Creating and using digital games for learning in elementary and secondary education

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***Abstract*—The use of digital games in education has gained considerable popularity in the last years due to the fact that these games are considered to be excellent tools for teaching and learning and offer to students an engaging and interesting way of participating and learning. In this study, the design and implementation of educational activities that include game creation and use in elementary and secondary education is presented. The proposed educational activities' content covers the parts of the curricula of all the Informatics courses, for each education level separately, that include the learning of programming principles. The educational activities were implemented and evaluated by teachers through a discussion session. The findings indicate that the teachers think that learning through creating and using games is more interesting and that they also like the idea of using various programming environments to create games in order to teach basic programming principles to students.**

Keywords—Education, Elementary, Secondary, Games in Education

I. INTRODUCTION

Nowadays the use of digital games is an important part of most children's leisure and it is increasingly becoming an important part of our culture as well [1]. It has been documented that modern students are not fully keen on and attracted by conventional educational methods but they are seeking more interesting, fun, motivating and engaging learning experiences [2]. Additionally, teaching inside and outside the classroom has evolved over the years, mainly due to the rapid technological advances, affecting and expanding the way teachers deliver their lessons.

In the context of game-based learning (GBL), educational games, digital or not, that are used in teaching and learning help students develop motivation, problem-solving skills, strategy development skills and creativity [4]. In addition to that, serious games, which are digital games designed for purposes other than pure entertainment and include educational games amongst other types of games [5], may offer motivating and engaging experiences, interactive learning environments and collaborative learning activities [2] and promote the development of skills and abilities through immersive experiences [3]. Hence, serious games can be used as educational tools, covering the requirements of many lessons. Furthermore, in order to practice GBL for various courses' curricula, the educators need software platforms for the automatized construction and flexible customization of digital games [6], and also a coherent and pedagogically informed educational design in order for learning with games to be deployed effectively within formal or informal learning contexts [7].

The interest in research around games in education has been significant; many researchers have explored the potential of using digital games for teaching purposes. In many cases, the researchers created games or used games as a learning tool for students with positive results on the students' engagement, motivation and learning of various subjects [8][9][10][11]. However, the integration of games in teaching is still somewhat an unexplored area [12]. The inclusion of games in educational contexts still generates a lot of controversy between teachers and society because many people and teachers still see games only as a playful activity [3] and, thus, they do not adopt game activities in their lessons.

In Greece, even the small number of the previously mentioned research and practices in education cannot be directly implemented due to the differences in the course curricula and content. Secondly, eventhough learning basic programming principles through game creation activities, using various educational environments like Kodu and Scratch, is suggested in the curriculum of several courses in the Greek schools, there is no textbook that offers practical activities in the form of proposed exercises for the students. Because of this, the teachers must create their own material or search for appropriate material in various repositories and adjust it properly in order to teach courses such as the Informatics course of the second year of the General Lyceum. Additionally, the plethora of the suggested tools and programming environments makes the teachers' work even more difficult because not all of the proposed software can be installed in the school laboratories due to technical issues. Thus, the teachers spend a considerable amount of time to find the right tool and then create or search for appropriate material compatible with this tool in order to teach their lessons.

Taking all the above under consideration, we started to work in order to produce material that covers the needs of practice for all the Informatics courses in all the levels of education separately and that fully complies with the content of each of those courses, focusing on learning basic programming principles. Hence, the purpose of this study is to promote a way of teaching and learning programming principles through game use, design and creation in elementary and secondary education. While designing and structuring the activities, we followed a constructivist approach by organizing the worksheets to follow a step-by-step progressive difficulty in the proposed activities and by providing step-by-step instructions for their implementation.

The contributions of this study to the learning approach through our suggested educational worksheets in the teaching process are the following:

- We approach the Informatics curriculum in each level of education focusing on making and using

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games rather than using traditional teaching methods.

- We offer students the opportunity to create their own games, hoping to inspire positive attitudes towards programming in the future.
- We cover the Informatics courses' needs, by providing structured supporting material for each level of education separately.
- We suggest programming environments and educational games that can be used in older technology laboratories as well.

More specifically, in our study we produced educational worksheets for the elementary and secondary education courses of Informatics that are taught in elementary schools, Gymnasiums, General and Vocational Lyceums in Greece. The educational worksheets include several activities that focus on designing and creating games through a constructivistic approach. The educational worksheets also include and use educational games in order to support the teaching and learning process. Most of the games include the teaching and learning of programming but we also suggest games platforms that can be used to teach and experiment with other content as well.

An important step in our development process was a discussion session that we organized with teachers of elementary and secondary education that helped us in gathering opinions and suggestions for the improvement of our original work. The results helped us reconsider and optimize our original approach where ever needed. Moreover, we found out that that the teachers have a positive attitude towards learning though using or creating games and they like the suggested in the educational worksheets activities.

The remainder of this paper is organized as follows. In Section II, we present our approach in the use of digital games in education for each level separately. In Section III, we present the methodology we followed in our research in order to gather the teachers' opinions while in Section IV we present the results of this research, focusing on the teachers' opinions about the educational worksheets content per level of education. Finally, Section V includes the discussion part of the produced results, while Section VI outlines the conclusions and suggests future steps for this research.

II. The Digital Games in Learning Approach

Given that even though learning through digital games is suggested in all the levels of the Greek educational system, as we describe in detail in the next sections, there does not exist any properly organized material that can be used during the courses and each teacher must search and create his/her own, we decided to create material for teaching each Informatics course in each level of education separately through game creation and occasionally through gaming. We believe that this approach provides an easy and effective teaching. By researching the use of games in education and through our experience as educators we created worksheets that include activities for creating, or in some cases just using, games specifically for the Informatics courses, in order to support the teaching and learning process.

A. Elementary Education

In the elementary school curriculum in Greece, Information and Communication Technology (ICT) is a lesson where students between the ages of 9 and 11 years are called to learn basic programming principles. The teaching directions of the Greek Ministry of Education (Ministerial Decision Φ.20/130336/Δ1/22-08-2019) suggest the programming of interactive games and stories in order for students to learn how to design, develop, use and test a set of commands and programming structures. For this purpose, the official guidelines also suggest the use of various programming environments like Scratch, Kodu, Microworlds Pro and Easy Logo.

In our work we decided to use the Kodu Game Lab [13]. Kodu Game Lab is a tool that can be used in the educational process in order to give the ability to students to be introduced in 3D object designing and also to the basic principles of programming through the production of 3D worlds, in a very simple and comprehensive way. In other words, programming is being taught without a deluge of programming concepts but through a visualized environment. This simple approach turns out to be the most effective for students in early ages.

Taking the above under consideration we created eight worksheets that include activities which exploit the use of simple commands, in the form of blocks, and also a few basic programming structures, like for example the conditionals. The activities include the creation of a 3D world that depicts a running track in an island, with a motorcycle in it (Fig. 1). The object "motorcycle" is led by the user through the keyboard in order to gather other objects and win awards.

Fig. 1. 3D Running Track.

Before starting with the running track activities, we also planned a two-hour preparatory lesson for the use of Kodu where some easy activities that did not require the knowledge of the programming environment were included. After that, for two hours the students worked in designing the 3D running track world following the worksheet instructions. The third hour included a worksheet where the students programmed the moves and the behavior of an object, i.e. of the motorcycle, using the simple conditionals structure. The fourth hour included the programming of several objects where the students discovered the way objects can interact with each other following certain rules (Fig. 2).

Fig. 2. Code sample for objects programming.

The fifth hour included the addition of more objects were the students could use their own imagination in order to expand the game's functions. The sixth hour included the use of advanced Kodu functions, like the path, where the students had to use the right commands to make the objects follow the path when needed in order to increase the score. In this case, they learned also the nested conditional and how to use it in a program.

Another advanced feature in Kodu is ability to program in different pages. This feature works similarly to the use of sub-programs, where the main program can call a function or a procedure to execute a block of commands when necessary. In the seventh class hour, the students created various pages of code using nested conditionals, and they were introduced to procedural programming.

Fig. 3. The complete running track game.

Finally, on the eighth class hour the students made adjustments in the settings of the 3D world and of the objects. For example, they adjusted the lights or the wind and the properties for each object producing the complete game (Fig. 3).

B. Secondary Education-Gymnasiums

In secondary education and specifically in Gymnasiums Informatics is a lesson where students at the age of 12 to 14 years are also called to learn basic programming principles. On the first and second grade the suggested didactic hours are limited, but on the third grade most of the didactic hours during the school year are dedicated to programming. The teaching directions of the Greek Ministry of Education (Ministerial Decision 143912/Δ2/17-09-2019) suggest the creation or use of simple games in order for students to learn basic programming structures. For this purpose, the guidelines also suggest the use of programming environments like Scratch, Microworlds Pro, Snap!, K-turtle, MSW Logo, Starlogo TNG, AppInventor, Alice and Blockly.

We decided to use the Scratch environment. Scratch is an educational software developed by the Lifelong Kindergarten Group at MIT Media Lab in collaboration with Yasmin Kafai's Group at UCLA. Scratch can be used to program interactive stories, games, and animations and to share all the creations with others in the online community [14]. The users are not obliged to know any programming language because they use commands in the form of blocks that can be attached to each other. With these commands 2D objects can be controlled and be given certain behaviors. Through this action, the students get accustomed to basic programming commands like conditionals, loops, and sub-programs.

We created two worksheets that include activities which exploit the use of the above-mentioned commands, in the form of blocks. The activities include the creation of a well-known game, the PacMan, and they are separated in four didactic hours.

The first hour includes the creation of the game's first level (Fig. 4), which has the labyrinth and the objects needed to start the game, like the PacMan, and the ghosts.

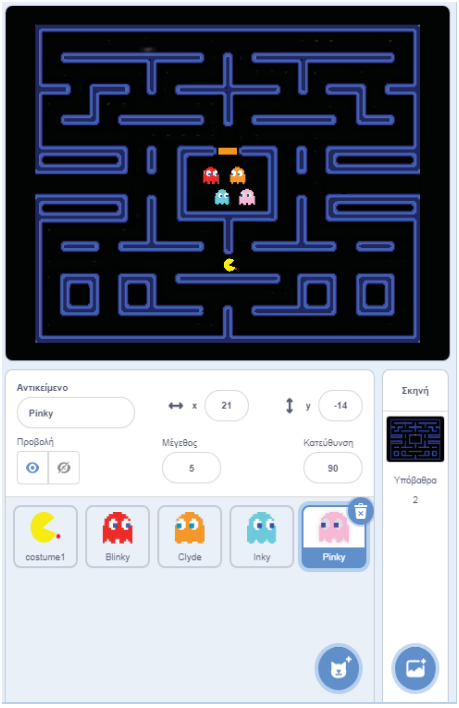

Fig. 4. First level and initial objects of the PacMan game in Scratch 3.0.

The second and third hour worksheets include the programming of the objects' behavior. For example, how the PacMan will move and eat dots in order to gain points and how many life points it will have.

The fourth hour assignment includes the programming of the ghosts in order to move towards the PacMan so as to reach it and make it lose life points and to move at random when the big dots are eaten by the PacMan (Fig. 5).

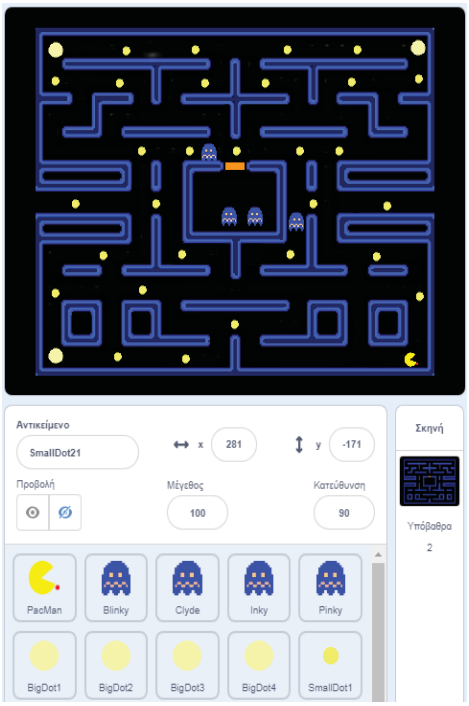

Fig. 5. The PacMan game.

After completing the worksheets, the students have been taught conditionals, loops, variables and sub-programming principles.

C. *Secondary Education - General Lyceums*

In secondary education and, specifically, in General Lyceums, Informatics is a lesson where students at the age of 15 to 17 years are also called to learn basic and some more advanced programming principles but in this case also the use of programming languages, instead of simple block commands, is included. In the first and second grades, Informatics is being taught for two hours and one hour per week, respectively. The teaching directions of the Greek Ministry of Education (Ministerial Decision 143633/Δ2/17-09-2019) suggest the creation or use of simple games in order for students to learn basic programming structures only in the first grade, while in the second grade structured programming activities in the form of mathematical, economic or everyday problems are included. For the first grade, on which we focus, the suggested programming environments are AppInventor, Alice, Snap!, Blockly and Greenfoot.

In our work we use the AppInventor environment [15]. AppInventor is an intuitive visual programming environment that allows everyone, even children, to build fully functional applications (apps) for smartphones and tablets. It also exploits the benefits of programming using blocks instead of commands, which makes it easier to use and comprehend. The AppInventor software supports the use of personal mobile devices in order to test the produced applications, and it also supports an emulator which provides a virtual smartphone with the ability to execute the produced application in real time. This feature is very useful when connectivity or legislation issues about the use of smartphones within the classroom settings arise [16].

We created three worksheets that include activities which exploit the use of conditionals, loops, global and local variables, lists, and sub-programs in the form of blocks and also the ability of changing screens. The activities include the creation of three different games, a hidden cards game, a ping pong game and a guess the number game. Each worksheet's activities are planned to cover two didactic hours.

The first two hours include the creation of the hidden cards game app. In this app the students must initially create the appropriate interface and then use variables, lists, conditionals and the loop commands (Fig. 6) in order to adjust the game's functionality.

Fig. 6. Sample of the commands needed for the hidden cards game.

The next two hours include the ping pong game, where the students had to create the appropriate interface and program the objects so as to simulate the function of the well- known ping pong game. In this game, the user can move a bar in order to change the course of a ball to gain points. In this worksheet, the use of sub-programming commands and of setting local or global variables is also needed (Fig. 7).

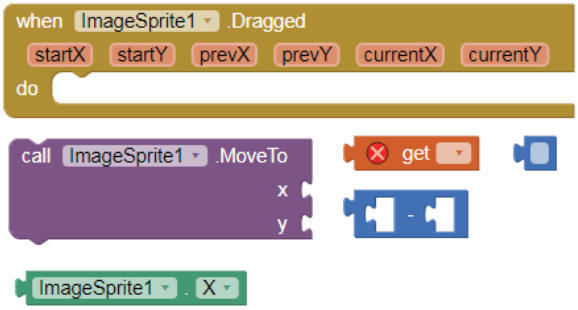

Fig. 7. Sample of the commands needed for the ping pong game.

The final two hours included the worksheet of the guess the number game. In this game two players are featured. Each of them must guess the hidden selected number. In this case different screens and multiplayer features are supported, so the student needs to take advantage of all the programming structures and commands that he/she was taught in the previous lessons.

D. *Secondary Education - Vocational Lyceums*

For the lesson of Informatics in Vocational Lyceums, the Greek Ministry of Education has issued a different set of instructions (Ministerial Decision Φ3/134083/Δ4/30-08-2019). For the first grade again programming environments such as AppInventor, Alice, Snap!, Blockly and Greenfoot are suggested in order for the students to learn programming, using also programming languages, like Java for example. The course in this grade can be approached through the design and creation of a simple game, according to the

guidelines. Again, in the second grade structured programming activities in the form of mathematical, economic or everyday problems are included but in the informatics specialty specifically, the course Special Programming Topics in the third grade includes the use of Greenfoot for the learning of more advanced programming principles through game creation (Ministerial Decision Φ3/134019/Δ4/13-08-2019).

In our work, we decided to focus on the first grade lesson and use Greenfoot [17], while our suggested material can be used in the third grade as well. Greenfoot is an Integrated Development Environment (IDE) using the object-oriented Java programming language designed for educational purposes and it is addressed to students from the last three grades of secondary education in order to motivate them to pursue further work up to the University [18] [19].

This work involves the design and creation of an object search game, under the title House of Mystery Exercise, H.O.M.E., using Greenfoot, as well as the design and creation of educational scenarios which also include practical and theoretical examples for learning Greenfoot through the creation of the aforementioned game. Each worksheet includes activities that cover three didactic hours where the students are called to create the H.O.M.E. game (Fig. 8) aiming at learning the use of both Greenfoot and the object-oriented Java programming language [20]. The total number of the worksheets for creating the game is three.

Fig. 8. Model of the house in the H.O.M.E.game.

In the first worksheet the students must create the world and place the objects in order to construct the house's rooms (Fig. 9).

Fig. 9. The H.O.M.E. game's living room.

Then, they must use the appropriate commands in order to make the navigation between the rooms possible. In the second worksheet, the students must program the objects' movement and the way the user can control it and also various limitations in navigation as well as additional game functions. In the third worksheet, the students are asked to include the creation of messages to make the game experience more interactive and, finally, to create the game's documentation.

E. Educational Games and Platforms

Additionally to the material that we created to support the course of Informatics in elementary and secondary education, we also used and suggested existing educational games and platforms. More specifically, for learning basic programming principles in elementary schools and Gymnasiums we included the LightBot game [21]. LightBot is a game in which the students are required to program the movements of a robot, giving the appropriate commands to reach the end of a path (Fig. 10).

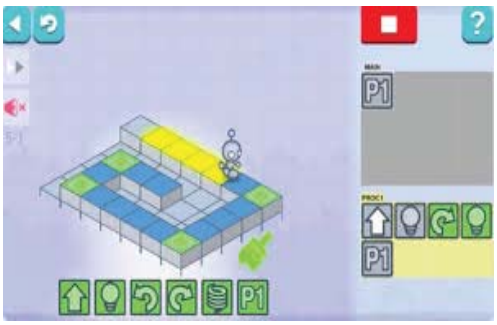

Fig. 10. The LightBot Game.

Furthermore, a platform that can support the creation and use of games is Kahoot! [22], which is a game-based student response system that can be used by schools. Using Kahoot! a user can create, play and share games in the form of quizzes (Fig. 11) and also assign games as homework. Kahoot! is a flexible and simple tool that works on any device, supporting several ways of accessing and without any cost. It can also be engaging because it fosters social learning in various ways [23].

Fig. 11. Kahoot!'s Quiz Game (in Greek).

Lastly, we need to mention that we also presented and analyzed some educational games that can be used for teaching and learning and focus on informatics principles in general rather than only programming, like for example WildWebWoods [24] which is an educational game that focuses on the right use of the internet and the threats that one might encounter while navigating in the web.

III. THE RESEARCH APPROACH

Our research took place in June 2019 at the University of West Macedonia, with the participation of thirteen teachers. The participants attended the course Digital Games in Education, of the postgraduate program studies of "Advanced technologies of Informatics and Services – Technologies of Informatics and Communications in Education" that is organized by the University of West Macedonia and the University of Piraeus in Kastoria, Greece. In the context of this course the entire material included in the previous sections was presented to the teachers. The teachers implemented selected worksheets activities and in the end they gave their opinion about the entire work through a discussion session. This qualitative research method is useful and necessary for understanding the meaning and context of the material studied [30], and in this case helps in gathering the opinions of professionals that can considerably help in improving the educational material before its implementation in the teaching process.

A. Methodology and Evaluation

The purpose of this research was to gather the teachers' views, opinions and suggestions over the proposed material for each level of education. The participants were teachers from the specialty of Informatics that currently taught in Gymnasiums and Vocational Lyceums and one of them was a teacher of an Elementary school, but had previous experience in other types of schools as well.

Initially, we distributed to the teachers the entire material which is available in Greek at the link:

https://digitalgameseducation.wordpress.com/.

The teachers had the opportunity to study the material also on their own time. During the nine-hour course of Digital games in education we implemented the activities per level of education as follows:

- a 2-hour lesson for elementary education.
- a 2-hour lesson for secondary education Gymnasiums.
- a 2-hour lesson for secondary education General Lyceums.
- a 2-hour lesson for secondary education Vocational Lyceums.
- a 1-hour discussion session.

The teachers performed tasks that included the use of the suggested worksheets for each type of school. To get further insights, we also asked the participating teachers to share their opinions through a discussion session. This session was performed after the educational activities implementation and lasted a full didactic hour, as it was mentioned above.

In the beginning, a conversation was held regarding the game concepts for each level of education, next about the activities content and lastly about the concept of learning through creating a game. After that, more attention was paid to the quality of the content, the difficulty in executing the activities and the interest and emotion that was derived in the implementation process. The responses were noted in order to be used for reaching conclusions, as we will see in the next section.

IV. RESULTS

A. Discussion Session Results

The number of teachers who participated in the discussion session was thirteen, from which five were women and eight were men. Most of the teachers had a work experience in education between 11 and 20 years and the majority of them was over 40 years old, as it is demonstrated in F'igure 12.

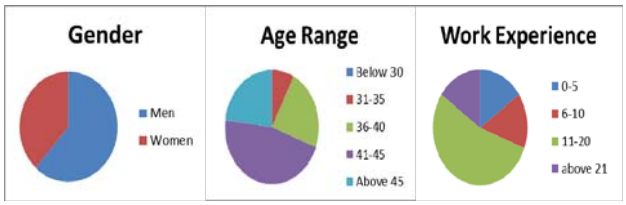

Fig. 12. Demographic statistics.

The discussion session was held in the last didactic hour. First, the teacher outlined the basic activities' actions in order to warm up the conversation and then posed five questions:

- What is your opinion about the content of the worksheets' activities for each level of education?
- Do you think that the worksheets' activities are appropriate for the level of education that they are suggested?
- Do you think that the students need to place considerable effort in completing the suggested activities?
- Do you think that the suggested activities will raise the students' level of excitement and interest?
- Do you think that learning through creating and/or using games helps in better a understanding of various concepts of Informatics?

Some of the answers received are presented in Table I.

TABLE I. SAMPLE OF RECEIVED ANSWERS FROM THE DISCUSSION WITH TEACHERS' SESSION.

Questions	Answers
First Question	- There is a good balance between what is needed to be taught and the content that the activities include. - The suggested activities are interesting. - I think that the concept included in the worksheets for each level of education is relevant to what needs to be taught..
Second Question	- I think that the concept of the worksheets activities for each level of education seperately, is appropriate for the students. - The elementary worksheets activities could be better structured including more

Questions	Answers
	images in some cases.
Third Question	- No, the activities are simple and comprehensible. - No, because the activities clearly describe the steps that needs to be followed for their completion.
Fourth Question	- In some cases yes. - I thik the activities for the elementary school which include the creation of a 3D world would spark the students interest. - The use of the Kahoot! platform I think will excite the students.
Fifth Question	- Yes, definetely. - I think playing and learning is more interesting for our students. - I think that creating games is a very interesting approach for teaching basic informatics principles to students.

As a general result of the discussion session one can say that the teachers think that learning through creating and/or using games is more interesting and they also like the idea of using various programming environments to create games in order to teach basic programming principles to students.

B. Teachers'Suggestions

During the discussion session, we also asked the teachers to give us their opinion for the suggested material's improvement. Some of the comments included the following suggestions:

- I think that in the elementary school worksheets it is better to include more images because the students are at an early age.
- The planned time in some activities must be reconsidered; for example, it would be better to expand the time given for the Gymnasium worksheets' activities.
- In each level of education add a list of suggested activities as homework for the students.

V. DISCUSSION

The previous results raise interesting issues. According to the opinions of the teachers, who studied all the worksheets activities per level of education and implemented some of them, the concepts follow each other in a clear and comprehensive way and seem to be well-organized. Also, the teachers seem to like the idea of using several programming environments, different for each level of education, in order to teach basic informatics and programming principles to students.

Furthermore, most of the teachers think that the activities are easy to be processed by the students, but the planned time needs to be reconsidered in some cases. Lastly, the homework assignment is important to teachers so they think that including more activities as suggested homework is necessary.

VI. CONCLUSIONS AND FURTHER RESEARCH

In this paper, we tried to explore and evaluate the use and the creation of games in the Informatics course in elementary and secondary education. For this purpose, educational activities were created taking into consideration relevant educational theories and the Informatics course's curriculum for each particular education level. The collaboration with teachers in order to evaluate the produced material before its implementation in classroom settings was an essential part of this study.

The feedback from the teachers that studied and used the worksheets was positive about the content and the concept included per each education level. The worksheets designed for teaching and learning through creating and using games, according to the teachers' opinions, can be used in order to teach and learn basic informatics principles and also to practice and enhance programming skills, but in some cases the planned time needs to be reconsidered.

In the future, we intend to add more activities that will work as homework assignments following the teachers' comments. Also, we are going to reconsider the planned time for some of the activities according to the teachers' suggestions.

After these improvements, we are going to ask once more the teachers' opinions in order to test the improved worksheets' content and then proceed in their implementation and thorough evaluation in school classes.

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