Make World, a collaborative platform to develop computational thinking and STEAM

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Abstract. The demand for computer programming professionals in STEAM-related areas has rocketed in the last decade. Initiatives such as the Hour of Code or CodeWeek take advantage of online platforms like Code.org to reach millions of students through a one-hour introduction to computer science and computer programming. Despite the excellent curricular design of Code.org courses, we believe that learners could benefit from a platform where they can create their own programming challenges that can be shared, assessed and remixed by the rest of the users. We named this platform Make World (http://makeworld.eu). After more than one year of use, we studied how students and teachers used this tool to propose and solve learning activities where computational thinking and STEAM skills are developed at the same time. This paper describes the main characteristics of Make World and analyses the use and piloting phase where more than 500 students of primary education have participated to measure the impact of Make World in their learning. The result of this analysis provides a better understanding of the difficulties students face when using a technological platform for STEAM and computational thinking education.

Keywords: Computer-supported collaborative learning, Serious games and gamification, Technology-enhanced learning, computational thinking, STEAM

1 Introduction

STEM (Science, Technology, Engineering, and Mathematics) is a priority area in education in Europe, and basic skills in numeracy, mathematics and sciences are considered key foundations for further learning [1]. Similarly, increasing academic achievements in mathematics and science is also a critical goal for the education reform in the United States [2]. Recently, Arts was also included in this set of key competences. Therefore, STEM replaced STEM as a broader vision of the needed skills for the future.

One of the main reasons to promote STEAM vocations is to cover the lack of workforce in these areas foreseen for the coming decades. Compared to the estimated rise in overall employment of 3% by 2020, it is estimated that employment in STEAM related professions will increase by 14% in Europe [3], very similar to the rise of 14.8% for all

Science and Engineering occupations in the United States by 2022. What is more, it is estimated that 80% of jobs will need some type of scientific or mathematical skill.

But working to improve STEAM education is not just about making money. As Gago [4] pointed out, “in many countries the profit motive for choosing a STEM career was over-emphasized and this was actually driving young people away from science and technology”. Conversely, we should focus on the human and ethical values of science, on the development of critical citizens who understand the technology around us with a positive attitude.

In order to achieve good results, engagement and a positive attitude towards STEM, children have to feel attracted to these subjects at school [5]. Tai found that the aspirations for STEM before 14 yr. is a good indicator of choosing STEM studies in the future [6], so interventions have to be at early stages and maintained over time.

1.1 Programming and Computational Thinking

Computer programming is a process that involves the analysis of the problem, the design and verification of the algorithm, and its implementation in a programming language. Though related, Computational Thinking (henceforth CT) goes beyond programming to include solving problems, designing systems, and understanding human behavior [7]. CT also helps to understand today’s digitalized society and foster 21st century skills like creativity and logical thinking.

Initiatives such as the Hour of Code or CodeWeek take advantage of online platforms like Code.org to reach millions of students through a one-hour introduction to computer science and computer programming. Of 21 countries analyzed in Europe, 16 have already integrated coding in the curriculum, mainly at secondary level but increasingly in primary school [8].

According to the NMC Horizon Report K12 [9], “honing these skills in learners can lead to deeply engaging learning experiences in which students become the authorities on subjects through investigation, storytelling, and production. Other components include game development, and access to programming instruction that nurtures learners as inventors”. Teachers and students require new methodologies and tools providing opportunities for communication, co-creation and collective assessment in a social environment that leverages the positive reinforcement techniques and personalized assessment of games, story-telling and CT to improve the understanding and assimilation of complex ideas.

Despite the excellent curricular design of Code.org and similar courses, and in line with the Horizon Report, we believe that learners could benefit from a platform where they can create their own programming challenges that can be shared, assessed and remixed by the rest of the users. We named this platform Make World (http://make-world.eu). It aims at offering a tool where both STEAM and CT are addressed in the same activity, it is oriented to primary school and extensible to secondary when students become authors of their own learning resources.

During the development of the project, we have tested the platform with 524 students in the three partner countries (Spain, Greece and Poland). This internal piloting has provided valuable feedback from students in the classroom using developed resources

and tools. The result of this analysis provides a better understanding of the difficulties novice programmers in primary education face when they are challenged with a computational thinking challenge integrated with STEM concepts.

2 Make World platform overview

MW is a free and open online platform that includes ready-to-use educational resources and teacher's guides in English, Spanish, Greek, Polish and Basque. The Spanish, Polish and Greek collaboration was possible thanks to the support of the Erasmus+ program of the European Commission, within the Strategic Partnership category. One primary school in each country, a university and a research institution jointly designed and developed the platform and educational resources that were recognized as best practice by the Spanish national agency in December 2015. According to the EC rules and the consortium policy, all resources are released under Affero General Public License (AGPL).

Make World (MW henceforth) aims at creating a symbiotic relationship between CT and STEAM areas. Accordingly, activities in the platform should challenge students both in computer programming and in STEAM related concepts. But, is any scientific concept suitable to be addressed in a MW activity? The answer is no. In order to naturally merge programming and STEAM we have to consider the programming flow of actions, in our case the sequence of movements triggered by events. This makes concepts that involve cycles and systematic procedures the best topics to design a MW activity, e.g. the water cycle, food chain or digestive system.

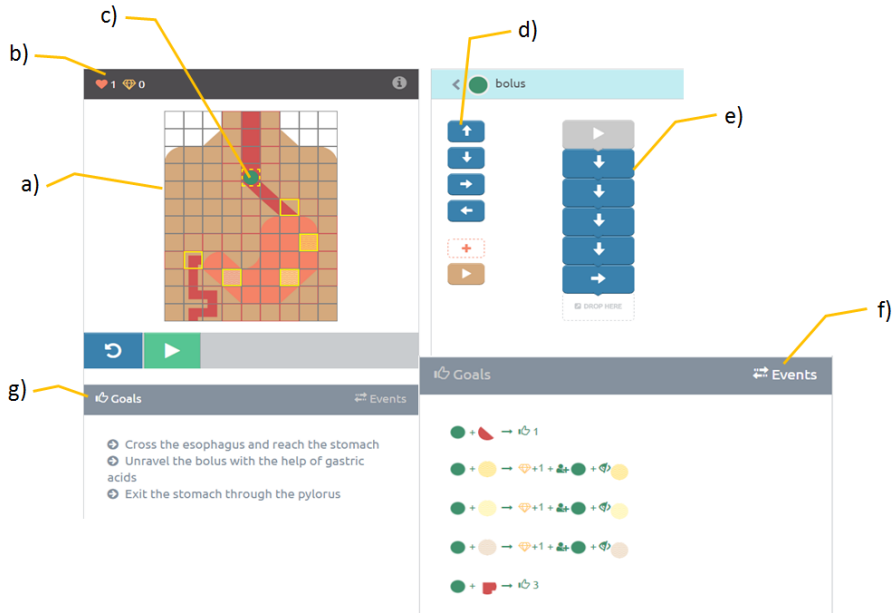

Fig. 1. Make World interface to solve a challenge, the key sections are: (a) world, (b) points and lives, (c) character, (d) available instructions, (e) program, (f) events, (g) goals.

The main concepts of the platform are worlds, stories and characters. A world is a two dimensional grid where characters interact (see Fig. 1). Each world has a set of goals the player has to meet by building the characters' programs with the set of instructions provided for each character. The student is who combines the available instructions to create the program, this is, the character behavior. Goals can be achieved when a given event occurs or when the user gets a number of points. Events are the rules of the game and trigger actions that change the state of the game.

Within Make World, a story is a sequence of worlds that may be intertwined by text explanations or multiple choice questions to create a learning track. The sequence is not necessarily linear. Depending on the score obtained in the previous world or the answer to the question of the previous explanation, the learning path may vary. This enables retrying the activity, providing extra content or reinforcing the learning concept. Figure 2 shows the way stories are built. On the right side, the sequence of explanations, worlds and jumps that form the story can be seen. The element highlighted on the right panel marks the step within the story that is being edited currently on the left. Editing a jump requires a description, the score range that will trigger the jump and the destination point within the story (the author has to point out where the jump will direct the program execution, it can be a world or an explanation included in the story).

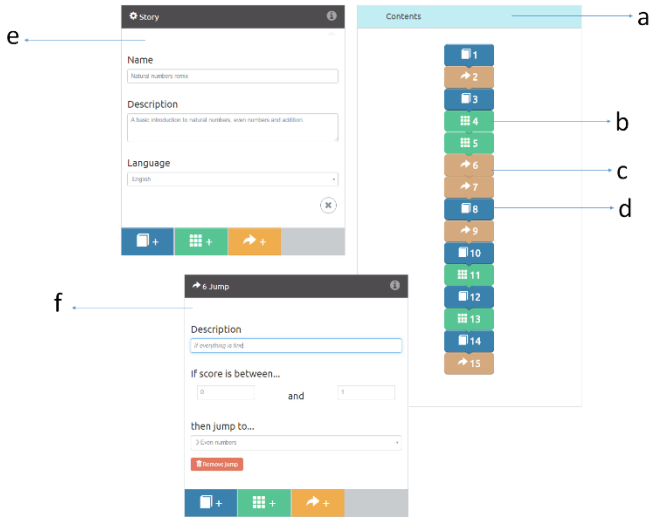

Fig. 2. Story editing interface, where you can see the story sequence (a), with worlds (b), jumps (c) and explanations (d); as well as the story description options (e) and the jumps options (f).

The social nature and flexibility of the platform are some of its biggest assets. In addition to the ready-to-use worlds and stories provided by project partners in the official gallery, users can remix existing resources to modify, adapt and create new versions. Users that get skillful in MW can also create activities from scratch. Players can follow the activities performed by other players, and also comment and like their creations. This social interaction enables gamification dynamics within MW. Players get

bronze to ruby badges for several activities in the platform, such as playing worlds and stories, getting their creations remixed by other players, being followed, or creating new resources.

Target users' involvement in the consortium is key to guarantee the success of MW, both in terms of utility for teachers and students learning, and concerning usability in a tool oriented to primary school boys and girls. Fatima school in Spain, Doukas school in Greece and Warsaw Bilingual school in Poland represented the final users during the whole project development. They participated in the initial design, as well as in interim testing and final piloting. The result is a simple and clear interface, with the minimum elements to interact with (i.e. one character is in one tile, one action represents one movement) that shows only the actions needed to complete the activities. Unlike other tools designed for novice programmers, no reading or writing skills are needed to code in MW, and only sequences and procedures are included as computer programming concepts. The little time (less than one hour) needed to train more than 750 teachers and students in the use of the platform is an indication of its usability.

Ethics and privacy issues regarding under-13 users was a big concern for project partners. As a consequence, no personal data has to be provided to use the platform. The sign up process only requires a username and a password. In order to avoid privacy and copyright related issues, image uploading is not permitted. Therefore, users have to use images provided in the MW gallery to define their avatars and create new learning resources.

2.1 The Community

MW success relies on its community. MW users play, remix and create worlds and stories, interact with other users, and therefore enrich their learning experiences. We have expanded this community organizing several workshops with educators and students in Spain, Greece, and Poland (167 educators took part in the workshops: 52 in Spain, 70 in Greece, and 45 in Poland). We also piloted the platform (524 primary students participated in the piloting, aged from 10 to 12 years old: 255 in Spain, 200 in Greece, and 69 in Poland); and held an international conference with more than 80 education experts and practitioners.

These dissemination activities result in an active community of 1,330 users, 670 of whom have created at least one world, and a total of 3,656 worlds created in one year. Without considering users from the project consortium, the community is made up of 669 males (51%) and 649 female users, the average age is 18 (33% adults and 54% aged between 10 and 14), and their preferred languages are: Spanish (48%), English (16%), Basque (15%), Greek (14%) and Polish (7%).

There have been a total of 8,000 accesses to the platform during the last year, with an average duration of 31.5 minutes for each session. Users have played with 6,959 worlds and successfully finished 58% of them. Their social activity can be measured in terms of the number of comments made (473); the average number of followers of each user (8.24), and average number of followees (10.24).

3 The piloting of Make World

The piloting of MW took place between January and April 2016 in three primary schools: ESC Fatima in Bilbao and Santander (Spain), Doukas (Athens, Greece) and Warsaw Bilingual School (Warsaw, Poland). Following we describe the steps followed during the piloting phase.

3.1 Approval of the ethics committee of the University of Deusto

Before contacting the legal tutors of students, the consortium obtained the approval of the ethics committee of the University of Deusto. This is especially relevant as the project deals with data registered automatically by the platform from the interaction of under aged students. However, it does not register any personal data that may harm participants' privacy, such as email, personal identification number, name or address. The only data needed to access the platform is a username and a password, which do not identify the user. In this stage the informed consent for legal tutors was also developed.

The platform also complies with data privacy and legal issues regarding working with minors. In this sense, the coordinators developed with the support of their legal department the Terms of Service of the platform.

3.2 Pre-piloting process

The informed consent previously mentioned was distributed among families, and the school collected those who accepted to get involved. In parallel, teachers provide a unique code to each student, so only they knew the identity of students who took part on the experiment, but researchers were able to match the answer to questionnaires with the activity in the platform. This way we ensured the anonymization of data gathered.

Teachers responsible for each participating group were trained for two hours in the basis of Make World, the objectives, approach, computational thinking and STEAM concepts; and they played with the platform as users. Project members also explained them the whole piloting process and tools.

3.3 Experimentation with students

Groups were randomly distributed in control and experimental groups. 524 students took part in the whole process (255-Spain, 200-Greece and 69-Poland), aged between 10 and 12 years old.

During the first session the experimental group (E-group) was introduced to the MW platform. They played worlds and stories, accessed their profile and stuff, and also used the social features, such as comments, likes followers and followees relations. Meanwhile, the control group (C-group) was introduced to the piloting process and talked about STEM and computational thinking skills.

In the next class, both groups answered a knowledge questionnaire about Recycling, the topic selected for the piloting. They also filled a questionnaire about their Attitudes towards STEM and the Flow of their traditional STEM classes, based on previously validated studies [11], [12] and [13].

Students have two or three days with no intervention in which those of the E-group could use MW at home. During the next class session, the E-group worked the recycling topic using a story developed in Make World, while the C-group followed a traditional learning process.

In the last intervention session, both groups answered a knowledge questionnaire about recycling, different from the first one but similar in structure and content. They also filled the questionnaire about their Attitudes towards STEM and the E-group filled a questionnaire about their Flow using MW, with more than 80 indicators of other measures from the literature related to the satisfaction of using technology.

4 Results

Since the platform was made public in January 2016, it has more than 2,200 users (51% men and 49% women), who have accessed in more than 8,000 occasions, and they have created more than 3,000 worlds. Users have played almost 7,000 worlds, and have successfully completed 58% of them. These data give evidence of the great user activity. In addition, the system registry allows us to verify that users repeatedly enter the platform, which indicates that they explore its use beyond the action that has developed during dissemination or piloting actions.

More than 500 students who have participated in the piloting have shown a high degree of satisfaction. They have answered several questionnaires that provide information about their attitude towards STEM areas, their opinion on the subjects and method of learning related subjects and on the use of MW as an innovative STEAM learning tool. We have collected more than 80 indicators, and the first analyzes allow us to conclude that the short-term impact on students has been positive. The results of the most relevant questions are show in Table 1, related to the use of the platform.

Table 1. Feeling about the use of MW

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
It is easy for me to become skillful at using MW	1%	4%	18%	34%	44%
MW is fun for me to use	2%	5%	14%	30%	50%
I find MW easy to use	0%	3%	10%	37%	50%
My interaction with MW is clear and understandable	1%	4%	12%	29%	54%

Table 2 shows some of the items in the questionnaires related to the learning process using Make World. You can see a high level of acceptance of the platform as a STEAM learning tool, since close to 80% of participants find it suitable for learning science.

Table 2. Learning with MW

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Using MW improves my learning	1%	7%	11%	38%	44%
Using MW makes it easier to learn science	3%	4%	15%	38%	41%
I find MW useful in my learning	1%	2%	14%	33%	50%
Using MW enhances my learning effectiveness	1%	3%	20%	42%	35%

Satisfaction questionnaires completed by teachers after training show a high level of satisfaction. Bearing in mind that several of these workshops were offered when the platform and resources were not yet complete (January and February 2016), we consider the responses to be very positive. Here are some of the data collected:

- +85% consider Make World “interesting”, “funny”, “useful for teaching” and “easy to use”, with answers in degree "yes" and "yes, a lot".
- +60% have come up with new ideas to promote STEM in primary school.
- +50% declare their intention to use it in their class. Those who have indicated that they will not, mostly are high school teachers or non-academic staff.

Moreover, MW has had a positive impact in their attitude towards STEM. Comparing the attitudes questionnaire filled before and after using MW, you can appreciate an increase in some items, such as:

- Technology is fascinating: +1.06 points
- A career in STEM is interesting: +0.81 pts.
- Mathematics are attractive: +0.80 pts.

5 Conclusions

Increasing the interest on STEAM fields and improving the way they are learned is a priority at international level. Not only due to the current demand for STEAM professionals, but also because there is a need for critical and literate citizens able to understand the 21st century world. Over recent years, policy makers, the educational community, and other related initiatives have been promoting computational thinking skills among young people. It helps them to understand the technology they use every day and involves the development of crucial skills to deal with unforeseen challenges such as problem solving, logical thinking and creativity. The piloting performed with Make

World and data collected through several questionnaires shows the positive feeling of students towards MW as an attractive and effective tool for STEAM education.

Considering the cognitive categories defined in the Bloom's taxonomy [10] regarding the skills involved in the learning process, we find that synthesis and assessment are at the top level of the taxonomy. Even in the new approach used in the revision of this taxonomy made by Anderson, et al. [14] "evaluating" and "creating" are also the learning skills that involve the highest level of development. This is the main reason for the development of MW.

The online platform presented here not only tries to address computational thinking issues but also fosters the creation and assessment of new user-generated learning activities. We need STEAM professionals not only able to appropriately use what others have developed before, but also capable of creating their own tools (either remixing existing solutions or from scratch), debugging and solving their errors, and sharing them with the community.

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