Enhancing Teachers' Computational Thinking Skills Through Game Based Learning

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Abstract

Computational thinking is a concept which involves formulating and solving problems in a way computer would do it, though not necessarily with the help of a computer. It is considered to be the necessary skill for successful functioning in the technology driven society of the 21st century, therefore it is important to integrate it into the education system. Since the role of the teacher in that context is important, the paper considers activities in the development of computational thinking of pre-service and in-service teachers, especially through game based learning. Two projects that explore this topic are presented: the Erasmus+ project GLAT and the Digital games project.

1 Introduction

After the influential work of Jeanette M. Wing in 2006, Computational Thinking (CT) became widely accepted term of universally applicable concepts, attitudes and skills characteristic to the STEM and information science way of thinking [Win06].

Most CT related work is focused on students of older age, within STEM areas and subjects, as well as students on various courses within the domain of information science and programming. It is to be expected that the level of CT in such population is above the level in general population. The demand for modern education is to adopt the essential concepts of CT within the population uncomfortable to STEM area, programming and informatics. In order to educate creative and innovative people able to cope with contemporary technology of tomorrows, which are not just technology consumers but their active creator, it is important to influence students as early as possible. When their interests are still shaped and they are still motivated for learning, they experience learning as a game and not as a commitment. Constructive criticism is focused on the lack of research aimed at younger elementary schools students, preschool age groups (K-4; kindergarten through 4th grade) and especially teachers

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working with these students. For example, of 27 published papers about CT promotion from July of 2015 to April of 2016, only 3 studies are targeted at lower primary school age and teachers as aimed groups of research [deA16].

This paper focuses on the promotion of teacher's CT, both future teachers and teachers already participating in the teaching process (pre-service and in-service teachers). The activities that have started within the Erasmus+ project GLAT - *Games for Learning Algorithmic Thinking* and have continued within the UNIRI project *Digital games in the context of learning, teaching and promoting inclusive education* are presented. One of the projects' objectives is to encourage the integration of CT into the daily teaching of different subjects in the lower grades of primary school using game based learning (GBL). This research will include the design of a model for CT teacher education so that in their future work teachers could stimulate among their students important concepts that CT includes.

The paper is organized as follows: the second chapter provides some of the CT definitions, concepts, and models. The third chapter brings brief description of Game Based Learning (GBL) and Scratch Tool. The fourth chapter deals more closely with CT in the context of teacher education, with reference to the Croatian education system and the new curriculum. Next, there are chapters featuring projects activities: the fifth chapter presents *Games for Learning Algorithmic Thinking* (GLAT) project which ends in 2019 and the sixth chapter presents the project *Digital games in the context of learning, teaching and promoting inclusive education* (Digital Games) which begun in 2019, partly as a continuation of the GLAT project. At the end of the paper, the last chapter points out the main conclusions.

2 Computational Thinking (CT)

CT covers a wide range of features so there is no unambiguous definition of it. The CT definition is often the set of skills it consists of. Most of the authors agree that CT is a set of fundamental skills for everyone, not just computer scientists; it is a thought activity of formulating and solving problems in the way computers do it. Thereby the problem solving process does not necessarily involve computers themselves [Cun10].

A more extensive definition is given by C. Selby and J. Woollard in which the CT is referred to as "a focused approach to problem solving, incorporating thought processes that utilize abstraction, decomposition, algorithmic design, evaluation, and generalizations [Sel13].

Even more complete CT definition is formulated in the *Computational Thinking Toolkit* publication from 2010. Organized by the National Science Foundation (NSF), the International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA) from USA, by the synergy of a large number of leading education scientists, teachers and computer scientists, the operational CT definition is produced [Com10]:

Computational thinking (CT) is a problem-solving process that includes (but is not limited to) the following characteristics:

- Formulating problems in a way that enables us to use a computer and other tools to help solve them
- Logically organizing and analyzing data
- Representing data through abstractions such as models and simulations
- Automating solutions through algorithmic thinking (a series of ordered steps)
- Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
- Generalizing and transferring this problem solving process to a wide variety of problems.

Further, the publication states number of dispositions or attitudes that are essential dimensions of CT, which include:

- Confidence in dealing with complexity
- Persistence in working with difficult problems
- Tolerance for ambiguity
- The ability to deal with open-ended problems
- The ability to communicate and work with others to achieve a common goal or solution

The broad domains to which the CT relates implies that the research is limited to individual CT elements. The authors offer different models trying to classify the aspects of CT on the essential components. The Aspects of CT most commonly analyzed and found in the literature as fundamental are decomposition, abstraction, algorithms, debugging, iteration and generalization [Shu17]. Then the research is designed in such a way that the targeted aspect of the CT can be evaluated.

3 Game Based Learning (GBL)

While playing games children demonstrate many CT qualities [Lee12]. In the early years of schooling (preschool up to 4^{th} grade), children are still motivated to learn because they experience it more like a game and not a commitment. At that time, while their interest is still forming, it is important to focus their learning process in a way that promotes CT. The GBL approach to learning more demanding content at children retains a sense of play rather than a coercion, which is in line with contemporary theories of learning [Wu12].

Game based learning is a newer theory of learning, accepted as motivating for students, but there is a difference between playing games and building the game itself. In the latter case student's motivation is higher and the learning process is more efficient [Vos11].

Although there are a number of researches on GBL, this area is still relatively new, especially in the context of Croatian education. In order to increase motivation, efficiency, interest and engagement of students, there is a necessity to propose an innovative way of using GBL principles in Croatian education system.

An example of a very popular tool for programming and algorithmic thinking indirect learning is Scratch [Scr19]. The tool is created by the Lifelong Kindergarten Group, the MIT Media Lab. All contents are free for sharing, exploring, and upgrading. Scratch is very easy to use thus suitable for the younger students, offering a significant environment for development creativity, systematicity and cooperativity. Using Scratch, students design their stories, games, animations, and simulations by matching the already programmed code blocks as if they fit Lego dice [Res09].

Scratch is a suitable environment for the constructivist aspect of GBL, suitable for lower grades students and the development of programming concepts through game design [Wil13].

Based on the Scratch activities, Brennan and Resnick have formed a highly cited and accepted CT model [Bre12]. In their model, CT aspects are divided into three dimensions:

- *Computational concepts (the concepts designers employ as they program): sequences,loops, parallelism, events, conditionals, operators, and data*
- *Computational practices (the practices designers develop as they program): being incremental and iterative, testing and debugging, reusing and remixing, and abstracting and modularizing*
- *Computational perspectives (the perspectives designers form about the world around them and about themselves): expressing, connecting and questioning*

Scratch is represented in the curriculum of Faculties of Teacher Education in Croatia, as a part of education program for future teachers. It is also represented in the GLAT project presented in this paper.

There are a whole range of tools like Scratch, all represented in the educational process of different subjects. GBL is thus imposed as a natural medium for promoting concepts and ideas of CT.

4 CT and Teacher Education

Given the interdisciplinarity of primary school junior grade teachers, which are expected to be educated in all subjects, good teacher education is one of the crucial factors in the promotion of CT in the lower grades of elementary school [Adl18].

CT aspects can be taught in a series of school subjects, should not be related solely to math, computer science or natural science subjects. Yadav et al. conducted workshop based research about CT understanding of future teachers. After the completed workshop, the results indicates that future teachers in general are considering CT as integrating technology into teaching, while the experimental group has realized CT as a problem-solving approach, universally applicable in teaching and not related just to technology [Yad17].

Instead of focusing on the application of new technologies, the education of future teachers at universities should concentrate on the acquisition of skills and competences that characterize the CT as part of its primary profession and methodology courses, which can easily be applied to novelties in technology [Yad14]. Yadav et al. suggest that the education of future teachers should include co-operation with information science specialists, in order to incorporate core CT quality into pedagogical and methods course education. They suggest that such education should take into account the following components [Yad17]:

Curriculum. Develop a pre-service teacher education curriculum to prepare teachers to embed computational thinking in their classrooms.

Core ideas. Introduce pre-service teachers to core ideas of computational thinking by redesigning educational technology courses.

Methods courses. Use elementary and secondary methods courses to develop pre-service teachers' understanding of computational thinking in the context of the discipline.

Collaboration. Computer science educators and teacher educators collaborate on developing computational thinking curricula that goes beyond programming.

Teacher education. Use existing resources and curriculum standards to assimilate computational thinking into pre-service teacher education.

Teacher education should not end at formal education during the study. Apart from the fact that study programs are often obsolete or the process of redesigning syllabuses is too slow, the very speed of change in information communication technologies requires continuous teacher education.

A positive thing is the availability of a large number of tools and resources available for free use in teaching, free to use, upgrade and further share. Lockwood and Mooney in the 2017 review [Loc17] list over 50 different tools, software, programming languages, etc., which were the foundation of CT research in education. That the number is constantly increasing as well as the free sharing and usage facilities based on these tools. There is also a positive enthusiasm of a large number of teachers, scientists, and private technology companies to make their work massively available for better education and popularization of CT.

The Croatian educational system is currently implementing an experimental phase of curricular reform [Nac19] named "*School for life*" , which places emphasis on acquiring knowledge, developing ability and willingness of students to solve problems, making decisions, metacognition, critical thinking, creativity and innovation. Students should also be enabled for communication, collaboration, information and digital literacy and the use of technology. The advantage of the game as a natural activity of children which implies the importance of using the GBL especially in the lowest grades is stressed as well.

However, up to now, not sufficient attention is being paid to the development of CT in education for future teachers in their formal education. There are not enough appropriate courses that introduce CT in study programs for future primary junior grade teachers, and not enough courses within which models such as Game Based Learning into teaching could be implemented. Mostly there are implemented as elective courses e.g. one of the elective courses in the Graduate study of primary school education is "Extracurricular Informatics and Technical Activities" at Faculty of Teacher Education, University of Rijeka. The situation is similar in most study programs for teachers across Europe which was one of the reasons for connecting experts from different EU countries and starting a project which deals with these issues.

5 Project GLAT - Education for Teachers

One of the projects about enhancing teachers' CT skills and teaching them applying CT concepts with their students is Erasmus+ project GLAT - *Games for Learning Algorithmic Thinking* [Gla19]. The general goal of the project is development of algorithmic thinking of younger students which will improve students' attitudes towards coding and increasing students' interest in the selection of future career in the ICT and STEM areas. Main objective is encouraging the integration of computational and algorithmic thinking, problem-solving skills, logic and creativity into the daily teaching through different subjects in students' younger ages in a fun and attractive way.

Partners are European experts in the field of didactics of informatics, e-learning, and game-based learning from Croatia, Estonia, Slovenia, Macedonia and Bulgaria. The direct participants are Croatian primary school junior grade teachers and the most important project activities include professional development for teachers using workshops where they are introduced to innovative methods for teaching in the field of ICT.

In the context of the project, syllabus and learning materials for blended learning model of education for primary school junior grade teachers are developed. Learning outcomes are related to innovative teaching methodologies and tools such as: Problem Based Learning (PBL), Inquiry Based Learning (IBL), Game Based Learning (GBL), use of Web 2.0 tools for creating content for unplugged activities, creating logical tasks and online quizzes, games and tools for learning basics of programming.

Teachers were introduced to the learning management system Moodle and provided with access to the e-course "Games for Learning Algorithmic Thinking". Within this e-course, teachers access all learning materials, communicate with project experts, submit created learning scenarios, and share their impressions regarding implementation of learning scenarios in classroom with other participants.

The most important part of GLAT education are 3-day workshops for focus group of about 20 teachers (Figure 1) for f2f part of a total of 48 hours [Hoi18].

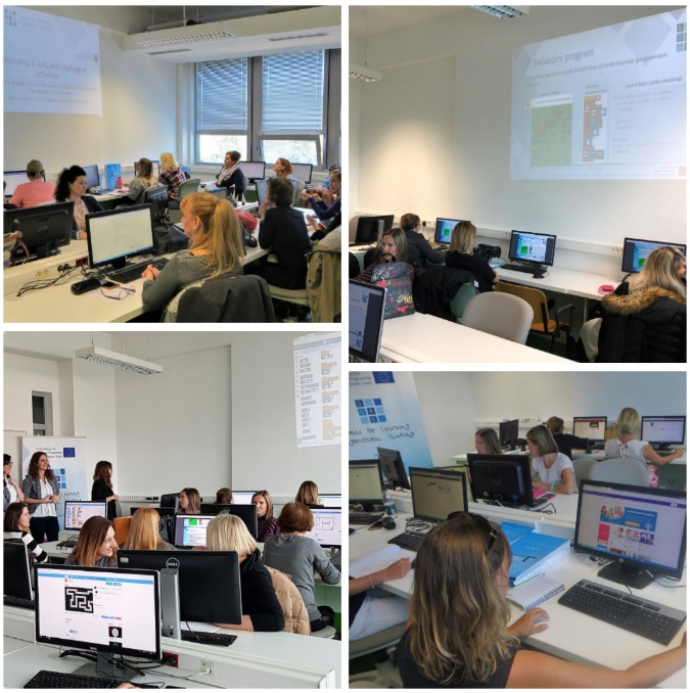

Figure 1: Participants during the GLAT workshops

The goal of the first workshop was to introduce the participants to the concepts and examples of GBL and game-based unplugged activities (activities that take place in the classroom without using a computer) for algorithmic thinking as well as tools for creating content for unplugged activities and designing learning scenarios.

After the second workshop teachers have been able to describe principles of PBL and teamwork, use Web 2.0 tools for creating logical tasks and online quizzes, apply digital didactic games into different school subjects, and create learning scenarios to develop innovative ideas for carrying out logical tasks and online quizzes (Figure 2).

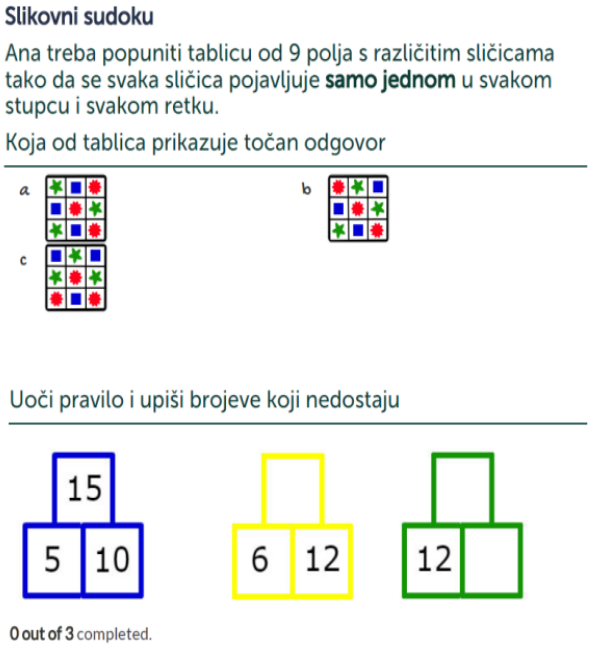

Figure 2: Logical tasks on the second workshop

The third workshop was related to IBL as well as learning CT and basic programming concepts using games and game-based tools. During the workshop, participants attended lectures, demonstrations, and practical work. Through individual and group activities, they analyzed and use games and tools for learning programming like Run Marco!, Code.org, Blockly Games, and Scratch – a block-based visual programming language by which students can program their interactive stories, games, and animations (Figure 3). Participants have also learned how to apply the micro:bit for encouraging algorithmic thinking.

Figure 3: Basic programming concepts through examples of games

During the GLAT workshops, attendants have learned how to prepare learning scenarios: documents in which the teacher develops innovative ideas to carry out educational activities by means of modern teaching methods with the use of appropriate digital content and tools. The most important elements of the scenarios are the learning outcomes and the activities for their realization by using contemporary teaching and learning methods and digital tools [Car17].

After each workshop teachers have started designing their own learning scenarios, with the help of mentors - experts from the project team. The main goal of these scenarios is encouraging algorithmic and computational thinking of students as preparation for later learning of coding. Besides the textual form of the scenario (Figure 4), teachers are supposed to design graphical form using the LePlanner tool [Hoi16]. Final versions of scenarios have been implemented in the classroom with the students from 1st to 4th grades of primary school.

Predložak za izradu scenarija poučavanja

(Learning Scenario Template)

Naziv scenarija (Learning Scenario Title)		
Nastavni predmet/Razred (Course/ Grade)		
Ishodi učenja (Learning Outcomes)		
Ciljevi i kratki opis aktivnosti (Aim and Short Description of Activities)		
Ključni pojmovi (Keywords)		
Korelacija i interdisciplinarnost (Correlation and Interdisciplinarity)		
Trajanje aktivnosti (Duration of Activities)		
Metode poučavanja (Teaching Methods)		
Oblici poučavanja (Teaching Forms)		
Potrebni alati (Tools)		
Materijali za nastavnike (Resources/materials for the Teacher)		
Materijali za učenike (Resources/materials for the Students)		
Razrada aktivnosti (Teching summary)	Motivacija – uvod u aktivnost	Trajanje (Duration)
	Provedba aktivnosti	
	Refleksija na provedenu aktivnost (evaluacija)	
Prilozi (Annexes)		

Figure 4: GLAT Learning Scenario Template

5.1 Evaluation of the GLAT Workshops

An evaluation was conducted after each workshop with aim to establish how participants were satisfied with the workshop content and lecturers. The evaluation in a form of an anonymous survey consisted of first part with Likert scale-based statements and second part with open ended questions. In the first part participants were asked to express their opinions on the applicability of the statement to the workshop using the Likert scale, where 1 refers to "extremely poor" to 5 - "exquisitely" . In open ended questions in the second part, participants were asked to mention the topics for which they considered to be of most use in their job in school (the value of education), and to give some suggestions and proposals for the improvement of the workshops.

The survey was completed by 24, 22 and 19 participants respectively per each workshop which is 65 questionnaires overall for the whole education. As shown on Figure 5 participants highly evaluated six of eight items: the contemporary (up-to-date) content, importance of a workshop for personal professional development, communication and collaboration within a group, preparedness of lecturers, an opportunity to express their own opinions and general evaluation of the workshop. It is significant that all above mentioned statements had high marks (above 4,7) for each workshop separately.

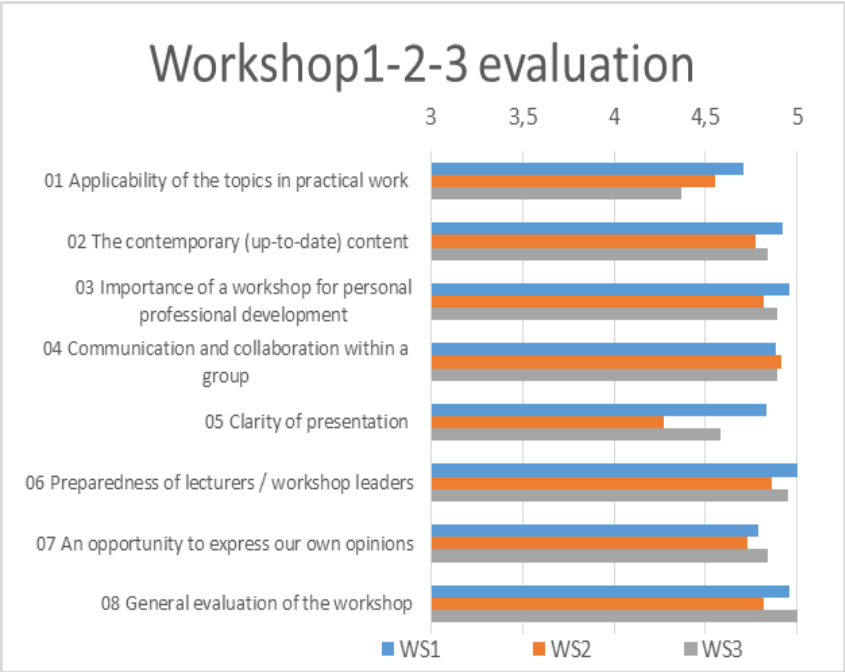

Figure 5: Evaluation items for three GLAT workshops

Generally, looking at the entire education of teachers trough three workshops, participants highly evaluated all statements with means' value above 4,55 as shown in Table 2. Only two statements overall had standard deviation over 0,5.

Table 1: Overall evaluation of the education

	N					
	Valid	Missing	Mean	Median	Mode	Std. Deviation
01 Applicability of the topics in practical work	**65**	**0**	**4,55**	**5,00**	**5**	**,613**
02 The contemporary (up-to-date) content	**65**	**0**	**4,85**	**5,00**	**5**	**,404**
03 Importance for professional development	**65**	**0**	**4,89**	**5,00**	**5**	**,312**
04 Communication and collaboration within a group	**65**	**0**	**4,89**	**5,00**	**5**	**,312**
05 Clarity of presentation	**65**	**0**	**4,57**	**5,00**	**5**	**,585**
06 Preparedness of lecturers / workshop leaders	**65**	**0**	**4,94**	**5,00**	**5**	**,242**
07 An opportunity to express our own opinions	**65**	**0**	**4,78**	**5,00**	**5**	**,450**
08 General evaluation of the workshop	**65**	**0**	**4,92**	**5,00**	**5**	**,269**

The second part with open ended question confirmed the satisfaction of participants. As the value of education, participants emphasized contemporary topics, applicability of presented topics, unique education opportunity, very good organization and preparedness of lecturers, great communication and collaboration with lecturers and colleagues. To point out some of the comments:

„I would emphasize the value of teaching about the use of digital tools; we use them more and more in teaching, especially in the experimental program of curricular reform "School for life"."

„Getting acquainted with new ways of learning that is much more interesting to children because it includes what is close to them, namely, the games and technology. "

„Excellent preparation and expertise of lecturers, the ability to develop creativity, encourage to continuous participation and learning, interesting content, pleasant lecturers, very responsive. Excellent education! Thank you¡'

There were not many suggestions and proposals for the improvement of the education. After the first workshop titled "Game based learning and unplugged activities" there was no suggestions at all, probably because teachers were familiar with topics in general. The last two workshop were more demanding for teachers because they were not familiar enough with digital tools that can be used in classroom, so they stated that there were too many tools to upskill. The comments were:

"More time for a particular application. More details on using a particular tool."

„The pace of presenting new content is too rapid. "

As presumed, our participants had no additional prior knowledge about using and implementing digital tools and game-based tools for learning programming concepts, so they found these tasks demanding.

The teachers will apply their work with students from 1^{st} to 4^{th} grade, and afterwards a more detailed evaluation follows. The interviews and questionnaire will also be prepared for students who took part in testing of the learning scenarios. All results and collected data will be used for improving the GLAT syllabus and teaching materials for formal and non-formal teacher training programs as well as for further research efforts about improvement of the CT education model for primary junior grade teachers in the context of the new project "Digital games".

6 Future plans – project "Digital games"

The above-described research started under the Erasmus+ GLAT project will continue in the University of Rijeka's scientific project Digital games – *"Digital games in the context of learning, teaching and promoting inclusive education"*. The project started in January 2019 and lasts for three years.

The purpose of the project is to explore the possibilities of using digital games to improve the quality of learning, teaching and promoting inclusive education, and the development and promotion of contemporary pedagogical-technological frameworks for the use of GBL in schools. The project will cover activities that correspond to specific research objectives, which are the selection and development of games and digital tools, as well as modern teaching models for building the GBL frameworks, and the designing of learning scenarios based on developed frameworks applicable in practice for learning and teaching subjects in primary schools.

Several studies based on the principles of GBL will begin in the context of the project. One of the studies is about encouraging the integration of computational thinking into the daily teaching of different subjects in the lower grades of primary school using GBL, which will stimulate creativity, logical thinking and problem-solving skills among students. In the context of this study, special attention will be given to the development of CT education models for future K-4 teachers to enable the transfer of CT knowledge and skills to their students.

Within the aforementioned study, based on GLAT project results, additional analysis of relevant research and the existing situation in schools, project members will select and develop games and digital tools and appropriate learning models to build pedagogical-technological frameworks based on GBL to educate the teachers for CT. The collaboration will be established with students - future teachers as well as teachers in schools with the help of which learning scenarios and CT learning materials will be built.

The research will use the Design Based Research (DBR) approach [Wan05] which represents a systematic but flexible methodology for research to improve the educational practice through iterative analysis, design, development and implementation based on co-operation between researchers and teachers-practitioners. DBR iteratively designs a learning model which is tested in a natural environment and revised after testing as many times it takes. The basic advantage of DBR in relation to the classical experiment is implementation in a real environment, not in conditions isolated from everyday life.

In order to ensure a balance between existing practice and pedagogical and technological innovations, the role of the teachers in the schools will be important. Quantitative (the software tools event logs, test results, surveys ...) and qualitative data (conversations with teachers and students, observation of class interaction and video analysis, analysis of student activities ...) will be collected during the research to evaluate developed pedagogical-technological frameworks for GBL application.

Design based research (DBR) will include improvement of existing e-learning models for learning CT by introducing GBL and gamification through learning resources with digital games, puzzles, logical tasks and similar elements for encouraging learning (technological aspect) and the contemporary learning and teaching strategies that place students in the center of the educational process (pedagogical aspect).

7 Conclusion

The technology-pervasive modern society, the rapid advancement of ICT, and the new learning strategies are usually seen as a challenge in educating the new-coming generations of students. This is a complex task for teachers who are expected to successfully teach these upcoming generations. More than ever, teachers must be students themselves, be educated on a continuous basis and keep up to date with contemporary tendencies.

Technological aspect of learning needs teacher to be an expert in 21^{st} century skills with the ability to choose appropriate activities and digital tools for their students. This also includes enhancing teachers' CT skills and teaching them how to apply CT concepts with their students.

On the other hand, pedagogical aspect refers to be good methodological expert in order to encourage multiple strategies to foster qualitative discussion and better learning. Teachers need to be flexible with managing new classroom dynamics and be willing to adapt their teaching styles to accommodate new pedagogical approaches to learning such as PBL, IBL, and GBL.

These two aspects require flexible education system as well as personal effort of teachers to communicate and collaborate with each other and with students. For the above to occur, teachers will need professional development opportunities and strong support systems.

This paper presents activities in the promotion of teachers' CT skills based on recent pedagogical methods and contemporary digital tools. Through project GLAT, based on game-based learning approaches, primary school junior grade teachers are educated in developing their own teaching materials that are then applied in class. The GLAT project results demonstrated the participants' satisfaction with the use of digital tools to promote CT skills, communication and collaboration is established. The main project results will consist of syllabus of workshops with the materials for learning in Croatian and English language, complemented by the examples of best practices, and available at online platform for e-learning. Syllabus will be used in the future for the organization of a program of professional development of teachers, course or similar forms of education in Croatia, partner countries and beyond.

In the context of the new project Digital Games, efforts on building pedagogical-technological frameworks based on GBL to educate the teachers for CT will continue.

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