources, necessary for training and teaching.

The course "Creation and use of the STEAM-oriented learning environment for the teachers' digital competence development" is focused on improving teachers' digital competence, which will enable them to create and support the STEAM-oriented learning environment and STEAM-projects for implementing STEAM education in schools.

For example, we offer our project for evaluation of the course by the participants. They should identify the positive aspects of the project and suggest how it can be improved. We have created the Project "Robot and Human", using Educational E-Platform Graasp (https://graasp.eu/) (Fig. 2).

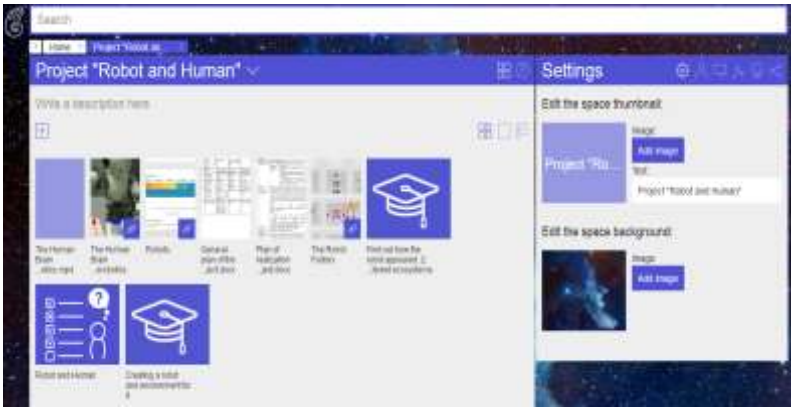

Fig. 2. The Project "Robot and Human" on the Educational E-Platform Graasp

The Project “Robot and human” based on the STEAM approach and designed according to the plan, which is described in the Table 3 “The plan of realization of the educational project “Robot and human”.

Table 3. The plan of the Project “Robot and human” realization.

№	The components of the project	Content	
1	Title	“Robot and human” (the project is designed for students of 5-8 grades)	
2	Basic questions	The key question	Will robots be able to exist without humans?
		Problematic issues	1. How did a robot come about? 2. What are the basic functions of a robot to support various human activities? 3. What should a robot look like in different environments, different ecosystems?
3	Brief description of the project	Robots are gradually coming into our lives. The age of accumulation of knowledge and theoretical science (information society) is moving to a new stage - an era when robots and mechanisms fill the world. According to the latest data, there are now 1.8 million different robots in the world today - industrial, domestic, toy robots and more. Object of study: robotization. Subject Title: Support for human robot functions for different activities. Task: 1. Find out how robots appeared. 2. To find out where robots are in human life and what functions they should have. 3. To find out the basic requirements for the support of robots in the conditions of different ecosystems.	
4	Subjects related to the project	Economics, Language, History, Informatics, Mathematics, Geography and so on.	
5	Assessment of students’ knowledge and skills	Assessment of students’ work in groups is performed according to the criteria created during the discussion over the project effectiveness with students. Self-assessment is done through tests and questionnaires.	
6	E-learning resources	The Human Brain Project SP10- Neurorobotics.mp4 (https://www.youtube.com/watch?time_continue=11&v=rn5PmXQyrjU&feature=emb_logo); The Robot Factory by Tinybop.	

The training courses with such tasks as suggested in “Creation and use the STEAM-oriented learning environment for the teachers’ digital competence development” (organization of practical and theoretical activity of the participants of the educational process, which is conditioned by the regularities and peculiarities of the content for pedagogical activity in the conditions of the STEAM-oriented learning environment in schools; introducing theoretical and organizational basics of the STEAM-oriented learning environment in schools to students; enabling students to acquire the necessary skills to create and use the STEAM-oriented learning environment in schools through the planning and organization of educational activities (lessons, educational projects, weeks on certain sectors for STEAM, etc.) using ICTs; raising the level for teachers’ digital competence) will be highly significant in developing the digital competence of teachers and the introduction of STEAM education in schools.

Conclusions and prospects for further research

The teachers’ digital competence development while implementing STEAM education in schools is one of the important decisions in the process of creation and support of the STEAM-oriented learning environment. Our specialized course “Creation and use of the STEAM-oriented learning environment for the teachers’ digital competence development” may facilitate this process due to providing the course participants with the research materials on implementing STEAM education in schools. The course participants will acquire knowledge of the content, forms, methods and tools as parts of the methodology for using the STEAM-oriented learning environment. This process is impossible without proper methodical support for the teachers’ training course which provide instructions how to use and create e-Learning resources, video lectures, give answers to common questions and the most interesting ones.

The prospects for the further research are to analyze the effectiveness of the methodology of using the STEAM-oriented learning environment for the teachers’ digital competence development, which can be evaluated through the course “Creation and use of the STEAM-oriented learning environment for the teachers’ digital competence development”.

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