

Game design based learning of programming for girls

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Abstract - We will present the use of game design as a method for teaching programming in primary and secondary schools. Students of the introductory course in computer programming design and program games. This represents a typical active learning approach that has proven to be the most effective way of learning programming. The act of building a game is itself a way to learn, regardless of whether the game is interesting to other people or not.

The described methodology and all corresponding learning materials for students and supporting materials for teachers are being developed within the Erasmus+ Coding4Girls project, which addresses equal opportunities for girls and boys in the highly rewarding computer science professions by highlighting links between programming and real life and highlighting the fact that such professions are rewarding regardless of gender or background. The results of the project will help to create the necessary background among the students that will enable them to succeed in their future endeavours either academic or professional. It will also address the development of teachers' competencies and the profile of the teaching profession by empowering educators to effectively build up the desired computer literacy skills among their learners.

Keywords - Game design based learning, Design thinking, Programming, Programming for girls

I. INTRODUCTION

Games are now widely used in the classroom, especially in the earliest stages of a child's development. However, in the later stages of student development, learning is still too often based on a teacher centred activities in which students play a passive role. On the other hand, learning theories developed over the last century encourage new student-centred approaches to learning and teaching that are problem based and motivating, directed to higher pedagogical and taxonomic levels and often supported by information and communication technologies (ICT) [1].

II. GAME-BASED LEARNING

Serious games should be designed to facilitate learning goals [2], [3]. In most cases, the game is not an independent learning activity, but a part of the learning activity that can be carried out before, during or after the game.

- *Pre-game activities*

We can use them as an introductory activity in which the teacher presents the rules and goals of the game as well as the context and learning goals. If students recognize rules and goals by

themselves, these activities can be left out, and the player is also more active and involved in the game.

- *Activities during the game*

They are used less frequently and are intended to support the player when problems in the game are too demanding or when additional feedback is needed.

- *Post-games activities*

The players must have the opportunity to discuss and reflect with their teacher and to contribute their own experiences with the game. These activities are necessary for the students to see what they have learned in the game, what knowledge they have acquired and what could be improved to achieve their learning goals [1].

According to Kolb [4], the opportunity for learners to reflect on their own learning experiences is crucial to the learning process. In this way students reflect on their activities and explore what and why they do. For effective learning, [4] Kolb suggests in his book a Learning Cycle of four stages that the student must go through: 1) to have a *concrete experience*, 2) to review and reflect on the experience (*reflective observation*), 3) to infer and learn from the experience (*abstract conceptualization*), and 4) to plan and try out what has been learned (*active experimentation*).

All the above mentioned activities are collected in a so-called *pedagogical package*, which has to be prepared and offered to teachers who want to use game-based learning for their students [1].

Although serious games require one or more learning goals to be defined, they must also have all the characteristic of the game. Prensky in his book entitled *Digital Game-based Learning* [5] defines seven key elements of the game: 1) *Story* - the game must be based on the story, which provides a framework and connects parts of the game into a whole, 2) *Objectives and challenges* - the objectives must be related to the story and challenges, 3) *Additional challenges* - the game rules give structure to the game and some additional challenges are recommended, 4) *Interaction with other people* - the player has active interaction with other people or within the game environment, 5) *Conflict relationship* - the relationship with others is usually conflictual or competitive, 6) *Control over events* - when interacting, the player has a sense of control over the events and also over the possibilities of influencing the course of the

game, 7) *Feedback* – the game must provide feedback to the player so that he can check the appropriateness of his actions and the effectiveness of his progress. All these key elements motivate the player, help him stay focused and have fun.

In the game, the player is guided to the learning goals that are normally hidden and not obvious in the game. Therefore, the learning goals are achieved without the player being aware of the learning [6]. Nevertheless, game-based learning is not suitable for achieving learning goals in all subject areas. The appropriateness and usefulness of the game for learning can be strongly influenced by the following factors: subject area, learning theory and didactic method, taxonomic level, student's background and teacher's experience and expertise [7].

Serious games can offer students many learning benefits - risk taking, problem solving, interaction, situational meaning, research, teamwork, and critical thinking. Studies by Ibrahim and Jaafar [8] have shown that students are very interested in using educational games for learning. The results from Nor Azan and Wong [9] indicated that 92% of the students included in their survey had experience with computer games, that they play games for a variety of reasons, and suggested that games could be used as an alternative approach to teach subjects with lower student motivation. According to a number of studies [10], [11], [12], [13] games motivate learners, provide immediate feedback, support skills and influence behavior and attitudes.

III. CODING4GIRLS PROJECT

Coding4Girls is an ongoing international project that addresses the gap between girls and boys in computer science education and careers. According to the European Commission, only 2.9% of women with a Bachelor or other degree hold a degree in ICT (compared to 9.5% men) and only 0.4% women eventually work in ICT. The Coding4Girls project aims to make computer science attractive to all and focuses on the late years of primary education up to the early years of secondary education (10-16 years), when many girls lose interest in STEM (science, technology, engineering and mathematics), including computer science [14]. Coding4Girls is also concerned with the development of teaching competencies and the profile of the teaching profession. Teachers guide their students in the learning process by constructing solutions to the given problems and implementing them through game design [1].

Students participating in the project will: be prepared for computer science careers by building programming skills; be able to apply developed programming skills in larger contexts; build analytical and critical thinking; learn how ICT solutions can improve quality of life and address common needs; learn to think entrepreneurially to introduce solutions to real-world problems through design thinking mind sets [14].

IV. GAME DESIGN BASED LEARNING

Within the Coding4Girls project, the students will learn programming concepts by creating games.

According to Kafai [15], students become even more active in game-based learning when they learn by developing games themselves. Also Zapašek and Rugelj [16] argue that learning by creating games can be more effective than traditional methods.

The act of building the game is itself a way of learning, regardless of whether the game is interesting to other people or not. Due to the expanding range of computer-based design and game design tools, the idea of "learning by design" has become widespread, based on the assumption that the best way to learn is to actively participate in the design and development process [17].

Between 2014 and 2015, extensive studies of published papers on the topic of children's learning while making games were conducted by Kafai and Burke [18]. Convincing evidence has been found that young children use different computer practises when developing games. In the project in which the fourth grade students designed the fraction game, they debugged, revised and tested their games again and again, especially after the evaluation sessions with younger students. They not only programmed the game, but explicitly focused on teaching fractions to younger students. Post-tests showed that the students who programmed the fraction game were much more familiar with programming in Logo (and also with understanding and representing fractions) compared to students who learned Logo in small, unrelated programming activities. These results have been confirmed in recent studies on the creation of mathematics games in Scratch by Ke [19], as students have been confronted with mathematical tasks on a daily basis and have improved their understanding. In another analysis, the students were asked to create different game designs. 30 college students in a semester-long course created 268 games and 33 middle school students in an 8-week class created 73 games. It turned out that both groups improved their computational thinking patterns, but the improvement for the college students was more substantial, as they started the course with more experience and also spent more time designing their games [18].

Serious games are also used to learn complex and difficult to understand topics in computer science education, such as data structures and algorithms. It turns out that students better understand the algorithms when they apply a new learning strategy for designing computer games that visualize algorithms [20]. For example, every computer game that teaches and visualizes algorithms has six common characteristics, which is also true for other serious games: 1) the game can be created by developing a new game from the beginning or by modifying an existing game, 2) the game must be simple enough so that the students do not lose concentration, but at the same time challenging enough so that they do not get bored, 3) the algorithm game must visualize the algorithm and its data structure and can be of any genre, 4) the game must be motivating and challenging, with clear goals, appropriate difficulty levels and feedback. The information in the game must be complex and unknown, which increases the curiosity of the players. The game must also increase competition and cooperation between the students, 5) the game graphics should reflect the characteristics of the

structure that the students are learning (e.g. using a group of boxes with a content to learn about the array data structure, or using an actual tree with leaves to learn about the tree data structure), 6) the algorithm game must simulate the behavior of the algorithm that the game visualizes.

V. INTERESTING GAMES FOR GIRLS

Before we prepared Snap! activities and wrote learning scenarios, we had to consider what kind of games would be interesting for girls.

Vermeulen et al. [21] stated that women play games more often, but less long than men, and that there are also different preferences for game genres between the genders. Female players like to play social games [22] with in-game rewards [23], educational and simulation games [24], cooperation and exploration games [25], virtual world games and party games [26], while men prefer action, strategy, role-playing and fighting games. An analysis of studies [27] reveals the following elements regarding the playing preferences of women:

- Explore: Women like role-playing and new identities, the exploration of new worlds and the discovery of new knowledge [28]. Studies have shown that women have a preference for exploratory play [23].
- Character customization: Women like to individualize their avatars, which includes customization of clothing, weapons and accessories. Role-playing games are known for these customization options [29].
- Storyline: The storyline is a main motivating element. It allows the player to interact with the characters and situations in the game [30] and women like to play games with a good story [29].
- Social interaction: Social interaction increases motivation and represents the element of collaboration and cooperation [31] and is a major factor for women to play games [32], [33].
- Collaboration: Collaboration is important for motivation and is one of the most popular forms of collaboration [30].
- Challenges: Challenge is a key component [34] and is one of the many motivating elements of the game for women [31].
- Fun: Fun and entertainment are a central motivation for women [34], [31].
- Control: Control also affects motivation [34] and the commitment and performance of players [35]. Women prefer to control the game, rather than the game controlling them [29].
- Feedback: Environments that provide feedback to the player improve engagement and performance [35].

In the No One Left Behind (NOLB) project, the students created 77 games (girls created 37 games, boys

34 and 8 games were created in mixed teams). Students aged 8 to 12 years developed games in the subject areas such as English, computer science and fine arts. The games made by girls were mainly adventure games - nature, winter wonderland, underwater world (33%), followed by text adventure games / storytelling - fantasy, nature, romance (24%), puzzle games - fantasy, crime story (17%), platform games - nature (15%), action games - nature, underwater world (9%) and action shooter / role-playing games - fantasy, realistic (4%). The games created by boys were also predominantly adventure games - space, nature, realistic (35%), followed by action shooter games - space, fantasy (22%), puzzle games - realistic, fantasy, fiction (19%), quiz - realistic (9%) and action games - nature, space (15%). The results show significant differences between gender and genre. Girls also used a nature-related theme most often (43%), while boys used a space theme most often (46%). The use of graphics for the main character shows even greater differences in gender. In games created by girls, the main characters were usually animals - dog, panda, butterfly, etc. (13 games), followed by fantasy - skeleton, fairy, Elsa, unicorn etc. (11), items (4), female characters (3), male characters (3), food (1) and no transport. In the games made by boys, the main character was usually transport - spaceship, UFO (12 games), followed by male character (6), animals - bird, dog (4), fantasy (3), food (2), items (2) and female characters (1) [36].

VI. LEARNING SHEETS FOR TEACHING PROGRAMMING

When writing learning scenarios, we took into account the goals of the Coding4Girls project and all the motivational elements and preferences of the girls in relation to the games. We have also tried to relate the activities to real-world problems.

The Coding4Girls approach encourages participation in programming activities through a "low-entry, high-ceiling approach", which initially places low demands on knowledge, but also includes complex challenges for more advanced students. The students solve partially completed solutions prepared in the programming language Snap! (similar to Scratch), adding missing blocks of code or creating their own solution [14].

Prepared learning scenarios contain all the information that will help teachers to integrate proposed serious games and design thinking learning methods into the learning process. The learning sheets contain all the following information:

- overall educational objective for each learning activity,
- concepts covered by the learning activity,
- specific learning objectives,
- expected learning outcomes,
- step-by-step use of the Coding4Girls game design-based learning approach,
- assessment methods for evaluating the developed knowledge,
- questions to stimulate discussion among learners [14].

More than 20 learning sheets for planned learning activities were prepared. Teachers will be able to use the scenarios and games in the suggested order, but they will be also able to customize the scenarios to suit their needs. The learning sheets cover the generic functionality of the proposed serious game, including user interaction processes, Snap! activities and half-baked scenarios with descriptions of all learning activities implemented in the proposed serious game [14].

The activities are divided into two parts. The first part contains basic activities covering one programming concept, followed by more advanced activities in several programming concepts. The duration of the basic activities is usually 45 minutes, while 90 minutes are provided for advanced activities. Students can design their games individually, in pairs or in groups.

In the initial activities, students familiarize themselves with the Snap! visual programming environment, followed by finding programming blocks, connecting these blocks into a sequence, moving a sprite, creating sprites that say something, and creating a meaningful sequence of blocks. Students learn how to change costumes and turn sprites by making a ballerina dance, how to add sounds by adding the voices of farm animals, and how to implement the chameleon's movement by using events and changing its colour according to the background by using conditionals. By helping the prince and princess find their animals in the maze, they learn how to draw a path, and by connecting dots on the board, they learn how to "write" a code to draw with loops. They meet with variables and duplicate sprites within a game where they pick up trash, clean up the park and count points. In the games where cats are fed and the number of cats in a shelter is guessed, random numbers and operations are introduced. There are more challenging activities such as catching healthy food, planting trees for a clean environment, inventing a story, catching the mouse, buying food for a picnic, calculator, recycling, playing a piano, testing, and Packman game.

The learning sheets will be published in the Coding4Girls web portal¹ and will be available in English and in all national languages of the project partners: Bulgarian, Croatian, Greek, Italian, Portuguese, Slovenian, and Turkish.

VII. CONCLUSION

The learning scenarios developed within the Coding4Girls project will be tested in different ways in primary and secondary schools. The test results will reveal our performance in composing activities, taking into account the girls' preferences in playing and creating games and their motivation in learning programming by creating games.

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¹ Coding4Girls web portal: <https://www.coding4girls.eu/>

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