Sofia University „St. Kliment Ohridski”

Faculty of Mathematics and Informatics
Information Technologies Department

Methods and Tools for Supporting Inquiry-Based Learning

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ABSTRACT

of Dissertation

for the purpose of acquiring the educational and science degree “Doctor”
in the field of 4.6 Informatics and Computer Sciences
Doctoral Program "Information Technologies (Information and Communication Technologies)

Doctoral supervisor:
Prof. Eliza Petrova Stefanova, PhD

Sofia, 2022

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Note: In this abstract, where it is not indicated, all references to pages, chapters, appendices, cited literature, tables, and figures refer to the full text of the dissertation.
All cited literature sources, tables, and figures in the abstract use the same numbering as in the dissertation.

Acknowledgements

To my supervisor Prof. Eliza Stefanova,Ph.D., for whom I embarked on the path of science. I would like to thank her for her personal example of an extremely active and productive person, for her valuable advice and comments, for her responsiveness, time and help.

To Prof. Krasen Stefanov, Ph.D., thanks to whom I had the opportunity to work on various research projects - national and international, and thus to promote the results of my research.

To Assoc. Prof. Nikolina Nikolova, Ph.D., for the encouragement and assistance for the realization of part of the scientific researches.

To Assoc. Prof. Aleksandar Dimov, Ph.D., for the collaboration on a research project, which contributed to part of the applied researches.

To Dafinka Miteva and Senior Lecturer Pencho Mihnev for our joint work and their support.

To the colleagues from the Centre of Information Society Technologies (CIST) of Sofia University "St. Kliment Ohridski" (SU) - Albena Antonova, Svetlana Dimitrova, Marin Barzakov, Assoc. Prof. Elisaveta Gurova, Ph.D., Maria Greenwood, Pavlina Dimitrova, with whom we actively worked during the European Researchers' Night over the years, as well as on other international and national activities.

To the colleagues who also contributed to the realization of the researches during the European Researchers' Night over the years - Katerina Stoyanova (CVS - Bulgaria); Assoc. Prof. Temenuzhka Zafirova-Malcheva, Ph.D., Assoc. Prof. Valeria Simeonova, Ph.D., graduate student Aneta Karachorova, PhD student Stoyan Apostolov, Hristina Topalova, Alexander Kasarov, Daniel Kamenov; Assistant Professor Ivaylo Atanasov (Medical University), Ph.D.; Kalina Stoimenova and Angel Dimitrov from the Department of Astronomy, Faculty of Physics, SU, headed by Assoc. Prof. Evgeni Ovcharov, Ph. D.

To colleagues from the Faculty of Mathematics and Informatics (FMI), colleagues from the University Centre for Information and Communication Technologies (UCICT), colleagues from other faculties and structures of SU, who directly or indirectly contributed to the realization of this doctoral work.

To all the teachers, pupils, students who participated in the demonstrations, experiments, surveys and interviews.

To all my colleagues from all over the world - Russia, Iran, Singapore, India, Poland, Hungary, USA, who believe in me, with whom we support each other and exchange knowledge and experience.

To my mother, Roska Peltekova, a teacher of Bulgarian language and literature, whose professional viewpoint helped the dissertation to be linguistically and grammatically well written. I thank her immensely for her dedicated support over the past year to enable the dissertation to be completed.

Thank you all from the bottom of my heart!

Introduction

Actuality of the Problem

Today's world is characterized by a huge boom in technology, which requires much more in-depth and complete training of young people in all disciplines related to the development of technologies, identified by the abbreviation STEM, coming from Science - Technology - Engineering - Mathematics. In addition, all spheres of life need better trained professionals to succeed in the digital society, and the acquisition of STEM competencies is a key. One of the main problems is how to optimize the teaching of STEM subjects in the current educational programs, but in the new conditions of increased need for such skills in the context of the technology boom.

STEM subjects are receiving increasing attention and there have been a number of reasons for that in the recent years (Danish Technological Institute, 2016), some of which are: STEM skills are related to modern technical skills, which are strong drivers of technological and knowledge-based growth, increasing productivity in high-tech sectors, including ICT services; The growing need for new and the replacement of former highly qualified specialists working in the fields of STEM professions. This leads to concerns that Europe may not have enough STEM skills to secure its future economic development.

In this context, educational institutions need to devote a lot of effort and provide their students with competencies such as algorithmic thinking, solving practical natural-mathematical problems, programming, etc. (Conde et al., 2021). This is a way to ensure that specialists are able to meet the needs of the society, and learners can be easily recruited and would become good professionals. One option is to implement a modular STEM curriculum as suggested in (STEMpedia, 2019) interdisciplinary practical approach such as extracurricular learning. Also integrate STEM practices into the individual subjects that exist in the current curriculum, for example, as described in (H. E. Gerlach, 2018).

In the "Strategic Framework For The Development Of Education, Training And Learning In The Republic Of Bulgaria (2021 – 2030)" (Doe, 2017), it is suggested that the modernization of teaching methods could be achieved by two means:

- Replacing "ready knowledge" with more active methods, provoking students to be more autonomous, creative and independent decision-makers;
- Wider penetration of ICT in education.

These two methods are characteristics of STEM training, although in themselves they (the methods above) are not related to specific subjects or educational trends, but rather to methodological approaches that students can successfully engage and participate in (Conde et al., 2021).

But the difficulties in moving towards this goal must not be overlooked. Scientists who need to help the implementation of new methods do not always have the full range of skills that STEM education requires from students and teachers.

The published results and analyzes from the latest study of the "Program for International Student Assessment PISA 2018" (OECD, 2019a), which is carried out by Organisation for Economic Co-operation and Development (OECD) every three years, marks unsatisfactory results for our country. The assessment covers the areas of Reading, Mathematics, and Science. As in Bulgaria, the average reading performance remains stable compared to previous years, within the country's participation PISA (2001-2018). In mathematics there is an improvement in the results between 2006 and 2018 but the improvement is in the first years (2006-2012 г.). In the Sciences, the presentation in 2018 falls below the level observed in 2012 and 2015 г. The decline in the average level of Sciences between PISA 2015 and PISA 2018, is one of the largest observed for this short period among all countries and economies participating in PISA (OECD, 2019b) (Table 1).

Table 1. Snapshot of performance trends in Bulgaria (in points) (OECD, 2019b), p.282, Annex D

Avarage Performance	Reading	Mathematics	Science
PISA 2000	430		
PISA 2003	-	-	
PISA 2006	402	413*	
PISA 2009	429	428	434
PISA 2012	436*	439	439
PISA 2015	432	441	446*
PISA 2018	420	436	424
Average 3-year trend in mean performance	+0.8	+5.9*	-1.4
Short-term change in mean performance (2015 to 2018)	-11.9	-5.1	-21.7*
Overall performance trajectory	flat	positive, but flattening (less positive over more recent years)	hump-shaped (more negative over more recent years)

* indicates statistically significant trends and changes, or mean-performance estimates that are significantly above or below PISA 2018 estimates.
Source: OECD, PISA 2018 Database, Tables I.B1.7–I.B1.15 and I.B1.28–I.B1.30.

On the other hand, in another publication from 2021 - „ Education in Eastern Europe and Central Asia: Findings from PISA" it is said that of all the countries participating in the latest OECD international survey, Bulgaria and Georgia are the two with the highest average age of teachers. (OECD & United Nations Children's Fund, 2021).

Within the OECD, the acquisition of information and communication technology (ICT) skills is one of the areas in which Bulgarian teachers say they need more training. Other areas where improvement is necessary are teaching in a multicultural / multilingual environment and training students with special educational needs. (OECD, 2019a).

We can conclude that there is a correlation between the level of student performance and the aging teaching staff, which needs additional qualifications (for example in IT).

In the "Strategic Framework For The Development Of Education, Training And Learning In The Republic Of Bulgaria (2021 - 2030)" of the Ministry of Education and Science (MES) of the Republic of Bulgaria, it is said that „from 2019 the efforts are also focused on the accelerated acquisition of knowledge and skills for work in the digital society. In 2020, the establishment of school STEM centers began. They are an integrated set of specially built and equipped learning spaces with a focus on the study and the application of competencies in the field of Mathematics, Science and Technology.„ (МОН, 2021). There is a website of the National Program "Building a school STEM environment" of the Ministry of Education and Science, https://stem.mon.bg/, through which schools in Bulgaria can apply for STEM centre creation in their school. This shows that at a national level some work has been done in regards to support and improvement the school environment, which concerns the learning of subjects in Sciences, Technology, Engineering, and Mathematics.

On a European scale, again related to technology and digitalisation, based on a wealth of scientific data and in the framework of the European Commission for the promotion of learning in the digital age in educational organizations (European Commission, 2021) the tool SELFIE has been developed. It is free and it aims to self-assess schools for effective learning by encouraging the use of innovative educational technologies. It is designed to help schools implement digital technologies in the processes of teaching, learning and assessment (European Commission, 2021).

This dissertation is an attempt to give impetus to the development of research, focusing on the development of specific innovative teaching methods in STEM and plan, conduct, evaluate and analyze many specific scientific experiments on the application of these methods in practice.

Literature Review

To raise student achievement, the data in the (H. Gerlach, 2020) show: the need for an understanding of integrated STEM learning; additional training for all teachers and administrators related to STEM professional (The Department of Education, Skills and Employment of Australian Government, 2021). For example, teaching science using technology. Through such a lesson, it is demonstrated that each STEM subject has overlapping, shared skills to offer.

A popular method of active learning is the inquiry-based learning (IBL) approach, which has been extensively researched since 1970s. The approach is called "inquiry-based" because of the Latin word "inquirere" used, which in English means "to search", "to explore" (Krüger, 2022). In the work of (Khalaf & Zin, 2018), which reviews the study, points out that as learning theories developed between 1965 and 1975, there was increasing interest in applying new method of learning and investigating their effectiveness in different subject areas. Thus, alongside traditional learning based on the approaches and theory of behaviorism (Brau et al., 2020), researchers are beginning to experiment more actively with the methods of constructivism (Western Governors University, 2020), in which learners construct their own knowledge during the learning process. The interest in active learning coincides with new current and the transformation of teaching with traditional approaches, moving from teacher-centered classroom work to student-centered classroom work.

In the late 20th and early 21st centuries, an extensive literature on the topic of applying in the inquiry-based learning approach has been collected. A large body of empirical research, review reports, and meta-analyses provide significant evidence of the effectiveness and impact of inquiry-based learning in educational practice, and primarily in Science, Technology, Engineering, and Mathematics (STEM). Among the better-known authors working in English-speaking settings, the following stand out: (Weaver, 1989), (Bateman, 1990), (Alford, 1998), (Gibson & Chase, 2002), (Lee, 2004) and others.

Inquiry-based learning is based on constructivist learning theories and their methodology is student-centered, exploration is the main method. The theoretical foundation explain that knowledge is constructed by learners (Piaget, 2013). The inquiry-based learning model combines learning and practice. Its main advantages include building cognitive constructs and creating motivation in the process of developing learners' competencies and knowledge. As found in the (Khalaf & Zin, 2018), definitions of an inquiry-based learning address the learning process by focusing on several specific conceptualizations (Table2).

Table 1. Inquiry-based Learning as a Process

Inquiry-based Learning as a Process	Author(s)
The process of testing hypotheses and evaluating the results of related experiments or observations.	(Pedaste et al., 2012)
Inquiry-based learning approach provides a means to build knowledge through processes of interaction and communication.	(National Research Council, 2007)

Problem solving process and developing learners' problem-solving skills.	(Pedaste & Sarapuu, 2006)
A learning process similar to that of professional scientists to construct new specific knowledge.	(Keselman, 2003)

One of the representatives of the progressive movement in education, Dewey, tried to apply the scientific method in the classroom as early as the 1930s. He viewed inquiry as a complex process that involved "sensing confusion, clarifying the problem, formulating a tentative hypothesis, testing the hypothesis, validating with tests, and acting on the solution." Overall (Dewey, 1938) criticizes pedagogical approaches that emphasize memorizing facts at the expense of encouraging thinking. According to the research of (Dewey, 1938), key features of the research approach is to begin with an engaging discussion in which students make propositions about particular claims, prioritize them, formulate explanations from the available evidence, then relate these explanations to scientific theories, and finally present and explain their conclusions.

Inquiry-based learning requires better clarification of the process, which may involve individual or group work and consists of several phases, such as: learners develop their own questions to investigate - identify problems - formulate hypotheses - identify variables - collect data - document work - interpret and present results (Kikis-Papadakis et al., 2014)(Chaimala & Kikis-Papadakis, 2019).

Inquiry-based learning requires both teachers and students to actively participate and engage in the research process (Table 3).

Table 3. Process of the inquiry-based learning (Thalys, 2019)

Process of the inquiry-based learning (IBL)	Teacher	Student
Planning	A plan how each student can be actively involved; Supports classroom learning.	Knows research methods and tools.
Attitude	Accepts that teaching is a learning experience; Constantly expects obstacles and questions.	Accepts learning and readily engages in the process of exploration; Approaches the learning process critically.
Process	Encourages/allows the student to take greater responsibility for his/her learning; Asks key questions - Why? How do you know? What is the evidence? Asses students as an ongoing part of the learning process;	Asks questions, offers explanations and uses observations; Plans and conducts learning activities; Communicates using a variety of methods and tools; IBL generates many questions and reflections.

In the early 21st century, there is a growing interest in the inquiry-based learning as a teaching method in STEM subjects. This method has long been recognized in science education as a successful and promising approach to achieving learning objectives, as well as a means of fostering better student engagement and motivation in STEM subjects and beyond (Kikis-Papadakis et al., 2014).

Many studies have shown that students prefer to participate directly with active methods and experiments in science classes instead of learning with traditional approaches. In addition, when science is taught through IBL, students are more interested and motivated to put more effort into learning (Gibson & Chase, 2002). Some science teachers are fully convinced that IBL motivates learners more than other methods of learning (Duschl, 2003).

As highlighted in (Khalaf & Zin, 2018), the application of IBL is increasingly used in Science classes, but is limited in the humanities. This is a problem given that an IBL approach impacts the learning environment, enhances the learning process, and develops learners' knowledge. In this regard, IBL is recommended to increase students' interest in reading, writing and participating in discussions, solving case studies (National Research Council, 2007).

The diversity in learners' performance (level of knowledge) and the role of teachers, as well as the development of learners' outcomes, skills and background knowledge, lead this review to reassess these models of learning and summarise their pedagogical criteria in Table 4. In it, based on the scientific review of the (Khalaf & Zin, 2018) models of learning are reassessed and their pedagogical key criteria summarised - theoretical perspective, role of the teacher, level of knowledge, skills, level of confidence, motivation, performance and learner outcomes.

Table 4. Pedagogical Criteria of Key Learning Models (Khalaf & Zin, 2018)

№	Descrption	Traditional Learning	Inquiry-based Learning
1.	Theoretical point of view	Cognitive behaviorism	Cognitive constructivism
2.	Role of the teacher	Dominant role	Guidance and support
3.	Level of knowledge	Limited knowledge	Developed knowledge
4.	Skills	Limited skills	Develops skills
5.	Level of confidence	Low confidence	High confidence
6.	Motivation	High motivation	Low motivation
7.	Introduction	Poor performance	Good performance
8.	Learner outcomes	Poor performance	Poor performance

The claim of (Keys & Bryan, 2001) is that the main problem for the implementation of IBL in school remains the teachers, their attitude, interest and appropriate additional qualification for the implementation of the research approach to teaching methods.

Despite the many advantages of the IBL model, there are serious obstacles to its application and function (Khalaf et al., 2018). The challenges and drawbacks that relate to the implementation of IBL model in schools can be described in two groups:

Application: The disadvantages that concern the implementation of IBL are school systems, curricula and the role of the teacher.

Function (related to learners): issues such as motivation, learners' ability to use technology, basic knowledge of IBL and management of learning activities.

The Literary Review of (Khalaf & Zin, 2018) indicates that the characteristics of traditional teaching are raising student achievement and keeping students active in class. The characteristics of IBL - increasing learners' knowledge and skills. The literature review of (Khalaf & Zin, 2018) is based on 43 empirical studies conducted between 2002 and 2017. It highlights barriers to both traditional and IBL. This review analyses and critically evaluates the advantages and disadvantages of both educational methods. It concludes that there is a mismatch between current learning methods and the expectations of students to achieve the knowledge and skills that are embedded in education systems. This means that a new pedagogical design is needed. Such a design that highlights the strengths and at the same time addresses the weaknesses of both traditional and IBL.

This is precisely the purpose of samples of educational scenarios, which combine methods and tools to support IBL. As well as a model to support the process of generating, customising and using educational scenarios according to the methods, tools and context of their application.

Object

The object of the present research is to increase the interest of students and improve their results in STEM disciplines.

Subject

The subject of the research are the methods and modern technological tools which to support an inquiry-based learning.

Research areas in the dissertation

Informatics and computer science. Application of information technologies (IT) in education. Innovative teaching methods in STEM.

Research Questions in the Dissertation

Research questions in the present dissertation are as follow:

- Is there a combination of methods and tools that could support an inquiry-based learning, such as to ensure high interest of learners and to support teachers (school and university teachers, lecturers at different stages of education) in STEM disciplines?
- Is it possible to derive criteria for the selection of technological tools according to the context of an inquiry-based learning?
- Could a model be proposed that supports the process of generating, customizing and using educational scenarios, according to the methods, tools and context of their application?
- Could samples of educational scenarios that combine methods and tools to support inquiry-based learning to achieve learning goals be created?
- Does the application of educational scenarios lead to an increase in the interest and results of the students in Science disciplines?

Objective of the Dissertation

The dissertation aims to research and propose methods and tools to support the inquiry-based learning and teaching Science, Technologies, Engineering and Mathematics (STEM), in order to increase the interest and results of students, as well as to develop a methodology (system model) to build educational scenarios combining methods, tools and context according to its application.

Tasks of the Dissertation

In order to fulfill the goal, set in the dissertation, it is necessary to solve the following tasks:

Task 1.1 To study and analyze some factors that affect the increase of interest, motivation, and results of the students.
Task 1.2. To research and analyze methods (inquiry-based learning, some research methods in education) applicable in STEM teaching, which provoke students to independence, creativity and decision-making, wider use of ICT tools.

Task 2.1 To study and analyze modern technological tools applicable in STEM training, identifying their main characteristics, properties, limitations. To define the criteria for selection of technological means according to the context of research training.
Task 2.2 To explore and analyze the possibilities and attitudes for the application of modern technological means in education.

Task 3.1 To create a model of a system for creating educational scenarios.
Task 3.2 To create sample models of a platform for creating, finding educational scenarios, according to the methods, tools and context of their application.

Task 4.1 Describe, experiment and apply samples of educational scenarios that combine methods and tools to support an inquiry-based learning to achieve learning goals.
Task 4.2 To analyze and evaluate the extent to which the created samples of educational scenarios lead to increased interest and results in science education.

Methods and Tools for Performing the Tasks of the Dissertation

According to Andreychin's definition (Андрейчин et al., 2012), the method is a way, an approach for theoretical research or practical realization, doing something.
The research methods (those that are studied and those that simultaneously seek the problems and tasks in the dissertation) are:

- inquiry-based learning;
- research methods in education (experiment, demonstration);
- methods of data collection (surveys, interviews).

Tools are the items needed to accomplish a task (Андрейчин et al., 2012). In our case, to perform the tasks of the dissertation, the following are used:

- mobile technologies – smartphones and tablets;
- interactive boards;
- virtual reality (mobile virtual reality – smartphone in combination with VR goggles).

Structure and Content of the Dissertation

This introduction substantiates the relevance of the problem, it makes a literature review, defines the object and subject, presents the purpose, tasks and structure of the dissertation.

The first chapter discusses the methods of inquiry-based learning, research methods in education (experiment, demonstration), methods of data collection (surveys, interviews).

The second chapter reviews the tools used (technologies) - mobile technologies, interactive whiteboards and virtual reality technology, which are part of the experiments and researches of the dissertation.

The third chapter describes the researches on the applicability of methods and tools (discussed in the dissertation) in Bulgaria.

The fourth chapter offers a model based on service-oriented architecture for searching, finding, and creating educational scenarios. Model development aims to facilitate teachers in using more diverse methods and tools in their teaching.

The fifth chapter describes the developed scenarios for STEM subjects ("Man and Nature", "Physics and Astronomy"), experimented with: (1) PhD students and scientists from Sofia University "St. Kliment Ohridski" within the international project weSPOT and (2) students, teachers, teacher trainers within the European Researchers' Night in 2018, 2019 and 2020.

The conclusion chapter draws conclusions and examines future perspectives for learning that creates a link between teaching and research.

The chapter Contributions presents the scientific contributions, scientific and applied contributions, scientific publications and research projects related to the dissertation.

A **bibliography** is a list of used sources.

Appendix 1. Interactive Whiteboard Survey

Appendix 2. Virtual Reality Survey

Appendix 3. Virtual Reality Interview

Appendix 4. Virtual Reality Scenario

Appendix 5. Students' Feedback Card

Appendix 6. Student Monitoring Form for Teachers

Appendix 7. Qualitative Data: Reflection, Inspiration and Observation from "Space Safari" Experiment

Appendix 8. Survey „Space Rangers"

Appendix 9. STEM Training Feedback

Chapter 1. Methods

This chapter discusses: inquiry-based learning; research methods in education (experiment, demonstration); methods of data collection (surveys, interviews).

1.1 Inquiry-Based Learning

Inquiry-based learning is an educational strategy in which students follow methods and practices similar to those of professional scientists to construct knowledge. (Keselman, 2003). It can be defined as a process of discovering new causal relationships, as the learner formulates hypotheses and then tests them by conducting experiments and / or making observations (Pedaste et al., 2012). Inquiry-based learning emphasizes on the active participation and responsibility of the learner to discover knowledge that is new to him (De Jong & Van Joolingen, 1998). In this process, students perform a self-directed learning, partially inductive and partially deductive learning process (Pedaste et al., 2015).

weSPOT model (Mikroyannidis et al., 2012) is developed to serve inquiry-based learning. This model is used in the implementation of the dissertation tasks and it has six key phases (Figure 1):

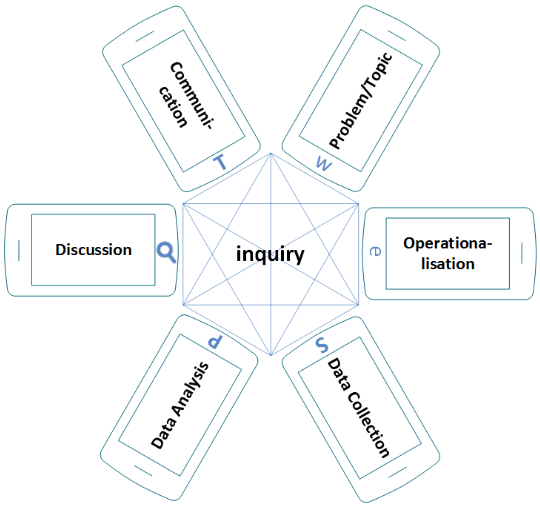


Figure 1. weSPOT model with its six phases (Peltekova et al., 2014)

1.2 Research Methods in Education

Research methods in education -experiment and demonstration, are discussed in the following subchapters.

1.2.1 Experiment

The experiment (*Demonstration and Research Design - Kentucky Pesticide Safety Education*, 2021) is a controlled test that is designed to test a hypothesis or determine the effectiveness of something that has not been tested before.

Experiment is one of the most important scientific research methods (Cohen et al., 2018). Experimental research can be confirmatory, seeking to support or not support the null hypothesis, or research, discovering the effects of certain variables.

Researchers want to know if their experiment worked. How can they be sure of that? There are several answers to this question. One approach is to use the testing of the significance of the null hypothesis, and the testing of the significance of the null hypothesis seeks to determine whether the results obtained, for example, whether the interventions affect, cause change and whether or not it is accidental (Cohen et al., 2018).

1.2.2 Demonstration

The demonstration method is a teaching method used to convey an idea or present a technology using various tools.

Demonstrations are usually conducted to demonstrate the effectiveness of a proven or emerging technology practice (*Demonstration and Research Design - Kentucky Pesticide Safety Education*, 2021).

The demonstration is especially a specific characteristic of all science subjects. It is a way to engage participants in a challenging and demanding task (Hattie, 2012).

The demonstration method is important for the participants because (The Open University, 2014): provides experiences from real events, phenomena and processes, helping them (participants) to learn; increases interest and motivation; allows the attention to be focused on a specific phenomenon or event; can be used to develop and challenge understanding; can help to carry out their independent practical work more effectively.

1.3 Methods of Data Collection

Survey and interview are discussed in the following subchapters as methods of data collection.

1.3.1 Survey

The survey is a widely used and useful tool for collecting information, providing structured, often digital data that can be administered without the presence of the researcher and is often relatively easy to process (Cohen et al., 2018).

Stages of survey planning are presented at Figure 2.

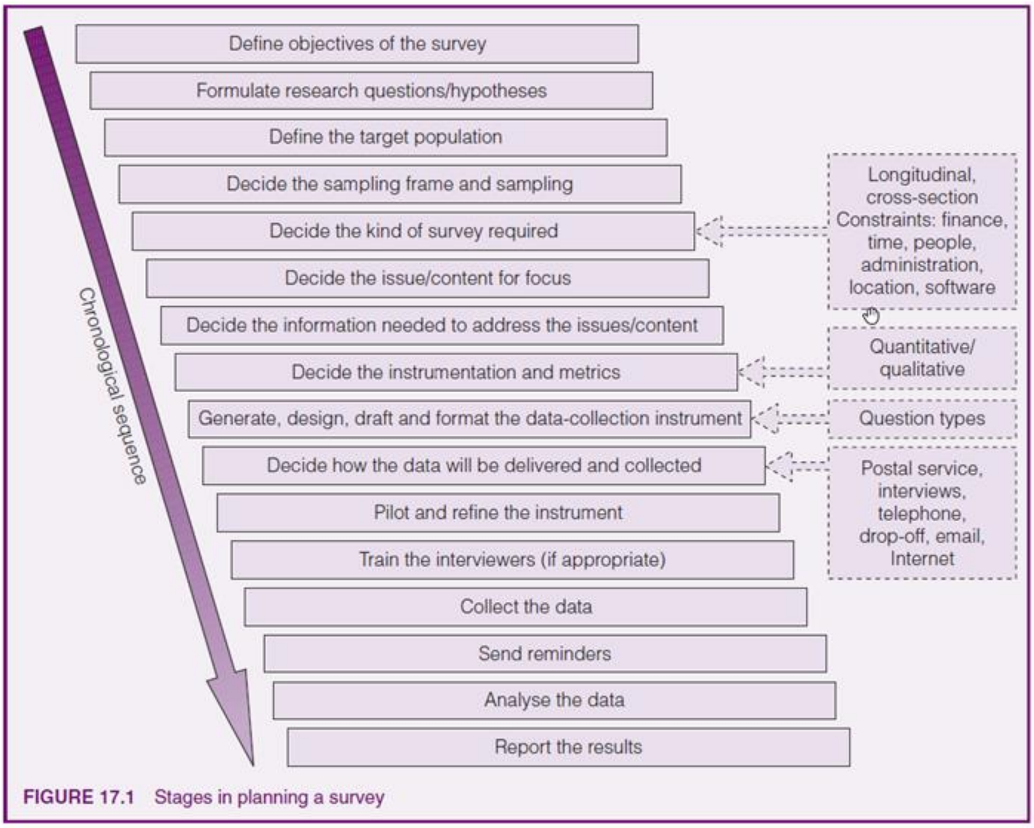


Figure 2. Stages of planning a survey (Cohen et al., 2018)

1.3.2 Interview

Interviews are a widely used method of data collection.
The research interview is defined as a conversation between two people, initiated by the interviewer and designed to obtain research data to achieve the objectives of the study, which relate to "systematic description, assumption or explanation" (Cannell and Kahn, 1968, p. 527) (Maynard, 1983). It involves collecting data through direct verbal interaction between individuals.

A quality research method is the semi-structured interview. In (Bogdan & Biklen, 2007) it is said that qualitative research is used as a general term to denote several research strategies that share certain characteristics.

Chapter 2. Tools (Technologies)

In this part of the dissertation, in three subchapters is done an overview of the used tools (technologies). They give an explanation, history of their occurrence and an example of use in learning. The tools are mobile technologies - smartphones and tablets, interactive whiteboards and virtual reality devices.

2.1 Mobile Technologies

The mobile technologies considered are smartphones and computer tablets. According to IBM (IBM, 2020), the world's leading manufacturer of computer equipment, mobile technology is technology that goes where the user goes. It consists of portable two-way communication devices, computing devices and network technology that connects them.

2.1.1 Mobile Phone (Smartphone)

According to (Techopedia, 2019), a mobile phone or a smartphone (from English: smartphone - literally translated as a smart phone) is a device with a more powerful processor, more storage space, more RAM, more connectivity and with a larger screen than a regular mobile phone

2.1.1.1 Use of Smartphones in Learning

In 2020 the number of users of smartphones worldwide (*Smartphone Users Worldwide 2020*, 2021) exceeds three and a half billion and this value is expected to grow by several hundred million over the next few years.

Myartspace is a mobile phone service for a research-based learning approach and has been used to conduct research with students in museums in the United Kingdom. This service allows students to collect information during school trips and this information is automatically sent to a website where they can view, share and present it in the classroom or at home. In the presented study in (Vavoula et al., 2009), it is claimed that the main attraction for students in the museum is the use of mobile phones. Smartphones are popular among students and they use them easily. However, when assessing the motivational aspects of technology, it should be borne in mind that this technology is "aging", perhaps even faster than other modern digital technologies. The consequences of such short-term attractiveness can be significant in terms of cost to upgrade; constantly updating the equipment could affect customer satisfaction.

2.1.2 Tablet

The tablet is a wireless touchscreen personal computer that is smaller than a laptop, but bigger than a smartphone. Modern tablets have wireless internet and a variety of software applications, including business applications, web browsers, games and many more.

2.1.2.1 Use of Tablets in Learning

In 2011, in the framework of the project "For the Movement of Increasing Opportunities and Improving Technology", in short FATİH, a study conducted in Turkey with 206 students, examined the benefits and challenges of implementing tablets in schools (Dündar & Akçayır, 2014). The results show that students have a positive attitude towards them.

Teachers say that the use of tablets has positive and negative aspects and that sometimes students focus more on lessons and use the opportunity to explore, search for additional information, but sometimes students just use the Internet for extracurricular activities and sending messages to each other.

In 2012 Acer and European Schoolnet (Balanskat, 2013) conducts a pilot study on the use of tablet devices to improve teaching and learning practices. During this study, Acer equipped 263 teachers in 63 schools in eight European countries with tablets. The participating countries are Estonia, France, Germany, Italy, Portugal, Spain, Turkey and the United Kingdom. The goals of the project are:

- research and documentation of the use of tablets by teachers at school and at home;
- identifying good practices regarding the use of tablets and promoting the exchange of practices between teachers;
- provides guidance to schools considering the application of this technology;
- to study the key factors for the successful integration of tablets in schools.

Providing sufficient time and training for teachers to familiarize themselves with the devices, as well as clear usage policies, including applications, other content, communication tools, and if necessary, software installation, seem to lead to successful adoption.

2.2 Interactive Boards

Interactive whiteboards or called only interactive whiteboards, smart boards, are a modern tool that it is used in different contexts - classrooms, training centers, business offices, etc.

2.2.1 Types of Interactive Whiteboards

When it comes to an interactive whiteboard (IWB), there are several components that need to be available - (1) a computer, (2) a projector, and (3) the IWB device itself in one of its variants:

- Mobile interactive whiteboard - small mobile receiver; an interactive device that visually strongly resembles a compact webcam.
- Fixed interactive whiteboard - large interactive wall mount; placed on a movable stand.

In order to actively use IWB and at the same time with high productivity, teachers are interested in getting familiar with well-designed, working electronic lessons for IWB, as well as with specific samples of IWB lessons. (Peltekova, 2015).

2.2.2 Application of Interactive Whiteboards in Teaching

In developed countries, governments and individual schools have invested heavily in interactive whiteboard technology. (Slay et al., 2008). In the United Kingdom, the government is investing huge amounts in this technology, "in the belief that their use in the educational process will increase the achievement of British students." (Hall & Higgins, 2005, p. 102).

Teachers consider the efficiency, flexibility, and multifunctionality of IWB. A commonly reported benefit of IWB is the ability for teachers to draw from a myriad of multimedia sources. (Glover and Miller, 2001, Levy, 2002)

Despite many attempts to use and implement interactive whiteboards, there is still no convincing research to show what their real impact is on the educational process. (Karsenti, 2016).

2.2.3 Comparison between Interactive Whiteboards and Interactive Displays

In the recent years, many schools have purchased specially designed interactive displays (which look like a large flat screen TV or sometimes are being compared with a big computer tablet) instead of an interactive whiteboard. There are several reasons why they have become a new standard in the educational cooperation.

While the interactive display eliminates the cost of lamps, requires no calibration and it serves well when applying flipped classroom method. The benefits of the latest education-focused interactive displays are particularly valuable in tackling the challenges of blended learning facing pandemic teachers and students in the world we live in.

2.2.3.1 Virtual Interactive Whiteboards

The virtual interactive whiteboard is a digital canvas for distance learning collaboration and meetings. It is a software application or online service. The virtual interactive whiteboard is not a physical device, like smart boards (interactive whiteboards), which have been used in education for about 15 years. Examples of virtual interactive whiteboards are Miro, Limnu, Microsoft Whiteboard, Google Jam, Explain Everything, Whiteboard.Chat, Whiteboard.fi (Whiteboard.fi, 2022), OpenBoard, etc.

2.3 Virtual Reality

Virtual reality (VR) technology and what is meant by virtual reality are discussed. A brief overview of what types of VR devices exist and which ones are used in the developed scenarios involving VR.

2.3.1 Application of Virtual Reality in Education

The integration of information technology in the classroom, in particular virtual reality technology, has the potential to add value to the educational activities in the classroom and increase the level of knowledge acquisition. VR can be integrated into different subjects (Пелтекова & Стефанова, 2017).

2.4 Selection of Applicable Technological Tools in Different Educational Context

In Table 2 are derived criteria according to which to make a choice can be made about the application of specific technological tools in a certain learning context - research activities outside the classroom; reality in the classroom, VR; remotely and independently. A "+" indicates which criterion/situation combines well with which instrument.

Table 2. Selection of Applicable Technological Tools in Different Educational Context

Criteria by types of activities	Tool 1 (IWB)	Tool 2 (IBL platform weSPOT/DojoIBL)	Tool 3 (VR/AR)	Tool 4 (смартфон, таблет)
Criteria 1 (Field trips/ research activities outside the classroom)	-	+	+	+
Criteria 2 (Classroom Reality, VR)	-	+	+	+
Criteria 3 (Remotely and independently)	+	+	+	+

Chapter 3. Studies on the Applicability of Methods and Tools in STEM Training in Bulgaria

The main goal of this chapter is through several studies - surveys and interviews, to understand and analyze the attitude of Bulgarian teachers towards the application of modern technologies in STEM education. This gives a real idea of the situation in Bulgarian schools and on this basis a reasonable proposal is made to support teachers and the overall organization of STEM teaching.

Conducted and described are: (1) a survey related to the applicability of interactive whiteboards; (2) a survey on the usability of virtual reality in education; (3) interviews to explore attitudes towards the application of virtual reality in education.

3.1 Application of the Educational Tool Interactive Whiteboard

A survey with Bulgarian teachers looked for their opinions and reasons why they use IWB, reasons why they do not use IWB and their opinion on what would motivate them to use IWB, what are the limitations of IWB according to the teachers, and the application of IWB.

The analysis of survey's results concludes that in order teachers to be able to use IWB with high productivity, teachers must have an interest, be familiar with already developed lessons for e-learning with IWB and if they have access to sample scenarios with IWB.

3.2 Application of Virtual Reality Technology in Education

The vision and attitudes towards VR of Bulgarian teachers are taken into account with the help of a survey and interviews, which are focused on teachers' intentions for implementation in their teaching process.

The results of the survey provide a picture of the knowledge about VR among Bulgarian teachers and highlight the fact they need training and support for VR Technology.

The results obtained from the interviews form the minimum requirements for the implementation of VR in the teaching and learning process through the development of educational scenarios.

Chapter 4. Model for Creating Educational Scenarios

This chapter presents a model for searching, finding, creating educational scenarios, which is based on service-oriented architecture (SOA). The idea for the implementation of the model is to facilitate teachers and help them to use a variety of methods and tools during teaching, which will enrich classes and increase students' interest in the subjects studied, which will lead to better results and more knowledge that is lasting.
It is described a model in which educational scenarios are easily created by assembling learning objects (LO) - different methods and tools in teaching and learning. The model is illustrated with wireframes (Balsamiq, 2021b)), presented as part of prototypes (mockups) created with the software Balsamiq Wireframes (for Windows) (Balsamiq, 2021a).

4.1 Software Architecture of the Model for Creating Educational Scenarios

The service-oriented architecture is architectural style that is concerned with loose coupling and dynamic binding between services (Weerawarana et al., 2005). The basic principle bind/publish/find underpin SOA are illustrated in Figure 1.

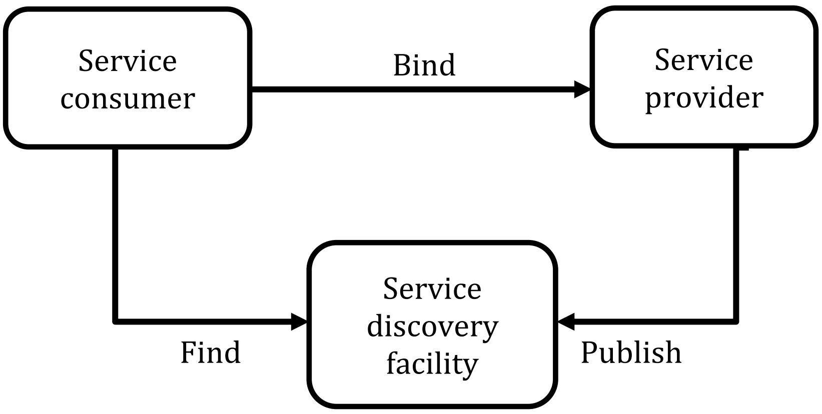


Figure 1. The Service-oriented architecture Triangle **(Weerawarana et al., 2005)**

4.1.1 Service-Based Solutions for Educational Scenarios

There are researches in which SOA is used as solutions for educational scenarios. For example, the work presented in the paper (Roberto Chinnici et al., 2007) shows an approach to implementing the LearnServe system. This allows interaction with the learners to be presented as a business process, which is actually a collection of autonomous applications implemented as services. This way the architecture could be easily upgraded in the future development.

4.1.2 Service-Oriented Architectute

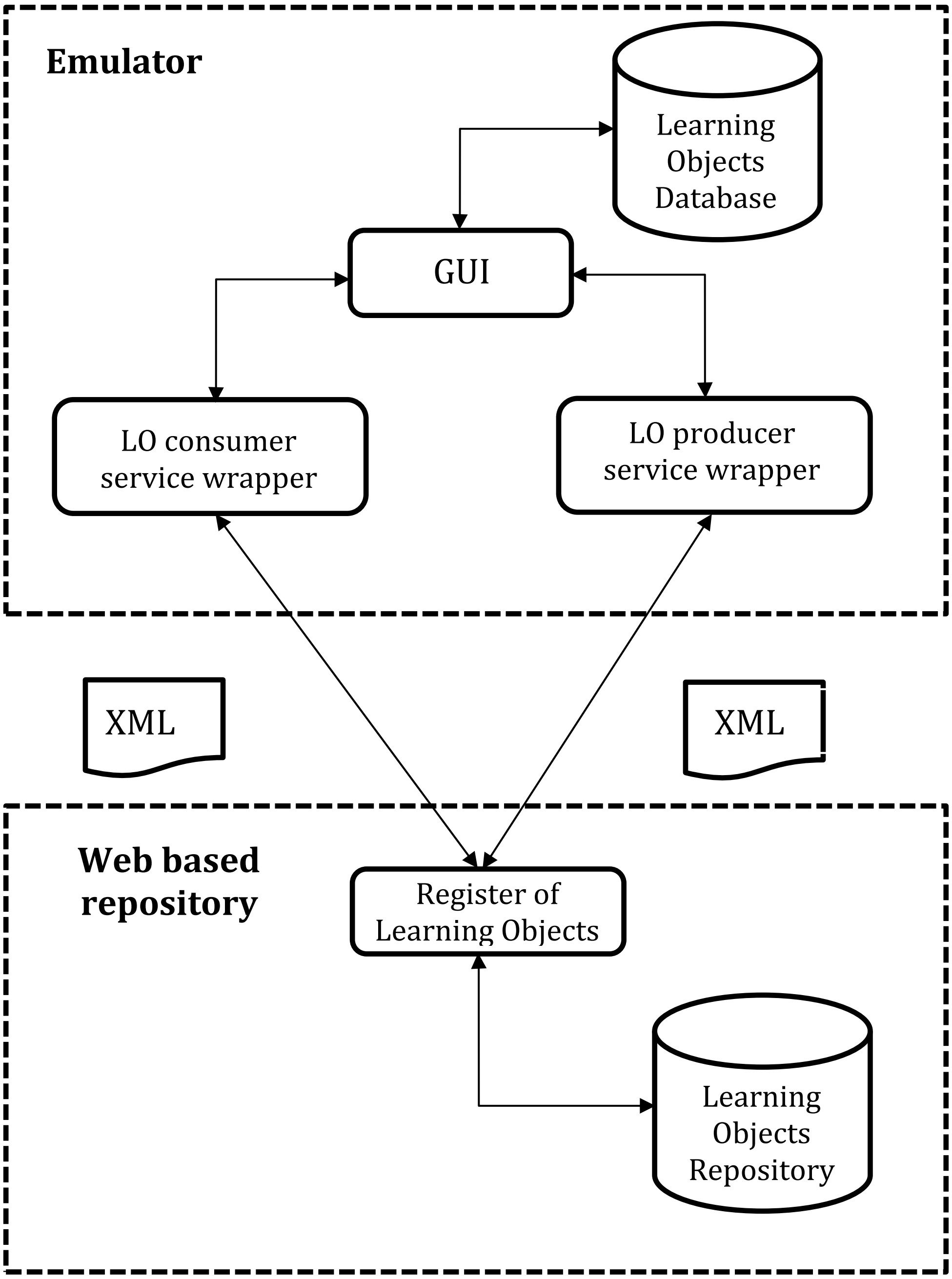
More than a decade ago emerge the concept of service-oriented architecture (SOA) emerged aiming to improve software development reusability. The main objective of SOA is to reduce complexity by providing resources for the development of large-scale software systems and at the same time to encourage future reuse of recently developed software products.

4.2 Platform for Creating Educational Scenarios Requirements

In the paper (Dimov et al., 2015) are formulated the following requirements for the platform for creating educational scenarios.

4.3 Architecture for Learning Object Reusability

The architecture presented in this chapter is based on the SOA approach described in Figure 31. It shows how different structural blocks need to be implemented as services. It should allow easy reuse of different Learning Object (LO) and consist of two main components: an emulator and a web-based repository (Figure 32).



Фигура 2. SOA-Based Model for Creating Educational Scenarios

4.4 Mockups of the Model

Mockups in Figure 33 and Figure 34 show what such a platform would look like from user point of view, a teacher, how easily it is possible to choose different criteria - method, tool (technology), subject (s), class (optional), purpose, then a sample learning scenario to be recommended.

Mockup 1 - Scenario „Lost Energy"

- Method: Inquiry-based learning;
- Tools: Mobile technologies (tablet, phone), platform for research approach to learning;
- Subject: Physics and Astronomy;
- Class: 8;
- Learning Objectives (Издателство „ПРОСВЕТА – СОФИЯ" АД, 2020):
    - Formulates and implements the law for conservation of mechanical energy;
    - Summarizes the conservation of energy as a basic natural law.

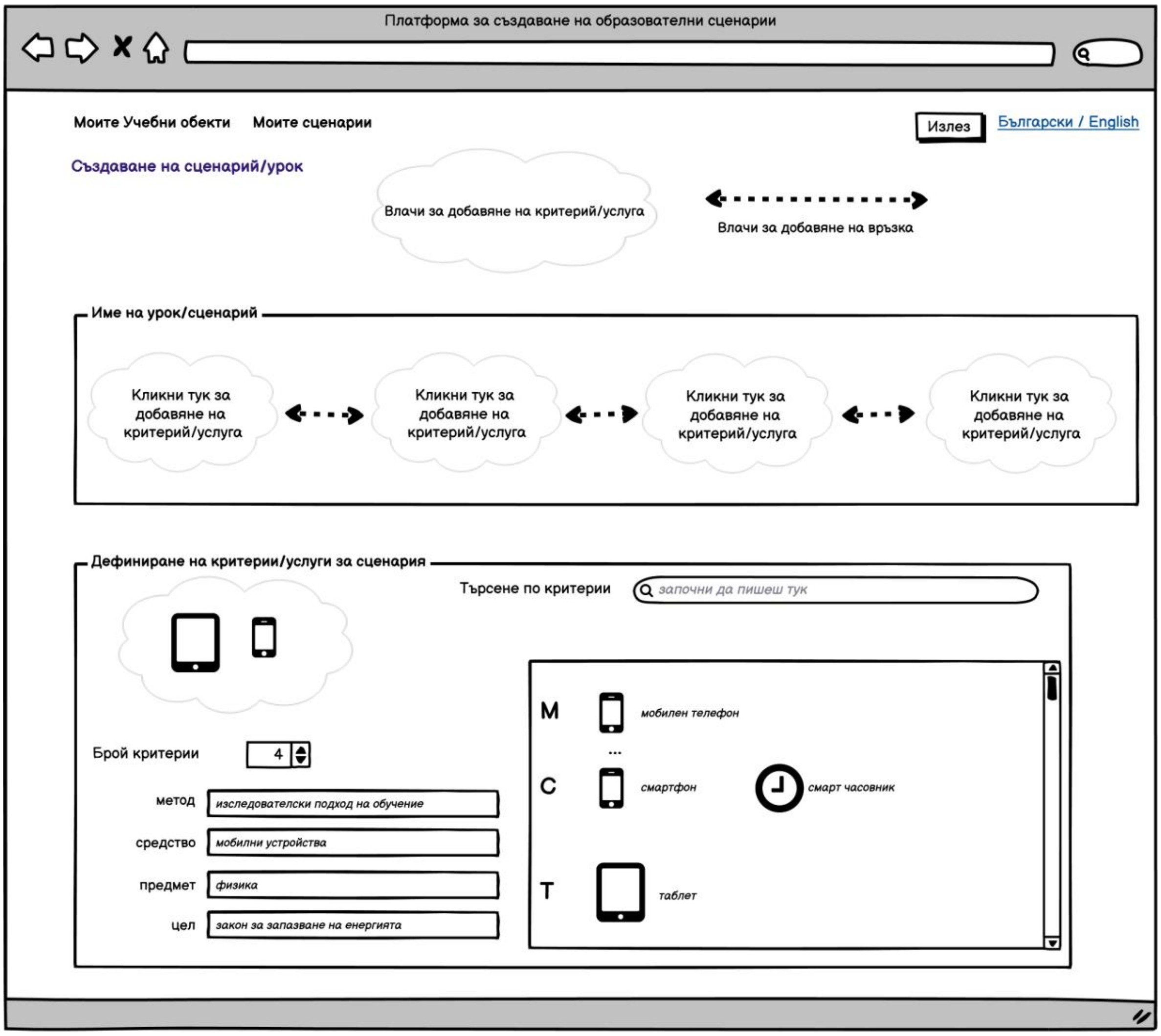


Figure 3 Defining criteria in a web platform for creating, finding lessons / scenarios - example 1

Mockup 2 - Scenario „Space Safari“

- Method: Inquiry-based Learning, traditional;
- Tools: virtual reality technologies, mobile technologies, platform for research approach to learning, interactive whiteboard;
- Subject: Man and Nature;
- Class: 5;
- Learning Objectives (Издателство „ПРОСВЕТА – СОФИЯ” АД, 2019):
    - Describes the stars;
    - Determines what a constellation is;
    - Describes the diurnal motion of the stars as a result of the Earth's orbit;
    - Lists and describes some constellations, such as Ursa Minor and Ursa Major;
    - Describes the position of the North Star and the related north direction;
    - Detects some constellations on the paper star map.

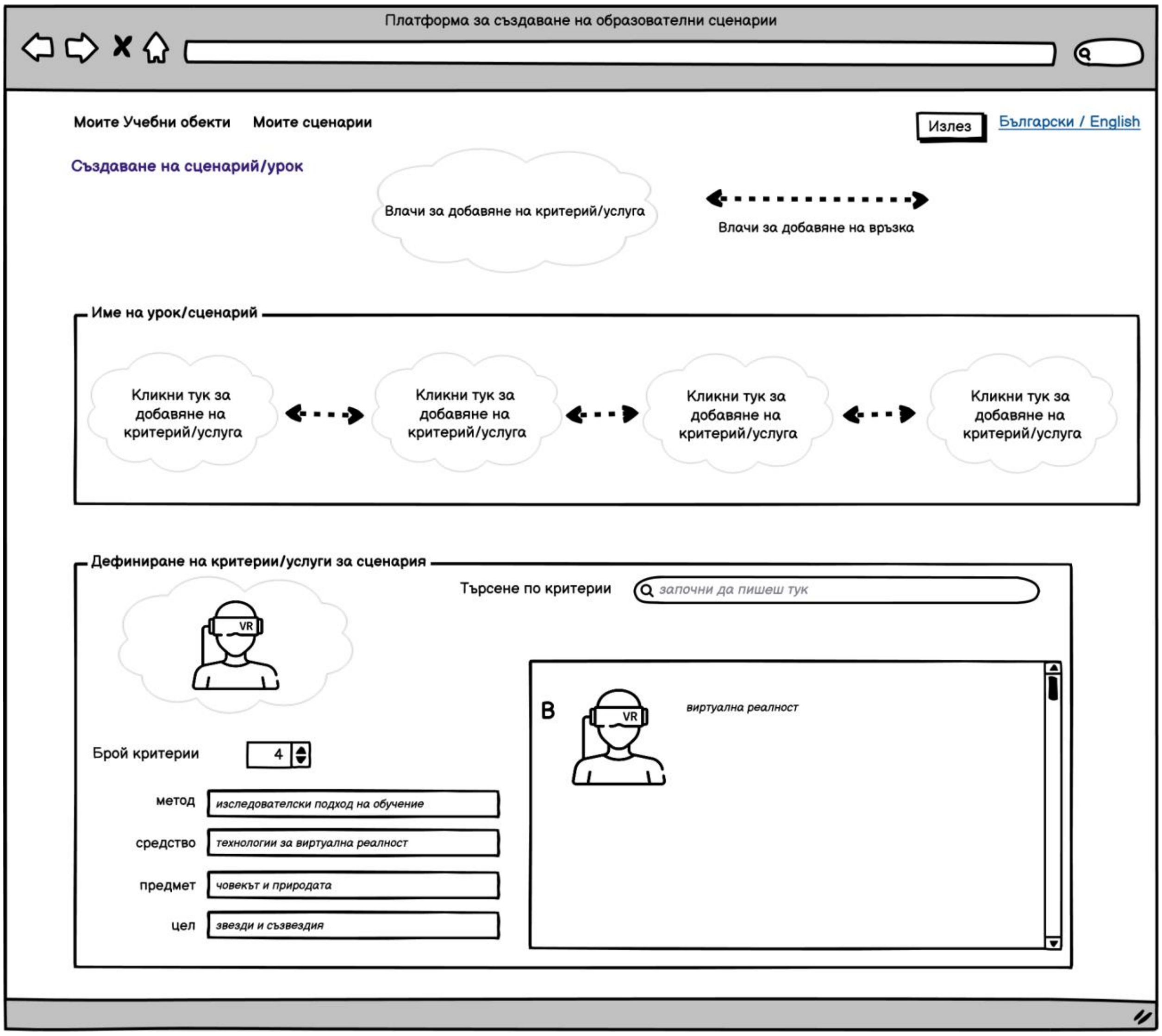


Figure 4. Defining criteria in a web platform for creating, finding lessons / scenarios - example 2

Chapter 5. Development, Testing and Analysis of Educational STEM Scenarios

The scenarios discussed in this chapter include an inquiry-based learning approach. All of them are STEM scenarios, as they cover the subjects "Man and Nature" and "Physics and Astronomy".

The scenario "Lost Energy", realized within the international project weSPOT, is presented.

"Dream and Reality" scenario is implemented as part of the international ELITe project, a continuation of the weSPOT project. This scenario is based on ELITe project template and it has been translated into several languages.

The "Space Safari" experiment is based on the "Dream and Reality" scenario, which was tested during the European Researchers' Night 2018. This study continued in the next two events - the European Researchers' Night 2019 and the European Researchers' Night 2020, respectively as an experiment-demonstration “Space Rangers” and demonstration “XR Space”.

5.1 STEM Scenario „Lost Energy“

The "Lost Energy" scenario presents the use of mobile technologies with tools provided by the weSPOT project: (1) from a teachers' point for the creation of learning scenario; (2) from the student's point of view through data collection and inquiry-based learning.

As a result of extensive pedagogical research, weSPOT has developed a model that is based on an inquiry-based learning approach and a set of technological tools to assist learners in their research (Protopsaltis, A. et al., 2014).

5.2 STEM Scenario „Dream and Reality“

The "Dream and Reality" scenario uses a template from the ELITe project, which is specifically designed for teacher training and it is based on the six- inquiry-based learning process model of weSPOT (Figure 1). "Dream" means online tools, virtual reality technology, augmented reality and others, and "reality" means a real, physical place for an educational visit - a science center, observatory or other.

From the "Dream and Reality" scenario followed the "Space Safari" experiment, the "Space Rangers" demonstration-experiment, and the "XR Space" demonstration.

5.2.1 „Space Safari“ Experiment

"Space Safari" is an experimental STEM lesson conducted simultaneously in three separate groups located in three different classrooms, implementing inquiry-based learning and oriented toward students and teachers. This experiment is based on the scenario "Dream and Reality".

The goals of the “Space Safari” experiment are students to recognize the constellations Ursa Major and Ursa Minor, students to discover the North Star. Another goal is for students to acquire knowledge and skills without leaving the classroom by using traditional or modern tools (information technology).

At the end of each of the three lessons, students completed a paper "Feedback Card" (Appendix 5). It explores the relationship between the methods - teaching approaches (traditional and inquiry-based learning), the tools used in the lesson (paper star maps, interactive whiteboard, VR devices or online platform) and what is the perception and attitude of students are to the STEM subject during the experiment and after it.

5.2.2 Experiment-Demonstration „Space Rangers“

The experiment-demonstration “Space Rangers” is a continuation of the “Space Safari” experiment. It is a part of the Children's Scientist for a Day Programme on European Researchers' Night 2019.

The topic of the experiment-demonstration is from the STEM disciplines - "Man and Nature" ("Physics and Astronomy"). During the experiment-demonstration, “Space Rangers” teaching and learning tools are tested and demonstrated: traditional (star maps and puzzle) and modern - mobile virtual reality devices (VR glasses Google Cardboard and similar), mixed reality (Microsoft HoloLens Generation 1 headset for Mixed Reality), and computer games to create sustainable Galaxies.

At the end of “Space Rangers” experiment-demonstration, participants have the option to fill out a paper "Questionnaire" (Appendix 8) and complete a task. The questions examine the tools used (VR devices) and how participants felt about whether they experienced discomfort while using VR devices. Another question reveals the participants' opinions about the use of VR technology and in which subjects they see the application of VR technology.

5.2.3 Demonstration „XR Space“

The "XR Space - Virtual and Augmented Reality in Education" demonstration is part of the European Researchers' Night 2020 programme. It is an event related to two previous events - the 2018 “Space Safari” Experiment and the “Space Rangers” Demonstration-Experiment in 2019, the name "XR Space" comes from virtual reality (VR), augmented reality (AR), mixed reality (MR). Extended reality (eXtended Reality) or abbreviated XR is a combination of the three concepts VR, AR, MR.

The lack of educational VR content and in particular, lack of content in Bulgarian language is a primary obstacle for the (wider) use of VR in education. This statement is based on studies in the scientific literature, as well as a result from surveys among Bulgarian educators on the application of VR in the educational process (Chapter 3.2.1 and Chapter 3.2.2). Two possible solutions to this problem are demonstrated with “XR Space”. The first proposed solution is the international platform for XR content EON-XR (EON Reality, 2021), which allows to customize and use available VR / AR content or to upload and use your own VR / AR. The second proposed solution is a newly developed course in FMI at Sofia University, which introduces XR technologies in Bulgarian language (Бойчев, 2021).

5.3 STEM Scenarios – Challenges and Conclusions

In order to successfully use inquiry-based learning in combination with different tools - traditional and modern, it is necessary to consider the challenges facing teachers and students in the various researches presented above (Chapter 5.2.1, Chapter 5.2.2, Chapter 5.2.3).

Experience from the developed and tested scenarios shows that teachers face some challenges:

- Formulation of the "right" question.
- Difficulties related to their computer skills and knowledge.
- Limitations in the functionality of the environment (in terms of weSPOT or DojoIBL platform).
- Which component in which phase of the IBL model to be visible (in terms of weSPOT platform).

- Promoting the variety of existing possibilities for combining "dream" (online tools, virtual reality, augmented reality, etc.) and "reality" (real places for educational visits) and how the two possibilities can enrich the teaching and learning process.
- Leaving the classroom (outdoor lessons, excursions, field trips, etc.).
- Interdisciplinary teaching should be the result of the combined efforts of teachers.
- Problems that arise in the implementation of technology-enhanced learning and in general, problems in the use of new technologies in education.
- Improving the skills for planning, organizing, evaluating students' activities, and evaluating students' achievements.
- Competence development:
    - study and application of regulations;
    - conducting pedagogical research;
    - designing "non-traditional" teaching and learning.

The scenarios, in addition to trying to implement a variety of methods and tools in education, seek answers to the questions of how best to use mobile devices in education, how to prevent "energy loss from learners" in the "digital ocean" of information

5.4 Responsible Research and Innovations

Researches in this dissertation could be considered as a responsible research (The European project RRI Tools, 2018), because during the experiments and demonstrations, which were conducted as part of the European Researchers' Night 2018, 2019 and 2020. During these three events, it was established a link was established between researchers, citizens, business, non-governmental organizations and the educational institution (Sofia University). This link contributes to results that are valuable to society and meet its needs. Volunteer associations and children, including refugee children (Arabs, Kurds and Farsi), took part in these dissertation researches.

Part of the "Space Rangers" demonstration-experiment was conducted in a team with an FMI graduate.

The experience and knowledge from the conducted researches - "Space Safari" and "Space Rangers", were shared with colleagues from the Institute for Space Research and TechnologyInstitute at Bulgarian Academy of Science (SRTI-BAS), on their initiative.

As a result of sharing the experience of the scenarios conducted with business representatives, under the Rebecca Mentoring Program "(REBECA, (*REBECA Mentoring Programme*, 2019)), the feedback was received from the business suggest that such scenarios will be useful in the private sector for employee training.

A future idea was discussed with some colleagues from the Department of Information Technology, FMI, Sofia University for the implementation of a new discipline to be included in the bachelor's program "Physics and Informatics" at the Faculty of Physics at Sofia University.

The head of the Distance Learning Department of the Higher Air Force School "Georgi Benkovski" in the town of Dolna Mitropolia took part in the "XR Space" demonstration and expressed interest in the proposed VR and AR solutions.

The plastic VR goggles used in the "XR Space" demonstration have been purchased on behalf of the PhD student as a participant in the the National Science Program "Information and Communication Technologies for Unified Digital Market in Science, Education and Security" (ICTinSES). The Ministry of Education and Science financially supported the program.

In order to validate the research in the dissertation, in April 2022, a doctoral student conducted a training with 33 teachers from 1st to 7th grade in 122. Innovative Primary School "Nikolay Liliev" in Sofia, where presented the scenarios "Space Safari" (2018), "Space Rangers" (2019) and "XR Space" (2020) were presented. During the training, the teachers were provided with traditional and modern technological tools, respectively paper star maps and VR devices (VR goggles and VR headsets), suitable for STEM training. The participants performed tasks related to Space. First, the teachers (the trainees) had to work with the paper star maps (Figure 50). Second, they use their smartphones, on which they needed to install a special mobile application (Star Tracker VR, 2018) and in combination with VR goggles (Noon VR) (Figure 65, (NOON VR, 2021)), observe the starry sky and discover Space objects. Finally, participants tested VR headsets (Oculus Quest 2, (Meta, 2022)) by studying an astronaut's suit through the EON-XR (EON Reality, Inc., 2022) application installed on the helmet.

After the training, the teachers had to fill in a questionnaire (feedback form, Appendix 9). Answers to two of the questions are presented. The scale is from 1 to 5, where 1 is a "Strongly Disagree" and 5 is "Strongly Agree". On the question "Is the presented sample scenario applicable in your school ?" ("Space Safari" scenario) (Figure 66), 27.3% of teachers chose "Agree" and 54.5% of them crossed out "Strongly Agree".

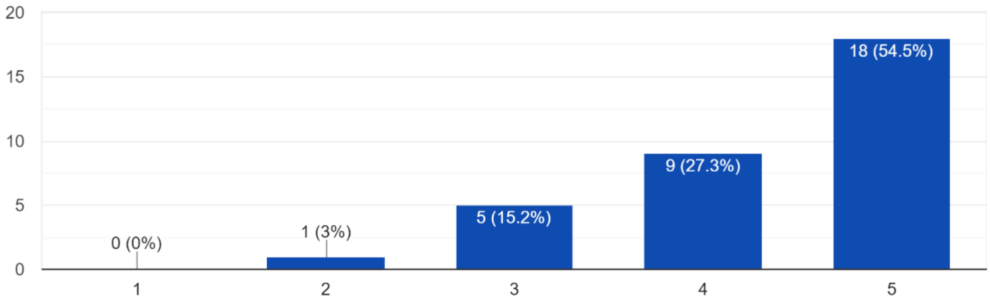


Figure 66. Is the presented sample scenario applicable in your school?

To the question "Would you like to have access to a platform with sample educational scenarios?" (Platform for Creating Educational Scenarios) (Figure 67), 9.1% of teachers are "Agree", 84.8% of them are „Strongly Agree", and hardly 6.1% said they are "Neither Agree nor Disagree".

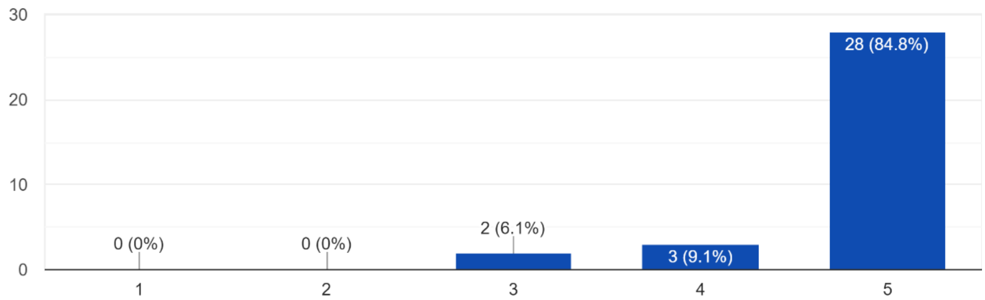


Figure 67. Would you like to have access to a platform with sample educational scenarios?

To the last question "Is there anything else you would like to share?", which is an open-ended question and concerns the training, one of the participants answered that he is completely satisfied. Another shared: "Extremely useful training. Both for the acquisition of new knowledge and for the exchange of experience. "

Conclusion

The dissertation "Methods and tools to support inquiry-based learning" presents some of the challenges of modern digital learning and traditional learning. These challenges are related to (1) computer skills and the knowledge of teachers, (2) leaving the classroom through VR and in a real environment, (3) interdisciplinary teaching and teamwork, (4) use of new technologies in teaching, (5) skills for planning, organizing and evaluating student activities and others.

Achieving better results for students in the acquisition of knowledge and skills in Science, Mathematics and Technology is the focus of the study. The solution is sought in the direction of the use of methods and tools in teaching and learning, so as to increase the motivation and interest of students. Inquiry-based learning is applied, supported by various technological tools, which emphasizes the active participation of students and provokes their discovery.

As a result, educational scenarios have been created. Their goal is to be able to solve one of the main problems in education in today's world (2014-2022), characterized by a huge boom in technology, namely teaching young people how to effectively use these technologies in acquiring STEM competencies.

The creation and implementation of a flexible learning environment (such as flipped classroom, the use of cloud technologies for education, etc.), is a tendency in schools and teaching in general, especially in the last two years (2020-2022) during the pandemic.

The following results have been achieved in the implementation of the tasks set:

- Awareness, use of technologies among teachers, as well as the educational content of modern technological tools as factors influencing the increase of interest, motivation and results of students are studied and analyzed. Active participation in the learning process is another important factor studied. (Chapter 1, Chapter 3, Chapter 5).
- Inquiry-based learning and research methods in education (experiment, demonstration, surveys, interviews), which are effective in teaching Science (Chapter 1, Chapter 5), are researched and analyzed.
- Modern technological tools, applicable in the STEM training, are researched and analyzed. Their main characteristics, properties, and limitations are identified. Criteria for selecting technological tools according to the context of inquiry-based learning are defined (Chapter 2).
- Possibilities and attitudes of students and teachers for the application of modern technological tools are researched and analyzed. The results of a survey for the general understanding among teachers for an interactive whiteboard and its use are presented. Another survey with teachers was focused on collecting information about the knowledge of VR and its application in the Bulgarian school. Criteria for the development, creation and implementation of educational scenarios using VR in STEM subjects have been formulated through interviews with experts (teachers and university professors) (Chapter 2, Chapter 3).
- A model of a system for searching, finding, and creating educational learning scenarios has been created, which is based on service-oriented architecture. Its aim is to make it easier for teachers to use a variety of teaching methods and tools. (Chapter 4).

- Wireframes represent use of the system for finding of scenarios according to the methods, tools and context of their application. Wireframes illustrate what the system would look like from user (a teacher) point of view, how easily it is possible to choose different criteria - method, tool (technology), subject (s), class (optional), purpose, and then to present an exemplary learning scenario (Chapter 4).
- Samples of educational scenarios combining inquiry-based learning with modern technological tools, which are suppose to support the achievement of learning goals in Sciences (Chapter 5) are described, tested and applied.
- It is analyzed and evaluated to what extent the created samples of educational scenarios lead to an increase in the interest and the results of the students in learning Sciences. After experimenting with one of the scenarios and through a survey of students, it was found that their interest in the topic of Space (from the subject "Man and Nature") has increased and after the event they will continue to be interested in it (Chapter 5).

From the results achieved in the implementation of the tasks, it is clear there are several factors that significantly affect the adoption and use of modern technological tools in education:

- teachers' computer skills and knowledge are crucial;
- the age and experience of teachers;
- technical support of equipment.

Technical problems often make it difficult to use technology in classrooms, and slow network performance and outdated computer technology are an obstacle to the use of technology in education.
Even if users have access to well-maintained infrastructures for the use of technology and The methods and tools for supporting inquiry-based learning turn out to be an important part for the development of qualities in young people, which can help them to be more competitive after they finish school. The implementation of the tasks of the dissertation, the application of mobile technologies in STEM classes provide a prerequisite for increasing motivation and interest in these sciences

The widespread use of digital technologies has changed almost all aspects of life: the way we communicate, work, the way we spend our free time, organize our lives and the way we receive knowledge and information. The changes the way we think and behave. Children and young people are growing up in a world where digital technology is everywhere. They do not know and cannot know otherwise. However, this does not mean that they have the right skills for the effective use of digital technologies. (European Commission. Joint Research Centre., 2017) provides a structure that allows European citizens to better understand what it means to be digitally competent, how to further develop and consciously use digital technologies.

Moving into the technological landscape can be a challenge without an experienced driver. Before investing in emerging learning technologies, there are many factors to consider. Namely this is the purpose of the sample educational scenarios that are presented to help teachers.

- STEM scenarios are proposed in the weSPOT platform for teaching students in different subjects:

  - The Lost Energy Scenario - an experiment to test the entire weSPOT model for inquiry-based learning:
    - Phases of the model.
- STEM scenarios are proposed in the ELITe project for teachers:
  - The "Dream and Reality" scenario is developed according to a special template based on the six phases of the weSPOT model:
    - "Space Safari" Experiment - participants acquire skills and knowledge about Space with the help of a computer, interactive whiteboard, virtual reality technology, traditional tools - paper star maps;
    - "Space Rangers" Experiment-Demonstration - Mixed reality is demonstrated and mobile virtual reality, paper star maps are tested;
    - "XR Space - virtual and augmented reality in education" Demonstration – it was proposed two possible solutions were proposed to the challenge lack of educational VR content and most importantly, educational VR content in:
      - International, multilingual platform EON-XR for XR content;
      - Bulgarian language XR course - "Virtual reality, augmented reality and extended reality".

Teachers are definitely interested in the different demonstrated approaches to teaching and learning. Through experiments and demonstrations, they see traditional and modern opportunities to increase interest, motivation, and respectively the results of their students to receive the right skills for effective use of digital technologies.

Contributions

Scientific Contributions

- ✓ An overview of research methods in education has been made (Chapter 1). The emphasis is on the inquiry-based learning.
- ✓ An analysis of the applicability of modern technological tools in Science education (Chapter 2), including mobile technology, interactive whiteboards and virtual reality technology.
- ✓ Criteria for selection of technological tools according to the context of inquiry-based learning are systematized (Chapter 2).
- ✓ The advantages and limitations for the application of technological tools in Science education are presented, based on studies on the applicability of methods and tools in STEM education in Bulgaria (Chapter 3), factors influencing the increase of interest, motivation and results of the students.

Scientific and Applied Contributions

- ✓ A model of a system for generating educational scenarios has been developed, which is based on a service-oriented architecture (Chapter 4).
- ✓ Wireframes have been created. They represent application of the software system for finding educational scenarios, according to the methods, tools and context of their application (Chapter 4).
- ✓ Developed and successfully tested in the framework of international research projects weSPOT and ELITe are sample educational scenarios (Chapter 5).
- ✓ It has been experimentally proven that the developed samples of educational scenarios lead to an increase in the interest and results in both teaching and learning of Science (Chapter 5).

Scientific Publications related to the Dissertation Work

Elitsa V. Peltekova's publications connected with the dissertation:

1. **Peltekova, E.**, Stefanova, E., Nikolova, N. (2019) Space Safari – Challenge for STEM Rangers, Proceedings of ACM CompSysTech'19, 21-22 June 2019, University of Ruse, Bulgaria, editor/s:Tzvetomir Vassilev, Angel Smrikarov, Publisher:ACM Digital Library, 2019, pages:292-298, ISBN:978-1-4503-7149-0, doi:https://doi.org/10.1145/3345252.3345273, Ref, SCOPUS, SJR (0.169 – 2018), ACM Digital Library
   "The paper is awarded by the International Programme Committee with the Crystal Award THE BEST PAPER".
2. **Peltekova, E.**, Dimov, A., Stefanova, E. (2018) Improvement of Students' Achievement via VR Technology, In proceedings of Interactive Mobile Communication Technologies and Learning. IMCL 2017. Electronic Education Magazine: Advances in Intelligent Systems and Computing, Springer, Cham, 2018, pp. 36-43, doi: https://doi.org/10.1007/978-3-319-75175-7_5
   1 citation.

3. **Peltekova, E.**, Stefanova, E. (2016) Inquiry-based Learning "Outside" the Classroom with Virtual Reality Devices, Modern Information Technologies and IT-Education, Vol-1761, 2016, pp. 232-236, ISSN: 1613-0073, Ref IF (0.14 - 2015)
   14 citations.
4. **Peltekova, E.**, Dimov, A. (2016) Software Architecture for Interactive Learning, In Proceedings of INTED2016, IATED Academy, pp. 1117-1125, ISBN: 978-84-608-5617-7
   1 citation.
5. **Peltekova, E.** (2015) Application of the Powerful, Educational Tool Interactive Whiteboard, In ICERI2015 Proceedings, IATED Academy, 2015, pp. 4388-4397, ISBN: 978-84-608-2657-6; ISSN: 2340-1095

Participation in Research Projects related to the Dissertation Work

1. The National Science Program „Information and Communication Technologies for Unified Digital Market in Science, Education and Security", https://npict.bg/, Ministry of Education and Science of Republic of Bulgaria, 2018-2021
2. ELITe (Enhancing Learning in Teaching via e-inquiries, EC-Erasmus+ project 2016-1-EL01-KA201-023647)
3. Use of high-tech tools in building competencies for applying an inquiry-based learning in STEM disciplines in high school, Sofia University Science Fund, 80-10-90/19.04.2018
4. Inquiry-based learning in the field of high technologies as an application of modern information technologies, Sofia University Science Fund, 80-10-217/24.04.2017
5. Study of the applicability in practice of new technological tools and approaches to teaching and learning process, Sofia University Science Fund, 30/31.03.2015, 2015
6. ASSETS, Methods and technologies to improve access to electronic services, funded by the National Science Fund, Ministry of Education and Science in Bulgaria – Part of the research team, November 2014 – April 2016
7. Working Environment with Social and Personal Open Tools for inquiry-based learning (**weSPOT**), FP7-ICT-2011-8-318499, 2012-2015

Declaration of Originality

I declare that the presented in connection with the procedure for obtaining the educational and scientific degree "Doctor" at Sofia University "St. Kliment Ohridski" dissertation on the topic: "Methods and tools for supporting inquiry-based learning" is my own original work. It was done during 2014-2022.

Citation of all sources of information, text, figures, tables, images and others are made according to the standards.

The results and contributions of the dissertation research are original and are not borrowed from research and publications in which I do not participate.

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