USING SCOTTIE GO! AS GAME BASED LEARNING TOOL FOR COMPUTATIONAL THINKING COURSE

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Abstract

The pervasiveness of information and communication technologies in everyday life imposes the need to be digitally proficient. Computational thinking and learning to code are necessary 21st century skills for students. Those skills can drastically influence future labor market. Carefully planned educational approaches must be used in order to develop computational thinking skills at primary school level. We propose to use game based learning combined with flipped classroom and collaborative team work. This can utilize students' energy and enthusiasm they have when playing games, in achieving educational goals. This methodological approach is also very useful to develop different level of digital competences focusing on a technology as a tool for achieving certain goal.

Scottie Go! is an interactive puzzle-based mobile game which aims to involve primary school children in coding using approach similar to popular block based coding approaches such as Scratch coding environment. The coding is very similar to making the ordinary paper puzzle, where each part of the puzzle is one coding instruction. The "compiling" of code is done using mobile app camera-based interface that is very popular among students. This simple and tactile approach makes easier for young learners to deal with abstract coding concepts without depending on technology at one side, and developing sophisticated digital competences (simplified augmented reality) at other side. The collaborative game approach is used in order to integrate less interested or talented students in achieving learning outcomes in a very natural way. By playing the game students have both fun and possibility to learn from the other in the flipped classroom manner.

The proposed approach was used with 120 students from six different primary schools over a period of two months. The students than took part in the survey concerning their overall experience in using the game for development of computational skills. Information concerning students' interest in the game, ease of use, students' quality of experience and correspondence to educational goals were obtained using the survey. In addition, An exam has been carried out to evaluate students' learning achievements and long term knowledge. Survey results together with exams' results indicate that the proposed approach has created collaborative, stimulating and motivational learning environments which lead to successful achieving of learning outcomes. Proposed teaching methodology and results of the survey are presented in the paper.

Keywords: Computational thinking, game based learning, mobile game, coding, collaboration.

1 INTRODUCTION

Development of students' 21st century skills, necessary for living in this constantly changing world, is the main goal of the contemporary education. The education must shift its focus from transmitting isolated knowledge and skills to acquiring complex competences, guiding learners in developing skills for learning and getting information from the diverse range of sources available in modern society [1]. In this way, education is increasingly becoming learner-centred and competence-based. Rapid developments in technology and ease of technology access, have determined the direction in which the educational process will change. International Society for Technology in Education (ISTE) emphasized the need of possessing digital competencies and skills by the students. ISTE underlines the importance of regular use of certain digital tools in teaching practices which will lead to empowerment of students' 21st century knowledge and skills [2].

In order to equip students with these competencies and skills, some educational reforms must be made concerning integration of ICT usage and coding in the curriculum, including ideas and tools for computer science, computing and computational thinking according to the age level. The rationale for integrating coding in school curricula is twofold: to equip all students with skills that are increasingly

perceived as important in today's digital society, such as problem solving and logical thinking skills, and, but to a slightly lesser extent, to respond to the lack of IT-skilled labour force in Europe [3].

There are many different pedagogical approaches for the delivery and practice of computer science education deployed in different countries: unplugged activities [4], block-based programming [5], use of coding in different subjects [6] etc. The selection of the approach depends on many factors, such are: the students' age, available resources in the school, teachers digital competences etc. Generally, computer science and computational thinking can be taught through technology-free activities, namely procedures such are: computer science unplugged, initial tools for learning coding concepts, robotic coding, and cross-curricular activities [7]. However, there is still no evidence which approach is better than the other [8].

Today's students are "digital natives", spending the majority of their time playing games on their computers, mobile phones or tablets on daily bases. Many studies demonstrated that using students' interest in playing games in educational context can be highly beneficial [9]. Digital games have become powerful contexts for learning by providing people with the opportunity to join new worlds by thinking, talking and acting, taking roles otherwise inaccessible to them [10]. The findings of a review study on empirical evidence for the potential positive impacts of gaming reveal that playing computer games is linked to a range of perceptual, cognitive, behavioural, affective and motivational impacts and outcomes [11]. Digital games offer students opportunities to reach goals that are not focused just on learning facts, but enable development of skills such as problem solving, decision making and strategic planning at the same time [12].

In the new game-based learning community, learners take a central position, are peer linked (work together, cooperate, network) and have mutual frequent interactions with teachers, who also work in teams, not in isolation. On the whole, educational digital games constitute an innovative learning process where teachers act as facilitators [13]. Game-based environments in which students can learn the basics of coding while playing games and having fun, is very popular in the last few years. These environments present a good opportunity for students to realise positive thoughts about coding, to learn coding while having fun, to gain experience in creating algorithms and directives, and to learn computer concepts at an early age [8].

Game based learning combined with flipped classroom and collaborative team work can utilize students' energy and enthusiasm in playing games in achieving educational goals. Flipped classroom approach can be used in encouraging the students to be active and make use of their own experiences. The game based learning is different from the traditional classrooms in terms of its objectives, which include creating a competitive environment where students are entertained, and their interests and motivation levels are elevated [9]. Flipped classroom can be defined as a class that utilizes practices and problem solving led primarily by the students [14]. Students are put in various more entertaining and creative situations, where searching for the solution of the problems they experienced during learning is the way of learning and achieving learning outcomes. This flipped classroom is a form of student-centered learning. It reduces the achievement gap among students and personalize the learning in the classroom [15]. At the same time, learning process is less depended on the teacher; teachers' role is just to facilitate the learning and lead the students in collaboration and sharing knowledge and skills.

This paper presents a methodological approach for using interactive mobile game for developing computational thinking in the classroom. The cooperative game-based learning and flipped classroom are used for introducing basic concepts of coding and problem-solving among primary school students Results about students' overall experience and achievement of learning outcomes give an insight into the possibility to use this kind of approach for developing computational thinking skills.

In the next section, the proposed methodology is elaborated in more details. The third section presents both results and discussion of the results. The last, fourth section, draws the conclusions.

2 METHODOLOGY

2.1 Description of used tool

Scottie Go! is an interactive puzzle-based mobile game for teaching coding to the young children in an interactive way. It uses similar block-based coding approach as Scratch coding environment, which is widely used in coding classes. The basic idea of this mobile game is to help a friendly alien Scottie to

get back home to the outer space. The game offers many levels, and offers opportunity to create dozens of codes.

The game is a combination of cardboard tiles (Fig. 1a), which are used by the players to create coding instructions, and a mobile application (Fig 1b) that sets tasks and scans the proposed code solutions that enable Scottie and other characters to move. The tiles are used to write instructions which will be performed by Scottie in order to complete the task. The mobile application can be downloaded on smart phones, tablets or any other computer device. After the installation on a device, the game does not require internet connection, and it can be played anytime and anywhere, even in a place where there is no IT infrastructure, e.g. school common rooms, corridors or even outside the building.

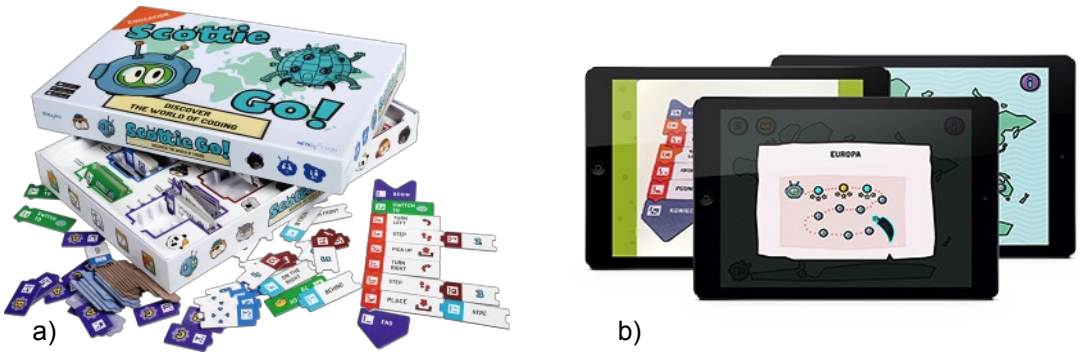

Figure 1. Scottie Go! a) box with tiles b) mobile application.

The game starts when the application assigns a task to the player. The player must analyze the task and plan the sequence of instruction that will lead Scottie Go! to the right spot, avoiding obstacles, picking up objects, etc. The coding is very similar to making the puzzle. The player "write" the code by arranging tiles in the right order on the game board. The code controls the main character's movements. With the use of the app, player scan the written code by capturing a photo or video. Once the program is scanned, Scottie will perform, on the device screen, the instructions placed on the game board, and give possibility to the player to see whether the task has been performed correctly. The application gives feedback to the player: if the command is correct, Scottie will carry out the task and go to the next level; otherwise players will be asked to rewrite the program. If the program is too long, or not efficient, players will be encouraged to optimize it (i.e. to shorten it). This is done by a gamification technique that assign stars to the created code (from one to three stars) once the code is scanned.

A unique coding interface, in the form of cardboard tiles, makes the game child-friendly and, allows children to collaborate by creating code in teams. Furthermore, children do not need to know the basics of coding to play the game. Scottie Go! gameplay improves the ability to think analytically and logically, develops algorithmic intuition, and teaches how to solve complex problems [16]. The game involves all basic concepts of coding, ranging from basic instructions, loops, conditionals to variables and functions. It can be used as a basic tool to introduce and teaching coding, or as a supplement of other tools that are used to teach coding.

2.2 Method

120 students from six different primary schools from Macedonia have used Scottie Go! as a code learning tool for two months. The main aim of the course during this period was to develop students' knowledge and skills for creating code with linear structure.

At the beginning of the course, students were introduced with the game. They have downloaded application on their mobile devices and the learning started. Students were working in groups (Fig. 2). Students had a central role in the classroom, due to their familiarity with the mobile and board games before. Their previous knowledge and skills in playing games were used in order to established a good base for further development on the subject, by learning from each other. The primary role of the teacher was just to facilitate the process, and to share the solutions of the problems noted by students. In addition, a teacher observed the learning process and lead discussions with the students.

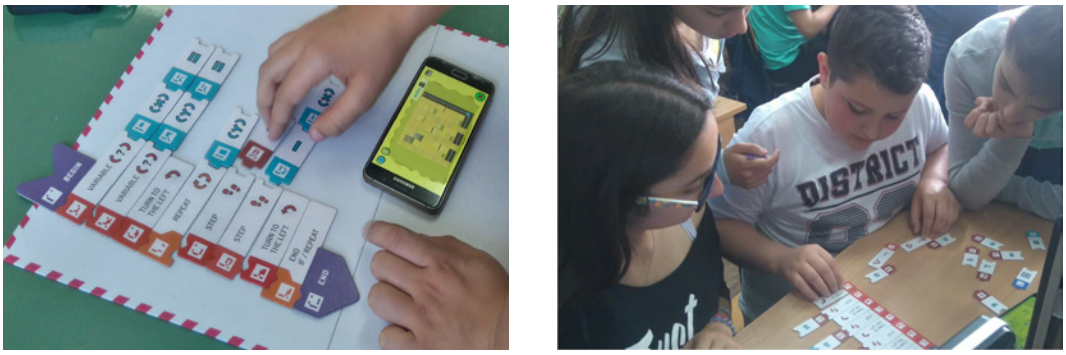

Figure 2. Learning how to code using Scottie Go!.

The game offers different levels of complexity which corresponds to different levels of students' knowledge and skills that should be acquired. Assessment of acquired knowledge and skills in the classroom was performed according to the defined criteria based on the Blooms' taxonomy [17]. According to the first level of this taxonomy - knowledge, students should only remember and recall information that they have learned (e.g. they should know that each program starts with instruction “Begin” and ends with instruction “End”). On the second level of understanding, students should be able to explain why concrete activity is performed (e.g. explain what will the following program perform). When applying knowledge, they should create their own sequences of codes (e.g. create a concrete program that is a solution of the given situation). Higher order thinking skills (analysis, synthesis and evaluation) are presented when students analyse given task, search for correct instructions, produce their own programs according to the new situations, test, are able to find and correct mistakes and reach desired solutions (e.g. analyze the given programs and decide which of them is a solution of the given situation). In accordance to this, the game starts with creating a very simple linear structure of code and each level is more complex than previous.

After coding with for two months, a survey regarding students' overall experience in using the game for development of computational skills was carried out. Information concerning students’ interest in the game, ease of use, students' quality of experience and correspondence to educational goals were obtained.

The first part of the survey was used for gathering demographic information about the participants (gender and type of school) and their experience in playing games. The second part was designed to measure students' attitudes toward using games as a tool for learning to code. Their attitudes were measured using a five-point Likert scale, with answer choices ranging from “strongly disagree” (1) to “strongly agree” (5). Attitudes toward: tool's ease to use, students' interest in the game, correspondence to educational goals, and students’ subjective attitudes for using the corresponding tool in the educational process, were investigated.

In addition to the survey, and in order to assess the possibility to use game as a tool for achieving learning outcomes concerning computational thinking, a short test was carried out with students. The test consisted of 10 multiple choice questions concerning linear structure in coding. According to the expected learning outcomes students should: know the elements of a program; create short and simple programs with linear structure; through logical thinking determine the result of created program; detect and correct errors. The test covered different levels of achieved educational goals (according to Bloom's taxonomy). The idea was to see did the students achieved the learning outcomes using the game and to measure the level of retention of students' learning with this playful approach.

3 RESULTS AND DISCUSSION

During the two months, students progress with their own pace, learning from each other, helping each other and without knowing it, taking control over their learning. Collaborative learning environment was established very naturally because in order for students to successfully play the game, they had to communicate, collaborate, and help each other. This collaborative game based approach helped in involving less interested (talented) students in achieving learning outcomes in a very natural way. Students from vulnerable categories (with less learning, social or economic abilities) were involved in the learning process, too. By playing the game students had both fun and possibility to learn from the other in the flipped classroom manner.

The survey was conducted among students in urban and rural school (with different technological equipment). There was a good distribution among participating students concerning their gender (52,07% of students were male and 47,93% were female).

More than 70% of the students play games on regular bases and even 69,17% of them do that on mobile phones or tablet. This was expected since today's students spend a lot of time on their mobile phones. This contributed to students' positive attitude towards using games in the learning process.

The results concerning students' attitudes towards: ease to use of Scottie Go!, students' interest in the game, subjective attitude toward the game, and its use in educational context are presented in Table 1.

Table 1. Students' attitudes toward using Scottie Go! as a tool for learning to code.

Item concerning students' attitudes/ N=121	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Mean
Interface of the game is easy to use	103	18	/	/	/	4,85
It was easy to learn how to play the game	109	11	1	/	/	4,89
I have fun while playing Scottie Go!	104	16	1	/	/	4,85
The game attracts my attention	102	18	1	/	/	4,83
I can play together with my friends	111	8	2	/	/	4,90
It is interesting to learn with Scottie Go!	107	14	/	/	/	4,88
It is exciting to learn on this way	99	21	1	/	/	4,81
I like this way of learning	103	14	4	/	/	4,82
I like the overall experience	100	20	1	/	/	4,82

Results showed that students think that Scottie Go! is easy for installing and has easy interface with clear instructions and requirements. This is confirmed with finding that the gameplay is easy to learn. Since the beginning of the course and the first introduction of Scottie Go!, students were excited and delighted that they are going to use mobile phones in the learning process. They like the interactivity of the game, the possibility to work in teams and to collaborate with other students.

All these lead to increased motivation and interest from the students. Almost all students (99% of them), agree of strongly agree with the facts that the game attracted their attention and that they had fun while playing the game. Students have positive attitudes regarding using Scottie Go! for learning to code. They find this way of learning very exciting for the achieving learning outcomes. The overall quality of students' experience is very high and they find learning with Scottie Go! very interesting, motivational and excited.

It is interesting that students have very high level of accordance with the statements of the survey. The fact that they can play the game together with their friends is the most appreciated characteristic of this game based approach. More than 90% of the students strongly agree with this statement. If we want to highlight the characteristic that they like at least it will be the one that it is exciting to learn by game. But there is no need for the further analysis in this direction since the results are satisfactory. Namely, only one of the students does not have his opinion about this and 17,35% agree and 81,82% of the students strongly agree with their satisfaction from game based learning.

Concerning other aspect of game integration - educational value and the possibility to achieve learning outcomes, results are presented in Table 2.

Table 2. Students' achievement of educational goals.

Educational goal complexity	Percentage of correct answers
Knowledge	100,00%
Understanding	95,83%
Applying	96,83%
Higher order thinking skills	90,28%

The results show that all students have correct answers of the questions concerning knowing facts. More than 95% of students don't have problem answering questions that need understanding of the concepts or applying of the knowledge and skills in new situation. Results from evaluation of higher order thinking skills, show that 90,28% of students using Scottie Go! have correct answers. Result are satisfactory and show that students achieve learning outcomes easily, even when the more complex situations are in front of them.

It is interesting that students have better results concerning applying the knowledge in new situation than in understanding of some coding concepts. According to the Bloom's taxonomy understanding is easier than applying the knowledge, but in our case students have better results in this higher level of cognitive knowledge. So. the question that should be discussed is whether cognitive dimension of Bloom's taxonomy is the most suitable method for assessing students' learning in computational thinking course. Experts in this area find it difficult to agree on an interpretation of the Bloom's taxonomy for computational thinking tasks [18]. For example, according to this taxonomy, creating is considered to be much more complex than understanding, but can we really say that creating a simple project – whose goal is to move a sprite from one point to another – is cognitively more complex than fully understanding the concept of concurrency? [19] One possible explanation of our results is the level of complexity of the given tasks. For getting more reliable results further research should be done.

4 CONCLUSION

The study presented in this paper shows that game based learning with the elements of flipped classroom can be used for establishing a student centered learning environment. Such learning environment is open and entertaining, students are playing games, and their interests and motivation levels for achieving educational goals are increased. The learning can take place without space and time limitation. Students take responsibility for their own learning and progress with own pace. Collaboration and learning from each other is another benefit from this game based approach. All students take active participation in the learning process, regardless their background and previous knowledge and experience.

By using this game based approach students can develop different digital competences and master basic coding concept on natural and interesting way. Students develop computational thinking skills during the play, demonstrating decomposition of the problem, logical thinking, abstraction, finding pattern, creating algorithm and evaluation of the created program. The results from the test confirmed that students were learning during the play, achieving learning outcomes and getting long-lasting knowledge.

The results from the survey and test indicate that Scottie Go! can be use as a game based learning tool for computational thinking course. This approach is a good opportunity for increasing positive attitudes about coding, and learning abstract coding concepts at an early age.

The findings presented in this paper can be used as a base for further research concerning game based learning approaches in developing students' computational thinking skills in primary schools. Using of different taxonomies as assessment method of students' learning should be further investigated taking into account specific character of computer science education.

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REFERENCES

[1] L.K.J. Bartman, T.J. Bastiaens, P.A. Kirschner, and C.P.M. Van der Vleuten, "Evaluation assessment quality in competence-based education: A qualitative comparison of two frameworks," *Educational Research Review*, vol. 2, pp. 114-129, 2007.

[2] ISTE. *International Society for Technology in Education- ISTE Standards for Students*. 2016. Retrieved from https://www.iste.org/my-profile/standards-download.

[3] European Schoolnet. *Computing our future - Computer programming and coding. Priorities, school curricula and initiatives across Europe*. 2015. Retrieved from http://fcl.eun.org/documents/10180/14689/Computing+our+future_final.pdf/746e36b1-e1a6-4bf1-8105-ea27c0d2bbe0.

[4] A.M. Paul, "Teaching computer science-without touching a computer," *Education Digest*, vol. 80, no. 5, pp. 23–26, 2015.

[5] T.S. Barcelos, and I.F. Silveira, "Teaching computational thinking in initial series," in *Proceedings of the Informatica (CLEI), 2012 XXXVIII Conferencia Latinoamericana En, Medellнn, Colombia,* pp. 1-8, IEEE, 2012.

[6] M. Videnovik, E. Zdravevski, P. Lameski, and V. Trajkovik, "The BBC Micro: bit in the International Classroom: Learning Experiences and First Impressions," in *17th International Conference on Information Technology Based Higher Education and Training (ITHET)*, pp. 1-5, IEEE, 2018.

[7] F. Kalelioğlu, Y. Gülbahar, and D. Doğan, "Teaching How to Think Like a Programmer: Emerging Insights," in *Teaching Computational Thinking in Primary Education* (H. Özçınar, G. Wong & H.T. Öztürk, eds.), pp. 18-35, Hershey, PA: Information Science Reference, 2017.

[8] E. Shein, "Should everybody learn to code?," *Communications of the ACM*, vol. 57, no. 2, pp. 16–18. 2014.

[9] H. Özer, S. Kanbul, and F. Ozdamli, "Effects of the gamification supported flipped classroom model on the attitudes and opinions regarding game-coding education," *International Journal of Emerging Technologies in Learning (IJET)*, vol. 13, no. 1, pp. 109-123, 2018.

[10] D.W. Shaffer, K.D. Squire, R. Halverson, and J.P. Gee, "Video games and the future of learning," *Phi Delta Kappan*, vol. 87, n. 2, pp. 104–111, 2005.

[11] T. Connolly, E. Boyle, J. Boyle, E. Macarthur, and T. Hainey, "A systematic literature review of empirical evidence on computer games and serious games," *Computers & Education*, vol. 59, no. 2, pp. 661-686, 2012.

[12] J. Lymbery, "The Potential of a Game-Based Learning Approach to Improve Learner Outcomes," *Computers in New Zealand Schools*, vol. 24, no. 1, pp. 21-39, 2012.

[13] S. Arnab, R. Berta, J. Earp, S. de Freitas, M. Popescu, M. Romero, I. Stanescu, and M. Usart, "Framing the Adoption of Serious Games in Formal Education," *Electronic Journal of e-Learning*, vol. 10, no. 2, pp. 159–171, 2012.

[14] J. Bishop and M. Verleger, “The flipped classroom: a survey of the research,” *120th ASEE Conference & Exposition*, 2013.

[15] M.K. Lee, “Flipped classroom as an alternative future class model?: implications of South Korea’s social experiment,” *Educational Technology Research and Development*, vol. 66, no. 3, pp. 837-57, 2018.

[16] Becreo technologies, Scottie Go!. [Online]. Available: https://scottiego.com/en/. [Accessed: June 3, 2018].

[17] B.S. Bloom, M.D. Engelhart, E.J. Furst, W.H. Hill, and D.R. Krathwohl, "Taxonomy of educational objectives Handbook 1: cognitive domain," London: Longman Group Ltd, 1956.

[18] C.J. Johnson, and U. Fuller, "Is Bloom's taxonomy appropriate for computer Science?," in *Proceedings of the 6th Baltic Sea Conference on Computing Education Research: Koli Calling 2006*. ACM, New York, NY, pp. 120-123, 2006.

[19] O. Meerbaum-Salant, M. Armoni, and M. Ben-Ari, "Learning computer science concepts with Scratch," *Computer Science Education*, vol. 23, no. 3, pp. 239-264, 2013.