Proceedings of the

Workshop of Making as a Pathway to Foster Joyful Engagement and Creativity in Learning (Make2Learn)

Organized in conjunction with the14th International Conference on Entertainment Computing (ICEC 2015)

Workshop Organizers:

Michail N. Giannakos

Monica Divitini

Ole Sejer Iversen

Pavlos Koulouris

Trondheim, Norway, 29 September 2015

Organization

Workshop Organizers:

- Michail Giannakos, Norwegian University of Science & Technology, Norway
- Monica Divitini, Norwegian University of Science and Technology, Norway
- Ole Sejer Iversen, Aarhus University, Denmark
- Pavlos Koulouris, C2Learn, Ellinogermaniki Agogi, Greece

Program Committee:

- Anna Mavroudi, Open University of Cyprus, Cyprus
- Eva-Sophie Katterfeldt, University of Bremen, Germany
- Helen Crompton, Old Dominion University, USA
- Janet Read, University of Central Lancashire, UK
- Letizia Jaccheri, Norwegian University of Science and Technology, Norway
- Michael Horn, Northwestern University, USA
- Monica Landoni, Università della Svizzera Italiana (USI), Switzerland
- Panos Markopoulos, Eindhoven University of Technology, The Netherlands
- Sarah Eagle, University of Bristol, UK
- Spyros Doukakis, The American College of Greece, Greece

Our Sponsors:

VITENSENTERET i Trondheim

NTNU – Trondheim
Norwegian University of Science and Technology

CEITE
Center of Excellence for IT Education

C²Learn

FAB LAB @SCHOOLdk

ISSN: 1613-0073
Published by CEUR Workshop Proceedings at CEUR-WS.org/Vol-1450

Address for correspondence:
Michail N. Giannakos
Norwegian University of Science and Technology (NTNU)
Department of Computer & Information Science
Sem Sælands vei 9,NO-7491
Trondheim, Norway

e-mail: michailg [at] idi [dot] ntnu [dot] no

Table of Contents

Make2Learn: Fostering Engagement and Creativity in Learning through Making

Michail N. Giannakos [1], Monica Divitini [1], Ole Sejer Iversen [2] and Pavlos Koulouris [3]

[1] Norwegian University of Science and Technology (NTNU), Trondheim, Norway
{michailg, divitini}@idi.ntnu.no
[2] Participatory IT Center, Aarhus University, Aarhus, Denmark
oiversen@cs.au.dk
[3] Ellinogermaniki Agogi, Athens, Greece
pkoulouris@ea.gr

I hear and I forget. I see and I remember. I do and I understand.
– Confucius

Abstract. The International Workshop of Making as a Pathway to Foster Joyful Engagement and Creativity in Learning (Make2Learn) aims to discuss the introduction of creative and joyful production of artifacts "maker movement" in the learning processes. A variety of environments have been developed by researchers to introduce making principles to young students. Making principles enable them foster co-creativity and joy in learning processes and construct knowledge. By involving students in the design decisions they begin to develop technological fluency and the needed competences, in a joyful way. Make2Learn aims to bring together international researchers, educators, designers, and makers for the exploration of making principles towards the acquisition of 21st Century learning competences, by employing the state art aspects of entertainment technologies, new media, gaming, robotics, toys and applications. The main objective is to build a research community around this topical area. In particular, Make2Learn aims to develop a critical discussion about the well-established practices and entertainment technologies of the maker movement, and expected outcomes of putting them into practice under different spaces such as Hackerspaces, Makerspaces, TechShops, FabLabs etc. This will allow us to better understand and improve the value of Maker philosophy and the role of entertainment technologies to support teaching and learning.

Keywords: Maker movement, entertainment technologies, creativity, knowledge construction, technological fluency, constructionist

1 BACKGROUND

Digital artifacts that enable people to exchange, create, and distribute information have, in the past couple of decades, profoundly reshaped the way we work and live [7]. The

Make2Learn 2015 workshop at ICEC'15, September 29, 2015, Trondheim, Norway.

creative production of digital artifacts and use of entertainment technologies in learning activities has been linked to teaching new computer and design literacy skills [1]. Common inspiration is the work of Papert [6] that stresses the importance of creating a 'felicitous' environment to facilitate learning. The idea here is that the students benefit from being happy and in a carefree and creative environment. In accordance with Papert, Csikszentmihalyi's [3] research has exhibited that students' motivation is highly predictive of achievement; however, educational systems neglect creative and joyful aspects on learning activities. Educational programmes focus on recall and reproduction abilities instead of emphasizing the development of problem solving, creative thinking and decision-making abilities.

Digital artifacts have the potential to make the symbolic and abstract manipulations involved in creative procedures more concrete and manageable for young students [2]. For example, artifacts allow students to learn by iteratively testing, rebuilding their designs and working collaboratively. The interactions between the young students and the artifacts in creative and joyful activities are vital [4]. During the past decade, we have seen an increased appearance of environments and community spaces offering diverse opportunities for young students to facilitate learning through construction. Environments like Scratch, Alice and Storytelling Alice and spaces like Hackerspaces, Makerspaces, TechShops, and FabLabs have allowed researchers to empirically investigate the potential benefits of the maker movement towards the acquisition of 21st Century learning competences. Collecting and discussing around those advances will allow us to formulate better understanding of several technical and practical aspects that could be valuable in designing effective making activities to foster joyful engagement and creativity in learning.

2 OBJECTIVES

The advances of digital environments, entertainment technologies, manufacturing equipment and community spaces offer diverse opportunities for making practices to facilitate learning, especially when supported by engaging and joyful entertainment technologies and designed in an appropriate pedagogical manner. From current research, it is difficult to tell what aspects of environments, engaging-entertainment technologies, applications, equipment and practices can have a positive impact.

The current drive in many countries to teach design and technology competences to all has potential to empower and support making as a creative, joyful and problem-solving tasks. However, there are a number of challenges in ensuring that procedures, tools and environments, embody appropriate progression and engender motivation and joyful. This workshop will attempt to address these key research challenges.

One of our main objectives is to bring together researchers, educators, designers who are interested for the exploration of making principles and supportive entertainment technologies towards the acquisition of 21st Century learning competences. Make2Learn aims to provide an environment where participants will get opportunities to: develop their research skills; increase their knowledge base; collaborate with others in their own and complementary research areas; and discuss their own work.

3 CONCLUSIONS

The contributions of Make2Learn covered several topics, such as tangible technologies, computer science and programming education, empirical examinations, augmented reality applications in schools and best practices to foster creativity in learning. The workshop proceedings are freely accessible from CEUR-WS series (http://ceur-ws.org/Vol-1450/).

In particular, Alsos [10] presents a programming course, where students of interaction design used Arduino to build interactive everyday things. Interaction Designers need to know and understand the virtual material they work with – in other words they need to know basic programming in order to make their products highly interactive. As illustrative examples, Alsos presents the six interactive innovative products made by the students. Videos of all the products are available on http://bit.ly/1K4YPYB

Svanæs [11] describes experiences from an introductory course for first-year computer science students. During the course Arduino, robot programming and app development with Processing was used to foster engagement and creativity. The main learning objective for the students was to learn basic hardware and software skills, while at the same time motivating for further computer science courses. The major challenges were related to creating exercises, educational material and a physical work environment for the students that allowed for creativity in the spirit of the maker culture. Crucial factors were found the development of a high number of well-documented small and complete examples as well as the adequate experience and training of teaching assistants.

Koulouris [12] presents the EC C2Learn project, C2Learn aims to foster co-creativity in learning through digital gaming activities whose design and development is grounded on rigid theoretical foundations. The project is shaped as a progression from theoretical foundations to design, development, pilot implementation and evaluation in real life educational settings. Careful pedagogical and game designs have defined the elements of learners' gameful digital experiences and produced the specifications for the development of the corresponding technologies and activities. Throughout the project, school communities have been engaged in iterative dialogic cycles leading to design decisions, their implementation and evaluation in real-life educational settings. Koulouris describes that, despite the fact that C2Learn is originating in a different context, there is a direct contribution to the 'maker movement'.

More et al., [13] discuss the making of interactive board games as a learning activity. They present AnyBoard platform which is currently under development, and demonstrate how AnyBoard supports the design and implementation of board games. The innovation of their approach stems from the fact that they do not use a game board virtualised on an interactive surface, but rather achieve interactivity through technology-augmented game pieces. Hence, they offer a broad design space and low costs of the final product.

Papavlasopoulou et al., [14] present the design and implementation of a computer science education, with the goal to encourage students to acquire programming skills and become creators and not only mere consumers. This paper presents an initial exploratory evaluation of the workshop program and the development of a set of guidelines for improving students' experience. The results aim to inform designers and researchers about the impact of a) gamefulness, b) guidance, c) programming experience, d) pro-grammable hardware platforms and e) technical problems in the design and implementation of creative programing experiences.

Karamanoli and Tsinakos [15] present a literature review focused on Augmented Reality (AR) and its current and future incorporation in modern education via various context aware technologies (e.g. tablets, smartphones). AR can provide opportunities for more interactive and joyful educational experiences, especially when combined with Open Course Project situations, such as the one which is available at the Eastern Macedonia and Thrace Institute of Technology in Greece. With the main purpose to inform "creators" and stimulate "users" to engage with this promising technology throughout the educational process.

4 CONCLUSIONS AND THE WAY AHEAD

The advances of digital environments, technologies, manufacturing equipment and community spaces offer diverse opportunities for making practices to facilitate learning, especially when supported by engaging and joyful entertainment technologies and designed in an appropriate pedagogical manner. From current research, it is difficult to tell what aspects of environments, technologies, applications, equipment and practices can have a positive impact.

The current drive in many countries to teach 21st century skills to all has potential to empower and support making as a creative, joyful, problem-solving and critical thinking tasks. However, there are a number of challenges in ensuring that procedures, tools and environments, embody appropriate progression and engender motivation and joyful.

To explore the future of technologies, tools, and various spaces to foster engagement and creativity in learning, we seek to promote interest in well-established tools and practices of the maker movement, and expected outcomes of putting them into practice under different spaces such as Hackerspaces, Makerspaces, TechShops, FabLabs etc. This will allow us to better understand and improve the value of Maker philosophy as well as to accelerate the process of disciplinary convergence. We aspire to bridge computer science, design, HCI and related disciplines to encourage ambitious research projects that could yield potent tools for many students to use. This workshop is implemented with an aim to collect high quality studies around this topical area, to envision what the next generation of technologies, environments, spaces and practices might look like. In particular, future work need to:

1. Accelerate research on Maker Movement by proposing ways to create greater interest and synergies among researchers, educators, students, policymakers, and industrial developers,

2. Promote rigorous multidimensional and multidisciplinary methods and implement rigorous experimentation strategies and metrics for in-depth longitudinal case studies,

3. Design tools, kits and spaces for individuals to promote "low floor" (easy to get started) and a "high ceiling" (opportunities to create increasingly complex projects over time) opportunities for young students.

5 Acknowledgments

We would like to thank Kirsten Panton for accepting our invitation to give keynote presentation. We would like to thank the workshop Program Committee members for contributing to the success of Make2Learn as well as the workshop and conference chairs for their constructive comments and their helpful assistance during the preparation and throughout the workshop, special thanks go to Letizia Jaccheri for her support and encouragement. Last but not least, we thank our sponsors: NTNU, Trondheim Science Museum, C2Learn EC project, KODELØYPA and FABLAB@SCHOOL.dk.

6 References

1. Buechley, L., Eisenberg, M., Catchen, J. and Crockett, A.: The LilyPad Arduino: Using Computational Textiles to Investigate Engagement, Aesthetics, and Diversity in Computer Science Education. In Proc. CHI '08, ACM Press, 423-432 (2008)
2. Cassell, J.: Towards a Model of Technology and Literacy Development: Story Listening Systems, Journal of Applied Developmental Psychology 25(1), 75-105 (2004)
3. Csikszentmihalyi, M.: Creativity: Flow and the Psychology of Discovery and Invention. Harper Collins, (1996).
4. Giannakos, M. N., & Jaccheri, L.: What motivates children to become creators of digital enriched artifacts?. In Proc. C&C 2013, ACM Press, 104-113 (2013)
5. Giannakos, M. N., & Jaccheri, L.: Code Your Own Game: The Case of Children with Hearing Impairments. Entrtainment Computing - ICEC 2014. Springer, 108-116 (2014)
6. Papert, S.: Mindstorms: Children, Computers, and Powerful Ideas. Basic Books New York, NY (1980)
7. Resnick, M. et al.: Design Principles for Tools to Support Creative Thinking. Technical Report: NSF Workshop Report on Creativity Support Tools. Washington, DC (2005)
8. Ryokai, K., Lee, M. J., and Breitbart, J. M.: Children's storytelling and programming with robotic characters. In Proc. C&C 2009, ACM Press, 19-28 (2009)
9. Shneiderman, B., et al.: Creativity support tools: Report from a US National Science Foundation sponsored workshop. International Journal of Human-Computer Interaction, 20(2), 61-77 (2006)
10. Alsos, O. A.: Teaching product design students how to make everyday things interactive with Arduino, In Proceedings of the Workshop of Making as a Pathway to Foster Joyful Engagement and Creativity in Learning (Make2Learn 2015), CEUR-WS, Vol. 1450, 7-14 (2015)
11. Svanæs, D.: A Maker Approach to Computer Science Education: Lessons Learned from a First-Year University Course, In Proceedings of the Workshop of Making as a Pathway to Foster Joyful Engagement and Creativity in Learning (Make2Learn 2015), CEUR-WS, Vol. 1450, 15-20 (2015)

12. Koulouris, P.: Games Fostering Co-Creativity in Learning as Contributions to the "Maker Movement", In Proceedings of the Workshop of Making as a Pathway to Foster Joyful Engagement and Creativity in Learning (Make2Learn 2015), CEUR-WS, Vol. 1450, 21-28 (2015)
13. Mora, S., Fagerbekk, T., Di Loreto, I., Divitini. M.: Making interactive board games to learn: Reflections on AnyBoard, In Proceedings of the Workshop of Making as a Pathway to Foster Joyful Engagement and Creativity in Learning (Make2Learn 2015), CEUR-WS, Vol. 1450, 29-36 (2015)
14. Papavlasopoulou, S., Giannakos, M.N., Jaccheri. L.: Designing Creative Programing Experiences for 15 Years Old Students, In Proceedings of the Workshop of Making as a Pathway to Foster Joyful Engagement and Creativity in Learning (Make2Learn 2015), CEUR-WS, Vol. 1450, 37-44 (2015)
15. Karamanoli, P., Tsinakos. A.: Use of Augmented Reality in terms of creativity in School learning, In Proceedings of the Workshop of Making as a Pathway to Foster Joyful Engagement and Creativity in Learning (Make2Learn 2015), CEUR-WS, Vol. 1450, 45-53 (2015)

Teaching product design students how to make everyday things interactive with Arduino

Ole Andreas Alsos

Department of Computer and Information Science
Norwegian University of Science and Technology
Trondheim, Norway

oleanda@idi.ntnu.no

Abstract. This paper describes how industrial design students made everyday things interactive with Ardiuno in a programming course. It also describes 6 innovative projects made by the students; (1) A beat machine inspired by Rubics Cube, (2) an interactive and moving lamp that scans the area for faces, recognizes your smile, take a picture of it, and posts it on Twitter, (3) a self-typing typewriter from 1920's which you can have a conversation with, (4) an interactive art installation where you use your own shadow to play with falling objects, (5) a digital audio workstation where you change the sound characteristics by moving tangible rubber blocks on a surface, and (6) a tangible music player where you discover new music by moving a cylinder around on a plane. The range of solution fit three different categories: (a) *Music***,** both creating and playing, (b) *Everyday things with personality*, and (c) *Interactive art.* Videos of all projects are available on http://bit.ly/1K4YPYB

Keywords: Arduino, programming, teaching, industrial design, interactive art

1 Introduction

The Department of Product Design at the Norwegian University of Science and Technology (NTNU) offers a master program education in industrial design [1]. The master program offer two study specializations: *product design* and *interaction design*, educating product designers and interaction designers, respectively. In the same way a product designer need to know and understand the *materials* they work with, an interaction designer need to know and understand the *virtual material* they work with – in other words they need to know basic programming in order to make good interaction designs, and to be able to communicate with developers. Further, in the age of *Internet of Things*, many products designers now need to know programming in order to make their products interactive and to give them life. Therefore, the Department of Computer and Information Science at NTNU offers a course to industrial design students where they learn how to make their products or artworks interactive. This course is called *Prototyping Interactive Media* [2] and aims to teach the students the art of programming through project based work.

Make2Learn 2015 workshop at ICEC'15, September 29, 2015, Trondheim, Norway.

1.1 Teaching industrial design students programming

In the course we teach the industrial design students programming with Arduio (using the *Processing* language), which is “an open-source electronics platform based on easy-to-use hardware and software (...) intended for anyone making interactive projects.” [3]. It is basically a small programmable computer where you can, with the help of code, sensors, servos, LEDs, and other cheap hardware components, create remarkable things. Arduino is open source, and there exist numerous code libraries where other programmers have solved problems before so that you don’t have to do it again. These are like LEGO pieces that you can connect to each other (with the help of a little code) to build new projects that does new things.

1.2 Course assigments

The course consists of two individual assignments where they get familiar with the possibilities of Arduino and the *Processing* programming language. In these assigments they build a traffic light and a music instrument. In addition the students are given an open group assignment, where about four of them collaborate:

> *Find an everyday thing, make it interactive and make it talk to the world (or other everyday things) or let it publish things on the Internet, for example tweet or update facebook status.*
>
> *It can be that does something useful for the user, or an art project that inspire the user. It can be something for your home or something for your study desk. The design challenge is to find the valuable interaction.*

1.3 Design process

Although the group assignment was open with few restrictions, the students had to reach a number of milestones with hard deadlines (which they had to show/demonstrate to the course staff).

- Project planning
- Idea generation
- Idea selection
- Wizard-of-Oz-test
- Iterations

The students had to deliver or present the following:

- A video of the project (maximum 2 minutes)
- A functional prototype presented on an exhibition where an audience could test and try it
- A short oral presentation of the project during the exhibition
- A long oral presentation of the project in a classroom

- A report that documented the product, the design process and wiring diagrams, and with references to code libraries used.
- The complete code

2 Project descriptions

Below is a short description of the resulting 6 projects. Videos are available on YouTube on http://bit.ly/1K4YPYB

2.1 PLAY

PLAY is an art installation where you (or you and a friend) use your own shadow to interact with falling (or flying) objects of different sizes and shapes. The objects cannot pass through your shadow, which allows you to stop, hold, bounce, hit, and pass the objects on to a friend. There are two modes, changed with the press of a button, that either shows your shadow or hide it.

The installation consist of a curved wall, where the final image is projected, a button on a pole that is controlled by an Arduino, and a back wall, which hides a projector, a Microsoft Kinect sensor, and a computer with the Processing code. The interaction with the objects is possible through blob detection and a physics simulator.

Fig. 1. PLAY

2.2 GhostWriter

GhostWriter is an old typewriter from 1920's that is given life – it responds to your input and writes it down on a piece of paper. When you write something on the type-writer, it responds as a human being; with quriosity and humor.

The typewriter is connected to wires that sense your typing, translates your key presses to a text string, sends your message to a chat-bot. Further the system translates the answer from the chat-bot to key presses, and press the keys using pneumatics so that the message is actually typed on the paper sheet.

Fig. 2. GhostWriter

2.3 RubberBeats

Rubberbeats is an interactive tool for creative music production. Colored rubber blocks represent different sound clips. These clips are played when you place the rubber blocks on a transparent surface. The sound image is changed by moving the blocks; by moving the block vertically you can change the pitch of the sound, by moving it horizontally you change the tempo. You can play several sounds clips simultaneously by placing several blocks on the surface. When you are happy with the sound, you can record the sound clip and post it on the web based audio platform SoundCloud with the hashtag #RubberTracks.

Rubberbeats uses a PIXY-camera and colour recognition to recognize the different blocks. The system also translate the position of each block to the corresponding pitch and tempo.

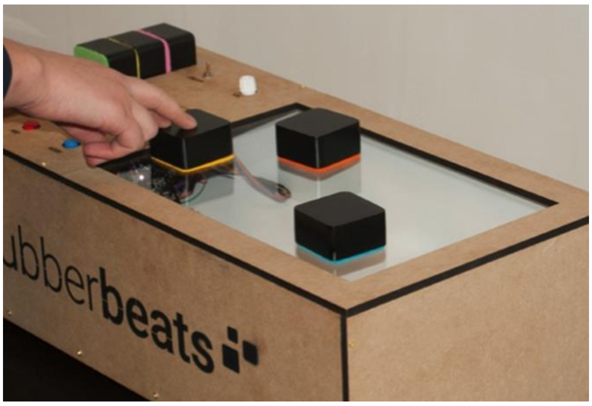

Fig. 3. RubberBeats

2.4 Beat Ball

Beat Ball is a beat machine that allows you to combine up to 3 different beats into a more complex beat. *Beat Ball* is shaped as sphere with movable panels, inspired by a Rubic's Cube. By moving a panel you switch from one instrument into another, for example a clap into a whistle, or a base drum into a bongo drum. In this way a user can experiment and play with sounds to make a beat that they like. All the technology is hidden inside the sphere. Only a headphone jack and a power button is visible on the outside.

Rubberbeats uses a PIXY-camera and colour recognition to recognize the different blocks. The system also translate the position of each block to the corresponding pitch and tempo.

Fig. 4. Beat Ball

2.5 Argus Ball

Argus is a curious lamp. It constantly scans the room for faces. When it see you, it moves closer. When you get too close, it moves back. When you smile to *Argus*, it takes a photo, shows it to you on a computer screen, and looks down on a big blue *Twitter* button. If you are satisfied with the photo, you press the button. Argus then nods and posts the image on *Twitter*. If you are dissatisfied with the photo, you do nothing, and *Argus* sadly shakes his lamp head and then continue to look for smiles.

Argus has an embedded video camera in the lamp head, and uses face tracking to find faces. Six servos continuously move the lamp to scan for faces, to make sure your face is in the middle of the image and has the right size, and to simulate its personality. It uses smile detection to take a photo, and a *Twitter* library to post the image on the Internet.

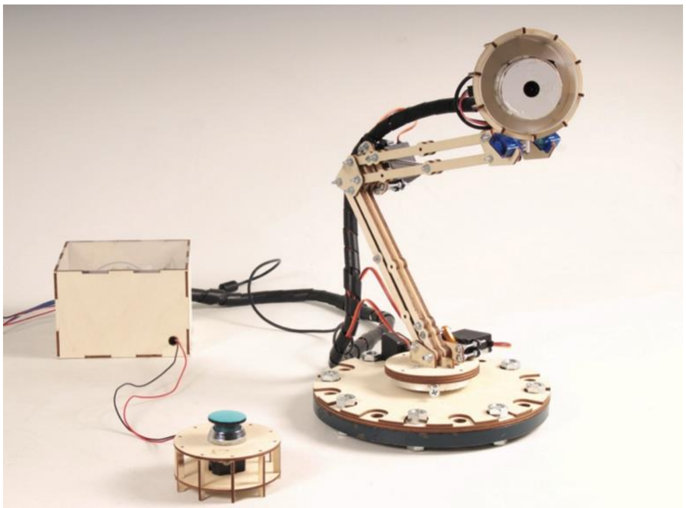

Fig. 5. Argus lamp

2.6 Discover

Discover is a tangible interface for the music streaming service *Spotify* with the intention to expand the user's musical horizon. The users start playing a playlist from *Spotify* by placing a cylinder on a circular plane. Based on where you place the cylinder, a specific music genre starts playing. At any time you can move the cylinder to play a new playlist from a different music genre. You can also push a favorite button to save the track in your favorites for later. In this way you can explore music and find new genres and tracks that you like. You stop the music by placing the cylinder in the dock at the base of the device.

Fig. 6. Discover

3 Discussion

Looking at the variation of solutions, they can be placed in the following categories:

Music: Here we find *BeatBall*, *Rubberbeats* and *Discover*. The two first are for *creating* music, while the last is for *playing* music.

Things with a personality*:* Argus and GhostWriter are both everyday things with a clear personality.

Interactive art: *PLAY* is an interactive art installation where the audience can interact with the installation.

4 Credits

I thank the clever, creative and hardworking students for delivering impressive work.

Argus: Christer Rebni, Magnus Oulie, Tuva Haddal, Astri Eiterstraum
BeatBall: Truls Ottesen Johansen, Ellen Wagnild-Antonsen, Polle van Duuren and Inga Nedrebø Søreide
Discover: Pål Jørgensen, Marianne Kleveland, Martin Kristoffersen og Camilla Dahlstrøm
GhostWriter: Kjersti Bjelkarøy, Aurora Brun, Alexander Jonassen, Sigve Lien, Ingeborg Skogsfjord
Play: Jan Magnus Neverdal, Kaja Drews, Johanne Parelius, Thea Togstad
Rubberbeats: Anja S. Hansen, Arne H. Aaraas, Emilie H. Weydahl & Viktor Rydal

References

1. http://www.ntnu.edu/design/studies
2. http://www.ntnu.edu/studies/courses/TDT4262#tab=omEmnet
3. http://www.arduino.cc/

A Maker Approach to Computer Science Education: Lessons Learned from a First-Year University Course

Dag Svanæs

Department of Computer and Information Science,
NTNU
NO-7491 Trondheim, Norway
dags@idi.ntnu.no

Abstract. We report from a one-semester introductory course for first-year computer science students where Arduino, robot programming and app development with Processing was used to foster engagement and creativity. The main learning objective for the students was to learn basic hardware and software skills, while at the same time motivating for further computer science courses. The course had a total of 250 university students with two teachers and ten teaching assistants. The major challenges were related to creating exercises, educational material and a physical work environment for the students that allowed for creativity in the spirit of the maker culture. We learned that much effort must be placed on making a high number of well-documented small and complete examples that the students can use as a starting point in their projects. We also learned that the teaching assistants should themselves have spent much time experimenting with the actual technology.

Keywords: Maker culture, Arduino, computer science education, robots.

1 Introduction

The computer science education at the Norwegian University of Science and Technology (NTNU) has traditionally been fairly theoretical in the first two years, with a focus on basic courses in mathematics and programming and little time for the students to explore technology or apply the theory on real-life problems before later in the study. This has its roots in the German engineering education of the early 1900s, with its emphasis on a natural science approach to engineering. The earliest engineering curriculums at NTNU were written in the 1910s and 20s by professors who had their training in this tradition, and the wisdom of the "theory first" approach to engineering education has not been challenged until recently.

In [1] Felder contrast this traditional *deductive* approach to engineering education with the *integrated* view:

Make2Learn 2015 workshop at ICEC'15, September 29, 2015, Trondheim, Norway.

- "**Deductive (Fundamentals --> Applications)**: Begin the first year with basic mathematics and science, teach "engineering science" in Years 2 and 3, and get to realistic engineering problems and engineering practice in the capstone course.
- **Integrated**: Introduce engineering problems and projects starting in Year 1, and bring in the math and science (and communication and economics and ethics) in the context of the problems and projects." (Ibid, p. 3)

Over the last three years the computer science curriculum at NTNU has been through a major revision, aiming for a more integrated model. One of the major motivations for making changes has been an increasing dropout rate in the first two years of the study, and a general dissatisfaction among the students with the strong emphasis on theory early in the study.

One of the changes implemented in the new curriculum is a new project-based "programming laboratory" course in the second semester of the first year. The main learning objective of this course is for the students to learn basic computer hardware and software skills, while at the same time motivating for further computer science courses. The course was run for the first time this year, and we made use of Arduino [2], robot programming [4], and app development with Processing [3] to foster engagement and creativity. The course was to a large extent inspired by the maker culture.

We will here present the structure of the course and some preliminary findings.

2 Course Structure

The course was named "Programming laboratory 1" to signal that it is a hands-on course. It is followed by a course "Programming laboratory 2" in the following semester that builds on this course. The course is mandatory for all 250 first-year computer science students at NTNU, and runs for the full 14 weeks of their second semester. The students participating in the course have learned basic programming principles in a first-semester course, but their experience with programming is limited.

Two teachers and ten teaching assistants were allocated to the course this year. The course was organized as teamwork in the lab, combined with one two-hour lecture per week. The course is 7.5 ECTS, corresponding to 25% of their teaching load. We consequently expected them to use at least one full day on the course per week, although each team only had access to teaching assistants four hours per week.

The course has no exam, and the grading was passed/not passed (P/NP) to put less pressure on the students. The course had four mandatory exercises throughout the semester that all had to be successfully completed to pass.

3 The Exercises

The two first exercises were individual, and two last were done in teams of five students. Starting out with two individual exercises was done to ensure that all students got the basic skills in electronics and Arduino programming to enable them to take active part in the following two team exercises. Our motivation for doing this was previous experience from programming courses with team exercises where we often found that the teamwork was taken over by one or two students with experience in programming, alienating the students with less programming experience.

The four exercises were:

1. Street signal (individual, 2 weeks).
2. Musical instrument (individual, 3 weeks).
3. Robot competition (team, 4 weeks)
4. Xbot - A robot and its world (team, 5 weeks)

3.1 Hardware, Software and Building Material

The learning material for the course consisted of an Arduino starter kit for each student and an electronics and robot kit for each team. In addition each team got simple cardboard building material for exercise 4.

The starter kit consisted of an Arduino, a breadboard, and basic sensors and actuators. The team kit contained additional sensors, actuators, and Bluetooth communication modules, in addition to a Zumo robot [4] with an Arduino on top.

To enable remote control of the robots from the students´ mobile phones, we made an Android app that executes Processing code on the mobile and communicates with the robot through Bluetooth.

3.2 Exercise 1: Arduino Street Signal (individual)

In exercise 1 the students were asked to use their Arduino starter kit to program a pedestrian crossing with a street signal.

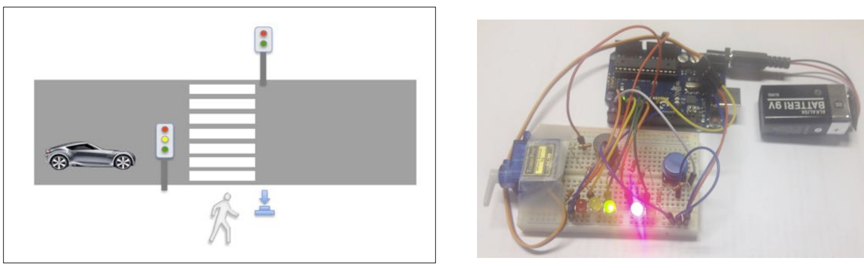

Figure 1. Street signal illustration (left) and Arduino implementation (right).

Figure 1 shows to the left the illustration used in the exercise text, and to the right an implementation of the street signal. In this implementation a servo is added to stop the pedestrians and a buzzer is added for sound. The feedback from the students was that they liked the exercise very much because it was easy to understand and because it was a real-world problem.

3.3 Exercise 2: Arduino Musical Instrument (individual)

In exercise 2 the students used the Arduino starter kit and sensors from the team kit to program an Arduino musical instrument of their own choice.

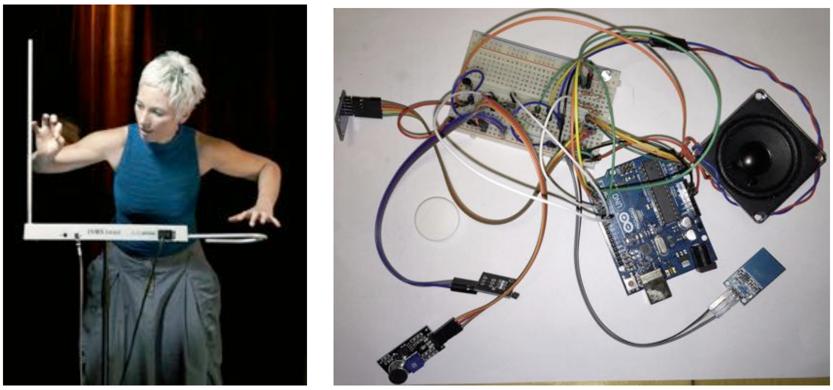

Figure 2. Theremin (left) and Arduino musical instrument (right).

Figure 2 shows to the left a picture of a Theremin musical instrument that was described as an inspiration. To the right is an implementation of an Arduino musical instrument using a combination of sensors (touch, tilt, magnetic and sound).

The students liked the exercise, in particular that the problem was fairly open and allowed them to be creative in choice of sensors and behavior. They further appreciated that we had provided a number of working examples on the course wiki for the sensors, together with examples of how to program tones and sounds through a loudspeaker.

3.4 Exercise 3: Zumo Robot Competition (team)

In exercise 3 the students worked in teams and were given the task of programming their Arduino Zumo robot [4] to compete against another robot in the zumo ring. The zumo robot is actually an Arduino shield on its head. We stages competitions between the 55 teams, leading to final rounds in one of the lectures. The two winning teams won cinema tickets for the team members. We used a slightly modified version of the international sumo robot competition rules [5]. The aim of the robot competition was simpoly to push the other robot out of the ring. Each match lasted for a maximum of two minutes, and the maximum weight was 500 grams.

The robot competition ran in two classes: (1) autonomous and (2) remote control. In the autonomous class the robots were programmed to compete with the other robot only navigating with sensors. For the remote control class we provided Bluetooth modules that enabled them to control the robot from an app that they programmed in Processing for their mobile phones. We had made a reference implementation of the app that they could use as a starting point for their own robot control app.

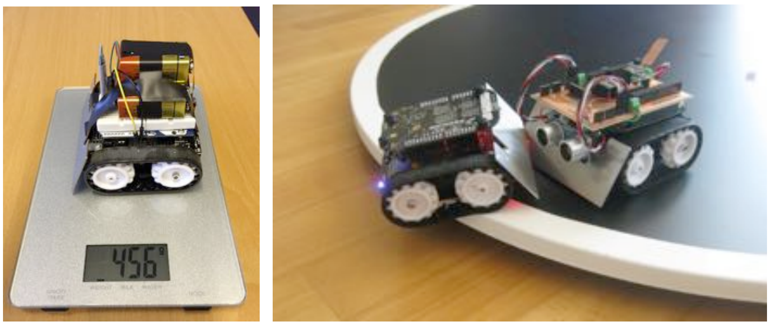

Figure 3. An Arduino zumo robot on a scale (left) and two robots competing (right).

The students found this exercise very inspiring and engaging, and the teams spent much time on perfecting their robots.

3.5 Exercise 4: Xbot - a Robot and its World (team)

Exercise 4 was more open than the previous exercise, challenging the students to be creative. The challenge was to make the robot into an "Xbot", a robot with some specific properties of the team´s choice. The teams were given an A0 cardboard (120x85 cm) that should be the Xbot´s world. In addition to the robot, the teams were required to use the Arduinos of the team members as stationary "helper bots".

Each team documented its Xbot in a 30 seconds video. The videos were shown in sequence on the final lecture of the course, and the students scored them using a modified version of the Kahoot system. The members of the two winning teams got a gift from a local semiconductor company.

Figure 4. "Firebot Sam" (left) and his world (right).

In Figure 4 we see "Firebot Sam", the Xbot of the winning team. The robot was programmed to put out fires in candles placed on the side of its "world". It communicated through Bluetooth with helper bots that detected heat with temperature sensors. It then navigated by line-following to the right candle. A servo on the robot was user to tilt a metal top to put out the candle.

The students enjoyed working with the exercise, and a number of innovative Xbots were created. Some teams had problems coordinating the work among the team members though, leading to some frustration.

3.6 General Observations

One of our major challenges was to create exercises, educational material and a physical work environment for the students that allowed for creativity in the spirit of the maker culture. We learned that much effort must be placed on making a high number of well-documented small and complete examples that the students can use as a starting point in their projects. The planning and preparation of the exercises was done in the previous semester and involved developing code examples, setting up a wiki and buying electronics. Two teaching assistants were hired for this purpose in addition to approx. 20% of the work time of the two teachers and an engineer.

Although the teaching assistants had a background in programming, we gave them a crash course in Arduino in the previous semester and encouraged them to experiment on their own. As a consequence they became an invaluable recourse.

4 Conclusions

The presented course was inspired by the maker culture, and we have made extensive use of Arduino and the open source maker culture around this product. A combination of structured and open exercises worked well to teach basic skills, and at the same time opened up for creativity. The course was well received, and we plan to follow the same overall structure next year with some minor modifications.

Acknowledgments. Thanks to the other course team members Asbjørn Thomassen, Terje Røsand, Pia Lindkjølen and Inge E. Halsaunet.

References

1. Felder, Richard M. "Engineering education: A tale of two paradigms." *Shaking the Foundations of Geo-engineering Education* (2012): 9-14.
2. Evans, Brian. *Beginning Arduino Programming*. Apress, 2011.
3. Reas, Casey, and Ben Fry. "Processing: programming for the media arts." *AI & SOCIETY* 20, no. 4 (2006): 526-538.
4. *Zumo Robot for Arduino*. https://www.pololu.com/product/2506 (retrieved 9. July 2015).
5. *Unified Sumo Robot Rules*. http://robogames.net/rules/all-sumo.php (retrieved 9. July 2015).

Games Fostering Co-Creativity in Learning as Contributions to the 'Maker Movement'

Pavlos Koulouris[1] and Kalliopi-Evangelia Stavroulia[1]

[1] Ellinogermaniki Agogi, Pallini, Greece
pkoulouris@ea.gr

Abstract. The C2Learn project aims to foster co-creativity in learning through digital gaming activities whose design and development is grounded on rigid theoretical foundations. The project is shaped as a progression from theoretical foundations to design, development, pilot implementation and evaluation in real life educational settings. Careful pedagogical and game designs have defined the elements of learners' gameful digital experiences and produced the specifications for the development of the corresponding technologies and activities. In this process and throughout the project, school communities have been engaged in iterative dialogic cycles leading to design decisions, their implementation and evaluation in real-life educational settings. This paper presents in summary the methodology followed and the results of a core part of the research, with a special focus on the C2Learn games which, despite originating in a different context, directly contribute to the 'maker movement' in education.

Keywords: games · creativity · learning.

1 C2Learn: digital games for co-creativity

C2Learn is a European research project (2013-2015) aiming to foster co-creativity in learning through digital gaming activities whose design and development is grounded on rigid theoretical foundations. In our project, current understandings of creativity in education and creative thinking meet with digital games and intelligent technologies to provide young learners and their teachers with innovative opportunities for *co-creativity* in learning. We aim at producing tangible research-based outcomes readily available for use in and outside classrooms. Therefore C2Learn is shaped as a progression from theoretical foundations to design, development, pilot implementation and evaluation in real life educational settings. Careful pedagogical and game designs have defined the elements of learners' gameful digital experiences and produced the specifications for the development of the corresponding technologies and activities. In this process and throughout the project, school communities have been engaged in iterative dialogic cycles leading to design decisions, their implementation and evaluation in real-life educational

Make2Learn 2015 workshop at ICEC'15, September 29, 2015, Trondheim, Norway.

settings. This paper presents in summary the methodology followed and the results of a core part of the research, with a special focus on the C2Learn games which, despite originating in a different context, directly contribute to the 'maker movement' in education.

2 C2Learn theory and pedagogy

The foundations of the project lie in a consolidated theoretical framework encompassing the theories of Wise Humanising Creativity (WHC) [1,2,3] and Creative Emotional Reasoning (CER) [4]. C2Learn theory provides insights into how co-creativity of children and young people can be fostered in formal and informal learning settings. Co-creativity is defined as educational activity in which learners, individually as well as mainly collaboratively and also communally, come up with novelty, new ideas. These new ideas: a) have emerged through asking 'what if' and 'as if' questions and through the use of disruptive techniques resulting in re-framing; b) have emerged from shared ideas and actions in an immersed dialogic rather than hierarchical pedagogical environment; and c) are captured or selected because they matter to the community and have a valuable impact on it. In this, learners take into account the impact of that novelty on the individual, collaborative and communal dimensions of their community.
The theoretical framework defines the vision of the project and frames the design and development of the envisioned C2Learn technological solution. C2Learn theory also defines the wider conceptual and pedagogical framework in which the use of C2Learn technologies and C2Learn-inspired learning and teaching practices are placed. Thus, starting from C2Learn theory, the project produces theoretically framed technological innovation combined with designs for its deployment, use, and evaluation in real educational practice.
C2Learn theory is provided to the project in an operational form so that it can be used for the design and evaluation of the C2Learn solution. Thus, the theoretical framework is manifested as: a) CER Techniques [4,5], which offer ways for the application of CER in practice; b) Learning Design [6,7], which describes how WHC and CER can be enacted in pedagogical practice; and c) co-creativity assessment methodology [8], which is used in the pilots to establish to what extent and in what ways the solution produced by the project has the desired effect.

3 C2Learn technology and gameful design

The technology produced is an innovative digital gaming and social networking environment incorporating diverse tools the use of which can foster co-creativity in learning processes in the context of both formal and informal educational settings.

Digital gaming constitutes the chosen means for the involvement of learners and educators in WHC-CER practices in and around this digital environment. C2Learn theory thus frames game design, so that the designed playful digital experiences can foster co-creativity as theorized in C2Learn.

The C2Learn digital environment and the wider pedagogical environment in which it is used are gameful environments where co-creativity occurs playfully. The pursuit of playfulness is a priority served through explicit gameful design [9,10]. In addition, background Artificial Intelligence (AI) technologies are employed to further empower learners as creators and creative thinkers within the defined frame of co-creativity.

3.1 Co-designing and piloting with school communities

Throughout, school communities are actively engaged in iterative dialogic cycles leading to design decisions, their pilot implementation and evaluation in classrooms. In close reflective collaboration with communities of educators and students in Austria, Greece and England, researchers gather user requirements, co-design locally appropriate solutions for the introduction of the innovation in real life learning settings, negotiate and plan various instances of such an introduction for the purposes of piloting and evaluation.

The aim of piloting in the project is to test and evaluate with users the C2Learn experience, including both the technologies developed and the pedagogical practices enabled by these technologies. In the pilots, educational activities specifically shaped around the use of the C2Learn technologies and methodologies are implemented in educational settings. The aim is to create conditions for evaluation that can provide the project with feedback used for further refining design and development and for introducing adjustments and improvements.

Evaluation is realized through the application of the co-creativity assessment methodology specifically developed on the basis of C2Learn theory. The core aim is to evaluate C2Learn's impact on learner's co-creativity as theorized in the project, by documenting change as well as the lived experience of engaging in C2Learn-enabled activity [8]. The co-creativity assessment methodology is applied in fieldwork during the pilots leading to the collection of rich qualitative data. The data collected is then analysed to lead to critical descriptions of the activities, evaluative findings and conclusions.

3.2 A scenario-based design approach

Educational scenarios [11,12,13] provide the integration of the various parts of the project into a coherent C2Learn user experience in a given educational setting, orchestrating the various technological and pedagogical parts of the project described in the previous sections. They are concrete designs of pedagogical practice in the context of given educational settings specified in terms of learner age group, curriculum links, the degree of formality of the learning activities, and the wider cultural/country setting. Educational scenarios thus ‘translate’ learning design and game design into plans for the implementation of educational activities in real life, predominantly in the pilots run within the project, but eventually also in other educational settings. At the same time, scenarios present the world of education with the range of possibilities offered and examples of effective use of the C2Learn solution.

Educational scenarios are designed in close collaboration with the school communities, providing input into the design process directly from educational practice. Indeed, they constitute that aspect of the design of the C2Learn solution which is most strongly shaped by the collaborating school communities and framed by their educational realities. They are a design tool aiming to ensure that the innovative technologies deployed and practices introduced will correspond to the needs, circumstances, expectations and aspirations of the end users. Therefore, their development is interwoven with processes aiming at establishing user expectations and requirements.

As we have described elsewhere [14], setting out from a theoretical perspective and motivation, the project has deliberately adopted a scenario-based approach to engage teachers as designers of learning experiences. In summary, in our approach a scenario is an adequate but flexible structure for sustained engagement and learning within open-ended environments, like the ones designed in C2Learn. In addition, scenarios can also enable teachers to manage the change in the flow of classroom activity induced by the technology-enhanced pedagogical innovation. Further, by shifting the pedagogical emphasis from the transmission of subject matter to the orchestration of experiences around the subject matter, C2Learn scenarios focuses on a crucial dimension that is often neglected in discussing the curriculum: making the learning situation meaningful from the point of view of the students. Scenarios can turn our curricular objectives into personal goals that students understand and embrace. Finally, scenarios can generate useful user input to inform the design of the envisioned technological system, as well as serving as exemplars for communicating pedagogical innovation to a broader population of potential users and other communities of interest.

An important aspect of this design is the distribution of C2Learn practice in the physical and digital spaces of C2Learn. In this context, educational scenarios propose appropriate configurations of the use of digital and non-digital C2Learn assets in the pedagogical environment, based on the affordances and opportunities offered by the various media and how those can be best used in a given educational setting. Attention is paid to the representation in the scenarios of a wide variety of configurations of C2Learn experience, including the use of different combinations of digital and non-digital assets, in various time frames, so as to illustrate the versatility, flexibility and adaptability of the C2Learn solution.

4 Learning through making while playing C2Learn games

The C2Learn games are hosted in C2Space, a web space which integrates all technological constituents into a unified user experience. It is a gameful social networking environment designed to foster co-creativity as theorized in the C2Learn project. C2Space offers playful digital experiences (‘C2Experiences’) for students to engage with. C2Experiences are structured in C2Space in ‘Creative Quests’, ‘Creative Missions’ and ‘Creative Challenges’, as presented in Table 1.
Among the various Creative Challenges, of particular interest from a ‘maker movement’ perspective are those based on the games 4Scribes and Iconoscope.

4.1 4Scribes

4Scribes is a story-making game. The objective of the game is to collaboratively create a story, while each player tries to steer the narrative towards their individual secret ending. The premise of the story can be given by a teacher, decided by the players, or generated by computational tools. The winner is decided through the players, who each anonymously vote which ending was the “best”.
The Light and Dark variety is a variation on the 4Scribes game, where learner-created endings are randomly attributed a dark or light modifier. This gives the players goals in different directions, and often results in more dynamic play, because of the conflicting goals. Dark and Light endings refer to the tone the learner should take into consideration when writing their secret ending. Dark refers to dark themed endings, working against the ideals of the premise. Light refers to lighter themed endings, working towards the ideals of the premise.
To play 4Scribes, players use the Creative Elements, i.e. cards carrying one word or short phrase each which are meant to disrupt players’ conventional thinking. In turns, players advance the story using one of their elements at each time. The words are not meant to be interpreted literally, but are an idea and an archetype that should spark the imagination of players. Thus, using the words or phases appearing on the elements in play serves as a creative seed in story-making.

4.2 Iconoscope

In Iconoscope players make icons to represent concepts given by the system. The player’s goal is to make their icon representative of the concept, but not too obvious, so that they make the others guess - and to guess what other players’ icons represent. Players score points for guessing right, and for having co-players guess what their own icon is representing.

Table 1. Elements of C2Learn gameful design.

Gameful design concept	Explanation	Example
CREATIVE QUEST	Players set out on Creative Quests, i.e. journeys towards specified goals. Quests can be longer-term ventures (spanning over weeks or months).	Save the Earth from Invincible Invaders!
CREATIVE MISSIONS	Players engage themselves in Creative Missions, i.e. actions with specific objectives contributing towards achieving the goals of the quest. A Quest can include a number of Missions. Missions are shorter-term ventures (spanning over a day, days, or weeks).	We will devise new defense methods against Invincible Invaders!
Problem	In the heart of each mission lies a Problem; one with no obvious ‘correct’ answers, e.g. a dilemma.	How can we outsmart Invincible invaders’ warcraft, which is by far technologically superior to ours?
CREATIVE CHALLENGES	To address the Problem, players choose Creative Challenges to pursue. A Mission can include a number of Challenges. Challenges take a relatively short time to complete (spanning over minutes).	
4Scribes	Playing structured story-telling to generate ideas for innovative scenarios of action. Usual duration: 20-30 minutes.	“You are the last ones still conscious and capable of action on the Earth. You have just received Invincible Invaders’ ultimatum before the Attack: the Earth is to be taken. Only one of you will be spared human consciousness to participate in the New Rule - provided you subscribe to the Cult…” Continue the story!
Creative Stories	Playing free collaborative writing to generate ideas for innovative scenarios of action. Usual duration: 10-30 minutes.	You are the last ones still conscious and capable of action on the Earth. You have just received Invincible Invaders’ ultimatum before the Attack. Write Earth’s Message to Invincible Invaders!
Iconoscope	Playing with the concepts to understand them better. Usual duration: 10-15 minutes.	Dare you look deeper into {concept1: War}, {concept2: Cunning} and {concept3: Threat}? Prove it, outsmart the others!

However, if all co-players interpret the icon correctly, the player loses points - hence the need to make an icon that is representative, but not too obvious.

The game requires participants to internalize the logic of a disruptor, and then produce one. The creativity (disruptive) part comes in through the way this icon is then evaluated. Usually signs or icons are meant to convey unambiguously whatever message they represent. A common measure of success is their having conveyed their message as accurately or fully, to as many people as possible. In Iconoscope the icon has achieved its purpose if it has conveyed the idea to as many people as possible, but not all. So an icon fails if it communicates its intended message to everyone, if it communicates its intended message to no one, or if it communicates its intended message to fewer people than another competing icon.

Acknowledgements. The C2Learn project (November 2012 – October 2015) is supported by the European Commission through the Seventh Framework Programme (FP7) under grant agreement no. 318480. The contents of this paper do not represent the views of the European Commission and the Commission cannot be held responsible for any use which may be made of the information contained therein. Responsibility for the information and views set out in this paper lies entirely with the authors.

References

[1] Chappell, K., Craft, A., Rolfe, L., Jobbins, V.: Humanising Creativity: Valuing our Journeys of Becoming. International Journal of Education and the Arts, 13, 8, pp. 1-35 (2012)
[2] Chappell, K.: Towards Humanising Creativity. UNESCO Observatory In E-Journal Special Issue on Creativity, Policy and Practice Discourses: Productive Tensions in the New Millennium, 1, 3 (2008)
[3] Craft, A.: Trusteeship, Wisdom and the Creative Future of Education? UNESCO Observatory In E-Journal Special Issue on Creativity, Policy and Practice Discourses: Productive Tensions in the New Millennium, 1, 3 (2008)
[4] Scaltsas, T., Alexopoulos, C.: Creative Emotional Reasoning: C2Learn Project Deliverable no. D2.1.1, http://www.c2learn.eu (2013)
[5] Scaltsas, T., Alexopoulos, C.: Creative Emotional Reasoning: C2Learn Project Deliverable no. D2.1.2, http://www.c2learn.eu (2014)
[6] Craft, A., Chappell, K., Walsh, C.: C2Learn Learning Design for CER: C2Learn Project Deliverable no. D2.2.1, http://www.c2learn.eu (2013)
[7] Chappell, K., Craft, A., Walsh, C., with Koulouris, P.: C2Learn Learning Design for CER: C2Learn Project Deliverable no. D2.2.2, http://www.c2learn.eu (2014)
[8] Scaltsas, T., Stenning, K., Alexopoulos, K., Craft, A., Walsh, C., Chappell, K.: Co-Creativity Assessment Methodology: C2Learn Project Deliverable no. D2.3.1, http://www.c2learn.eu (2013)
[9] Deterding, S., Björk, S., Nacke, L.E., Dixon, D., Lawley, E.: Designing Gamification: Creating Gameful and Playful Experiences. CHI'13 Extended Abstracts on Human Factors in Computing Systems, pp. 3263-3266 (2013)
[10] Walsh, C.S., Craft, A., Chappell, C., Koulouris, P.: Gameful Learning Design to Foster Co-Creativity? International Conference of the Australian Association for Research in Education

(AARE) and the New Zealand Association for Research in Education (NZARE): Speaking back through Research (2014)
[11] Dimaraki, E. (ed.): C2Learn Scenarios, Use Cases and User Requirements: C2Learn Project Deliverable no. D5.1.1, http://www.c2learn.eu (2013)
[12] Dimaraki, E., Koulouris, P. (ed.): C2Learn Scenarios, Use Cases and User Requirements: C2Learn Project Deliverable no. D5.1.2, http://www.c2learn.eu (2013)
[13] Koulouris, P., Dimaraki, E. (ed.): C2Learn Scenarios, Use Cases and User Requirements: C2Learn Project Deliverable no. D5.1.3, http://www.c2learn.eu (2014)
[14] Dimaraki, E.V., Schmoelz, A., Koulouris, P.: Scenarios as Pedagogical Devices: Designing Activities for Game-Based Learning. ICERI2013 Proceedings, pp. 3203-3209 (2013)

Making interactive board games to learn: Reflections on AnyBoard

Simone Mora[*], Tomas Fagerbekk[*], Ines Di Loreto[**], Monica Divitini[*]

[*] Dept. of Information and Computer Science, NTNU, Trondheim, Norway
{simone.mora, divitini}@idi.ntnu.no
[**] TechCICO, ICD-Université de technologie de Troyes, France
ines.di_loreto@utt.fr

Abstract. In this paper we discuss the making of interactive board games as a learning activity. We do this by presenting AnyBoard, a platform that we are currently developing to support the design and implementation of board games. In our approach we do not use a game board virtualised on an interactive surface, but rather achieve interactivi-ty through technology-augmented game pieces. In this way, we aim at offering to game designers a broader design space and lower costs of the final product. In this paper we discuss the possible use of AnyBoard in the learning context

1 Introduction

Making games, either analogic or computer-based, has long been used as a learning activity in different educational contexts. Making games has proved useful in areas as diverse as engaging students with cultural heritage [1] and teaching university students about software architectures [2]. Teachers have used making games as a way for teaching programming in high or middle schools for many years, for example using RPG maker[1] or Scratch[2].

In this context, we want to discuss the making of interactive board games to promote learning. With the term interactive we mean board games that use tangible computer-augmented objects. There are different benefits that could be achieved, mainly combining the learning strengths of creating games with the strengths of making tangible and interactive objects for educational purposes [3, 4]. In addition, board games are popular also among the elderly, offering a cross-generational form of entertainment. This is an aspect that could be exploited to create cross-generational maker activities. Finally, by making board games the learner does not get distracted by the complex graphics that is common to many video games. In this way, it is easier for the learner to concentrate on the game concept.

To ease the development of digital board game we present *AnyBoard*, a framework for supporting the making of interactive board games. *AnyBoard* supports the design of

[1] RPG Makers - https://en.wikipedia.org/wiki/RPG_Maker
[2] The Scratch project – http://scratch.mit.edu

Make2Learn 2015 workshop at ICEC'15, September 29, 2015, Trondheim, Norway.

digital board games by providing theoretical constructs, software tools and a set of augmented game pieces (all currently under development). The platform was not originally designed to be used in the educational context, but mainly targeting maker communities. However, it could potentially be useful in the context of educational maker activities. In this paper, after presenting the *AnyBoard* approach, we discuss the challenges connected to the use of this platform for learning building on our experience on the creation of an interactive board game.

2 The AnyBoard framework

The dominant paradigm for creating digital board games consists in designing games for interactive surfaces such as smartphones, tablets or tabletop computers. In some cases, artefacts that resemble game tokens, yet augmented with markers (e.g. barcodes, RFIDs), can facilitate interaction with the interactive surface [5, 6].

We propose a different approach: the game pieces are the means to bring interactivity, rather than the game board virtualised on an interactive surface. Distributing interactivity across multiple components opens for a wider space of possibility in designing game experiences. For example, game pieces can influence the state of a game not only when they sit on an interactive surface, but also when they are manipulated over and around it. In this way, the board is mainly used to stage the game and set a context for the use of the pieces, as in traditional board games. In addition, the interactive area of the board is less limited by size, which also determines the portability of the game and costs.

2.1 A new perspective on digital board games

In our approach to digital board games the role of technology is twofold. On one side it brings interactivity by augmenting, not virtualizing, pieces' material representations, for example we aim at providing developers with tangible game pieces augmented with visual, audio or haptic feedbacks (e.g. by means of LEDs or displays). On the other side sensor technology is used to capture players' physical interaction with pieces aiming at preserving their traditional physical affordances; for example, to sense the result of a dice throw, or the movements of pieces onto the board.

Game pieces still preserve their traditional aspect, having a tangible representation that complements an intangible one provided by technology. For example, in a revisited version of Monopoly tokens might preserve their physical semblances to identify players but might embed a graphical representation of the number of property owned by the player (e.g. in icons or symbols on a LCD display). The intangible representation is kept updated by a computer game engine during the playtime, as a consequence of players' interaction with game pieces and activation of game rules. The interaction with pieces is based on a double loop [7].

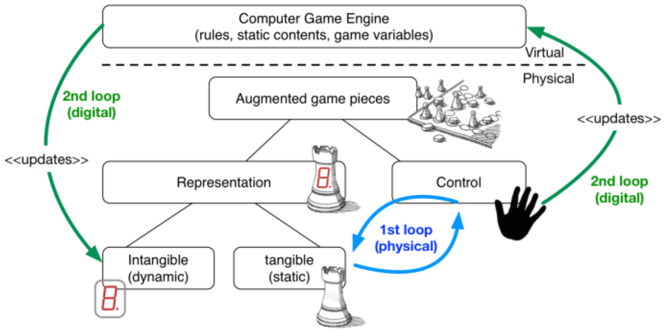

Fig. 1. Double interaction loop in interactive board games

A first interaction loop consists in the passive haptic and visual feedback the player perceives when manipulating pieces on the board, this loop is in common with traditional board games. A second loop adds interactivity by means of graphical and auditory feedbacks conveyed via the tokens' intangible representation (Figure 1). This loop requires technology for sensing tokens' manipulations as well as providing visual/audio feedbacks. The set of valid interactions with game pieces are defined by the affordances of pieces and by game rules. To formalize these rules we build on two theories: the T+C framework [8], providing a powerful descriptive language, and the MCRit model [9], addressing issues of representations and control in TUI.

2.2 Key design constructs

We define a game, which is composed by *game dynamics* (the sum of game logic and rules), as a sequence of player-initiated *interaction events* that modify *spatial configurations* of *tokens* with respect to board *constraints* and other tokens. In the following, building on the T+C framework, we describe key constructs required to develop an *Anyboard* game.

Tokens are technology-augmented artifacts capable of triggering digital operations that can activate game dynamics. They are an augmentation of traditional pawns, dice and cards. Tokens may be capable of sensing information (e.g. proximity with other tokens) and displaying computer graphic and sound.

Constraints are confining regions in the board space, for example checks in the Chess game and territories in Risk. The association or dissociation of a token within a constraint can be mapped to digital operations to activate game dynamic. Constrained regions are determined by a perimeter that could be visual, or physical.

Interaction events are player-triggered manipulations of tokens, that modify the (digital and physical) state of a game. We identified three types of events.

Solo-token event (T) - the manipulation of a single token over or on the board. For example, the action of rolling a dice or drawing a card.

Token-constraint event (T-C) - the operation of building transient token-constraint associations by adding or removing tokens to a constrained region of the board. T-C events can have different consequences depending on game rules.

Token-token (T-T) event - the operation of building transient token-token adjacency-relationships, achieved by moving tokens on the board. For example, approaching a token next to a different token to unlock special powers, or to exchange a resource between two players.

Sequence of *interaction events,* validated against game-specific rules, activate game dynamics and allow the game to evolve from a state to another. For example, we can model the act of capturing a piece in chess as a sequence of interaction events that modify proximity between two chess tokens within checkers constraints. For more details, see [10].

In the following section we describe how theoretical contracts have been implemented for the augmentation of an existing board game.

2.3 An example

Don't Panic, is a collaborative game inspired by Pandemic[3]. Four players start the game as member of a panic manager team that must work together to manage panicking crowds. A map representing a city map is displayed on the game board and the territory is divided in *sectors*. Each sector contains a number of people (PO) characterized by a panic level (PL). During the game randomly triggered panicking events (e.g. fires, explosions) increase PLs in determinate sectors. Each player is represented on the board space by a personal *pawn token* and gets a limited number of actions with the goal to lower the panic level in the city. Using the public *"Calm!" and "Move!" tokens* a player can either reduce the panic in a specific sector or move panicked people to an adjacent sector. Information *cards tokens* distributed in each turn can lower the panic in multiple sectors. Players collectively win the game when the PL in all sectors is zero. For a full description of game rules see [11].

Don't Panic is composed by a cardboard and a set of tokens:

The board (Figure 2-a) – is a cardboard that visualizes a map portraying a territory divided in nodes, sector and paths. Nodes feature physical *constraints* and no degree of freedoms for the hosted tokens; sector and paths provide visual *constraints* allowing tokens' translation and rotation, within the perimeter.

The card deck (Figure 2-c) – dynamically print information card *tokens*. Each card has a textual description of how it affects the game and a barcode that links the card to its digital representation. The top surface of the card deck can read the barcode on the card and trigger actions in the game (Figure 2-d).

Pawn tokens (Figure 2-b) – embody the players' presence on a node. Pawns can be moved from node to node and provide visual information via a LCD display. These include the role of the player, number of people present in sectors adjacent to each of the four pawn's sides; and their panic level.

The Calm! token – represent the field action of calming people talking to them, thus reducing the PL in a specific sector. This action is activated when Calm! is bumped towards a Pawn token (Figure 2-e).

---

[3] Pandemic board game - http://zmangames.com

The Move! token – simulates moving people across sectors, in this way people moved acquire the panic level of the recipient sector. This action is activated by dragging Move! across a border between two sectors (Figure 2-f).

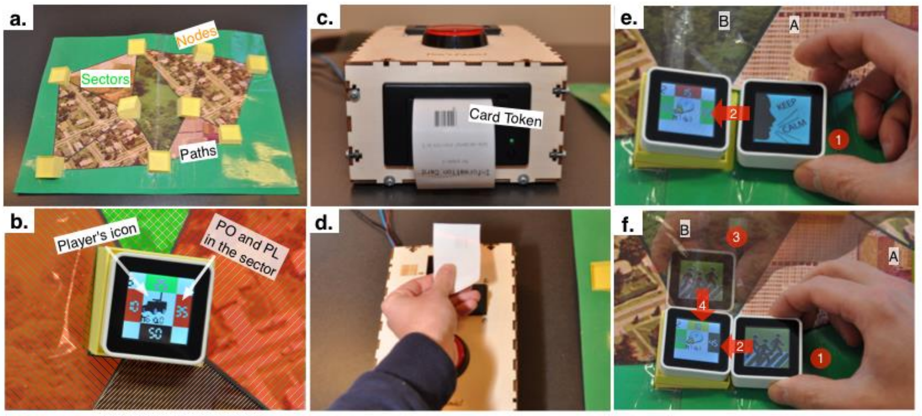

Fig. 2. Don´t Panic interactive tokens

3 The AnyBoard software library

We present here a library to bridge the gap between the theoretical constructs reported in section 2 and the making of interactive game pieces.

Game design communities, game developer environments and game engines already exist, and hence the main part that makes the AnyBoard framework unique is helping integrate the development interactive tokens interaction as a part of games (Figure 3). This role is performed by the *Token Manager* library.

The *token manager* provides a *Token API* to available game engines, so developers can listen to player-token events and send commands to the interactive tokens without the knowledge of the low level code or the tokens' hardware. The API provides primitives specifically suited for augmented board games, such as Token, Constraint and Interaction Events (Section 2.2). The API is generic enough to be used with popular game engines, both commercial and open source, such as Phaser[4] and Unity[5].

On the other end, the *token manager* is separated from any specific hardware implementation, and communicates with the physical tokens through *device-specific drivers*. Besides a set of tokens is provided as part of the framework, expert users can tinker them or build new tokens using popular toolkits such as Arduino and RaspberryPi. Drivers for the Arduino platform as well as a generic extendable driver will be provided to assist developers that wish to create their own tokens with specific technologies.

[4] Phaser game engine – http://phaser.io
[5] Unity game engine – http://unity3d.com

The AnyBoard library builds on the Apache Cordova[6] platform that enable games made for AnyBoard to compile to different operating systems, including mobile ones such as Android and iOS. We aim to use open source, free-to-use, modular and well documented tools, so that a developer can pick apart the AnyBoard system and add capabilities where need be.

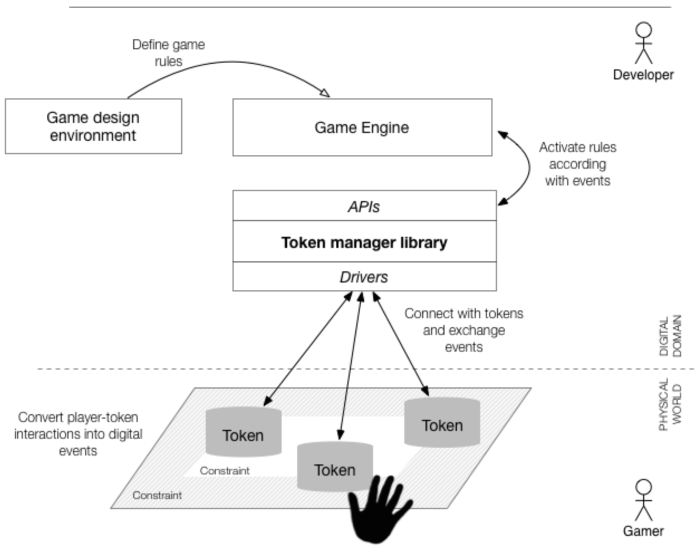

Fig. 3. High level components of AnyBoard

Standard example games, and templates implementing typical token capabilities, will be provided for developers that wish to create games with general token requirements.

Finally, a web-based community for AnyBoard is intended to grow a community and provide information for all roles involved with augmented board games. The AnyBoard platform will be available from there, and tokens sold from a third-party or made using prototyping techniques and open source schematics. The community will provide a knowledge base and tools for developers. Furthermore, it will feature a repository of ready to use *Anyboard games* and an assistive IDE for game.

4 AnyBoard for learning

Making an interactive board game with AnyBoard requires different competencies, varying from game design to software and hardware development skills, and it therefore opens for the design of learning activities with different and multiple learning objectives. In this section we reflect on how the platform, when fully developed, could be used for learning.

[6] Apache Cordova Platform - https://cordova.apache.org

The phases that are required for the full development of an AnyBoard game include:

- Game design, i.e. the definition of the game concept, logic and rules
- Interaction game design, i.e. the definition of the interactions of the players with the game tokens and the interaction among players, either directly or mediated by game elements
- Mapping of the game into the associated token+constraints system
- Implementation of hardware and software, this might range from implementation of the game engine to the development of the token interactions. This phase might also include the production of objects that are not computerized, like the board and cases to tailor the appearance of tokens, e.g. using 3D-printing.

The different phases allow to explore different learning goals through adequate activities. The design of the learning activity might focus on one or more of the following learning area:

- Specific subjects. If the game is designed as a serious game, i.e. by playing the game players are expected to learn X, it requires that students gain a knowledge of subject X to inform their design. In this perspective, the implementation part might be less relevant and the main focus is on the first phase of game design.

- Interaction design by designing the intended interactions among players and the interaction with the tokens. It should be noted that the actual design of the tokens appearance and interaction is strictly related to the game design. It can also become a way to learn about the game subject. For example, in developing a game for crisis management, one could work on tokens that resemble actual objects in the domain, mirroring their behavior in the real world.

- Abstract thinking/logic. To achieve this learning goal, in addition to the high level design, one should put focus on the translation of the high level rules into the framework constructs in terms of tokens and constraints.

- Coding. Learning to code can be achieved during the implementation phase. This might include both more traditional coding for the game engine and coding for embedded systems. In this way, different computational approaches, languages, and feedback systems might be explored.

- Tinkering. The design and implementation of the game requires to play around with different software and tangible components.

5 Conclusions: towards a revised framework

In this short paper we presented an innovative approach to design of interactive board games. The approach is based on the use of interactive tokens on an analogic surface, in alternative to current approaches that mainly rely on interactive surfaces. This approach, we claim, might be suitable to be used in the context of learning by making. The paper discusses the potential of the framework for learning.

To realize this vision there are a number of components that should be added to the framework, including:

- Graphical interface for coding, hiding if required by the design of the learning activity, the complexity of moving from high level rules to the token+constraint system.
- Templates for learning activities with different learning objectives. These templates should help the organizers of the learning activities to quick-start the design, choosing activities that reflect the intended learning objective.
- Scaffolding, possibly including support to hide complexity or irrelevant parts of the platform. This can be achieved in different ways at different level of complexity. It should be taken into account that board games might have a lot of objects and very complex rules that can be overwhelming for a non expert. At the same time, though learners are getting less distracted by developing graphics than in a traditional video games, still the development of the tangible parts might become very complex and distract the learner from other possible learning objectives.
- Community support oriented to education
- Analytics for reflection

As part of our future work we aim at developing these components following a learner-centered approach. This will require to identify more in detail the benefits of this approach compared to other types of game development for learning to focus the development of the component necessary for the more suitable learning activities.

REFERENCES

1. Yiannoutsou, N. & Avouris, N.: Game Design as a context for Learning in Cultural Institutions. In C. Karagiannidis, P. Politis, & I. Karasavvidis, eds. *Research on e-Learning and ICT in Education*. New York, NY: Springer New York, pp. 165–177, (2014).
2. Wang, A.I. & Wu, B.: Using Game Development to Teach Software Architecture. *Int. J. Comput. Games Technol.* (2011)
3. Horn, M.S., Crouser, R.J. & Bers, M.U.: Tangible interaction and learning: the case for a hybrid approach. *Personal and Ubiquitous Computing*, 16(4), pp.379–389 (2012).
4. Mellis, D.A. & Buechley, L.: Case studies in the personal fabrication of electronic products. In Proceedings of the Designing Interactive Systems Conference (DIS2012), ACM Press, pp. 268-277.
5. Haller, M., Forlines, C., Koeffel, C., Leitner, J., Shen, C.: Tabletop games: Platforms, experimental games and design recommendations. Art and Technology of Entertainment Computing and Communication. 271–297 (2010).
6. Bakker, S., Vorstenbosch, D., Van Den Hoven, E., Hollemans, G., Bergman, T.: Tangible interaction in tabletop games. In Proc. of ACE 2007. 163–170 (2007).
7. Ishii, H.: Tangible bits: beyond pixels. In Proc. of TEI 2008. (2008).
8. Ullmer, B., Ishii, H., Jacob, R.J.K.: Token+constraint systems for tangible interaction with digital information. ACM Transactions on Computer-Human Interaction (TOCHI). 12, (2005).
9. Ullmer, B., Ishii, H.: Emerging frameworks for tangible user interfaces. IBM systems journal. 39, 915–931 (2000).
10. Mora, S., Di Loreto, I., Divitini, M.: The interactive-token approach to board games. In Proceedings of AMI2015, LNCS, Springer (to appear).
11. Di Loreto, I., Mora, S., Divitini, M.: Don't Panic: Enhancing Soft Skills for Civil Protection Workers. In Proc of SGDA. 7528, 1–12 (2012).

Designing Creative Programing Experiences for 15 Years Old Students

Sofia Papavlasopoulou, Michail N. Giannakos and Letizia Jaccheri

Norwegian University of Science and Technology, Trondheim, Norway
michailg@idi.ntnu.no

Abstract. It is well known in the computer science education community that is important to encourage students to acquire programming skills and become creators and not only mere consumers. Different students have different needs and learning styles when introduced to programming and making activities, however it is challenging to accommodate all these needs while you design a workshop activity. In our approach we have designed and implemented a workshop program of 23 students' total, with the final goal of exploring and improving the design of appropriate workshops using the current learning environments. This paper presents an initial exploratory evaluation of a workshop program and the development of a set of guidelines for improving student experience. A set of best practices was developed through a focus group with experts using the technique of affinity diagrams. The results should be useful for designers and researchers who work with design and evaluation of programming workshop programs.

Keywords: Workshop program; design principles; creativity; programming; K-12 student

1 INTRODUCTION

Currently, several efforts to broaden participation in programming and introduce computational literacy to young students [1] [6] are in progress. Children interact with visual programming tools like Scratch [8] to learn how to code by creating interactive stories, games, animations, and simulations. Sesame workshop [9] has given new insights into how programming for children needs to be approached; in order to be both educational and entertaining. The process for achieving this mix relies on a development model that integrates expertise in media production, educational content (or curriculum), and research with children. Sesame Workshop philosophy [9] identify some of the challenges and solutions in designing interactive educational activities that can be used by children. Buechley et al. [1] argue that there is a need to make children programming a far more informal, approachable, and natural activity.

Although, programming activities for K-12 students have drawn great interest in the last years, little information is available on how to introduce computing literacy to pre-university students. Teachers and curriculum designers need to be aware and pay particular attention to any challenge students experience.

Make2Learn 2015 workshop at ICEC'15, September 29, 2015, Trondheim, Norway.

In this paper, we present our experience from a programming workshop focusing on K-12 students. With the knowledge extracted from this experience we aim to explore how any potential principles and recommendations can contribute to improve current practices and workshops. This paper focuses on our efforts to develop a programming workshop that will allow K-12 students to explore their potential interest in computer science education. Hence, we provide some first insights on: Principles for facilitating programming workshops for K-12 students.

To do so, we designed, implemented, and evaluated a programming workshop program. For the basic evaluation we employed response cards, where students write their feedback. After the workshop, we organized a focus group with two computing education researchers in order to organize the collected data.

2 MATERIALS AND METHODS

2.1 Workshop

The Norwegian University of Science and Technology offers six science programs for primary and secondary school students with the objective of introducing them and raising their interest to various science disciplines from physics, chemistry, mathematics, biology, energy, to computer science. The program, dedicated to computer science education is based on the hypothesis that the interactions between the young students and artifacts in a creative activity are vital. In this program (see figure 1) students introduced to programming by playfully interacting with digital artifacts that also exhibit physical and aesthetical characteristics. Such artifacts allow students to learn by iteratively testing and rebuilding their designs [3].

Fig. 1. Picture from one workshop: children play, program, interact with the assistants.

Programming concepts are introduced as needed for the progress of the development of the artifact. For example, we did not introduce and explain all possible loop constructs, but rather introduce each one when and if it is needed. Students experienced problems, but the problems did not frustrate students since the needed concepts have been introduced to them. The activity designed to be and finally flowed as an artifact development project. Each of the sessions was based upon a specific concept such as movement, sound and visual effect of the artifact. For each session, a set of tasks is presented to the students: make the artifact to move its hand, connect sensors input with character movements etc. By constructing programs to implement the tasks one after another, students ended up with constructing/participating in an "artifact development", while being taught different programming concepts. The workshop program was based on Scratch programming environment as well as different hardware like Arduino, sensors, motors etc.

2.2 Extracting Principles via Focus Group and Affinity Diagram Analysis

The main objective of our study is to perform an exploratory investigation of the programming workshop and justify the different principles, which are vital for students' experience. The first step of our methodology was to collect students' feedback. Hence, by the end of the workshop we asked students to fill a response card with specific activities and attributes helped them learn best, and additional over-all comments/recommendations related to the 2-day workshop program (see figure 2).

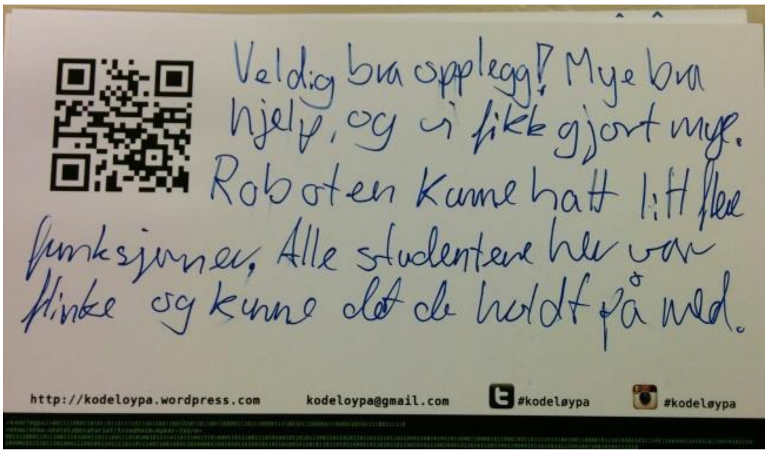

Fig. 2. Example of student's response card.

After cards collection a text analysis was performed and identified 73 comments/recommendations. Afterwards all the recommendations were translated into English, reprinted on to post-it notes and stuck onto the wall. Then, a focus group session was organized in order to analyze the gathered data. The purpose of the focus group, was to short all the comments/recommendations and form different principles. The focus group was consisting of two participants working in the area of computing education research, not involved with the workshop; the objective was to organize all the collected data within an affinity diagram. The affinity diagram technique organizes the loads of data (students' recommendations in our case) to greater detail and often leads to results based on a consensus among participants [7]. This technique is appropriate to organize large amounts of qualitative data in groups according to the relationships among the ideas or topics. Affinity diagram technique includes tree main steps:

(1) Create notes for each idea
(2) Identify related ideas
(3) Categorize all notes in groups

As aforementioned all the post-it notes stuck onto the wall. Then, both participants review, group and reposition them within the different categories and tried to construct sub-categories, if possible. This was an iterative process that consisted of adding or removing post-its until a pattern was discovered. Finally, the participants made headings for the constructed categories and subcategories (see figure 3).

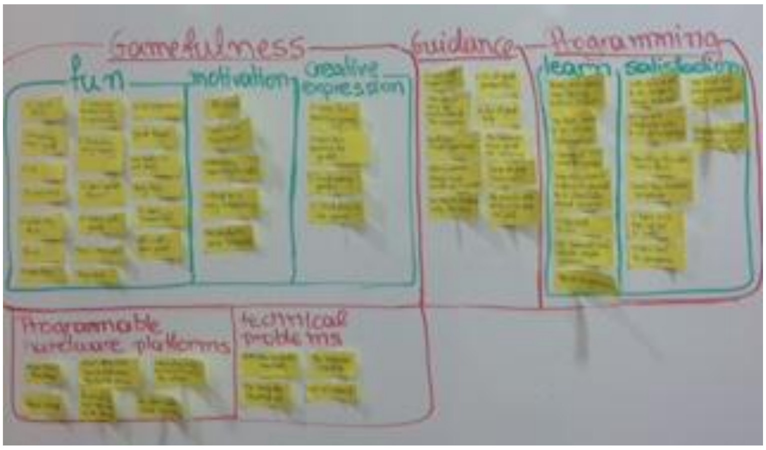

Fig. 3. The finalized affinity diagram: Overall recommendations categorization.

3 RESULTS

The affinity diagram consisted of the 73 recommendations and sorts them in five categories (figure 3): a) gamefulness, b) guidance, c) programming experience, d) programmable hardware platforms and e) technical problems. Initially, each category was consisted of 5-31 items. Then, the focus group indicated that within each of two general categories (gamefulness and programming experience) could correspond three subcategories. Also, six best practices were removed because were considered as irrelevant. The five general categories and their subcategories are described below.

Gamefulness: The "Gamefulness" category was defined as the use of game elements during the workshop with an aim to increase engagement and motivation. This category includes three sub-categories (fun, motivation and creative expression) that clarify the different aspects of children's attitude to coding. "Fun" includes all practices/ ideas that describe the workshop as joyful experience. The "Motivation" sub-category was defined by the focus group as all the recommendations showing that coding was an interesting experience for students and most of them would like to participate in another workshop. Third sub-category, "creative expression" consists of practices/ideas that allow students' to express their creativity on coding, like making games controlling the artifacts.

Overall, almost all students agreed with the idea that they had fun during the workshop program. Programming workshops should aim to provide a pleasant atmosphere, giving the impression that programming is an enjoyable experience. Student's intention to participate again in other creative programming workshop increases when they feel happy during the workshop [4]. The attractive appearance of the digital artifacts with physical and aesthetical characteristics can be important for student's interest in programming. For example, artifacts should look like a character that students are familiar with and could support relevant play activities that student's can explore.

Guidance: In this category, all recommendations related to the importance of help and assistance during the workshop were sorted. As mentioned, each loop construct was explained only when and if it was needed. Some of the students seemed to be more familiar with the programming environment and other had more limited understanding. Students expressed their appreciation for the guidance and help on how to apply the different programming concepts in order to interact with the artifacts.

Some of the most important aspects of this category were collaboration and communication among the students. Also, peer support and guidance allowed students to become confident with programming. In summary, proper and sufficient guidance was very beneficial to help students to construct the appropriate competences during the workshop [2]. As aforementioned, programming workshops should provide a happy environment and students should feel free to ask and collaborate for a better "artifact development".

Programming Experience: In order to describe the general category of "programming experience" the focus group created two sub-categories. The first sub-category is "learn", which contains the recommendations related to the learning procedure of the workshop. For example, some of the comments mentioned "I learn about coding" indicating that the workshop achieved its goal. Also, recommendations that showed satisfaction from coding were sorted in the second sub-category "satisfaction". Many students liked very much constructing programs and execute the tasks successfully. Their satisfaction derived from the fact that they were able to complete the asked tasks, and construct the needed artifact.

It is also important to stress the benefits of students' satisfaction. The instructors noticed that satisfaction leaded students to minimize their frustration and follow the needed tasks. Therefore, it is crucial for the design of the workshop to adapt to different students' needs like age and previous knowledge.

Programmable hardware platforms: This category includes the recommendations related to the interaction with the physical components. Students have the freedom to explore how artifacts could move, communicate with the environment, make sounds, etc. The workshop is based on a visual programming environment to construct these affordances. The programming environment (Scratch for Arduino) requires that a physical artifact is the beneficiary of the developed software. Students felt more positively interacting with the artifacts, understand the functionalities and explore how they work. They had the opportunity to see in practice how different programming concepts are applied.

Students participated in an “artifact development” using computing tools and techniques for creative expression. Interaction with the artifacts requires flexible hardware and software tools. These tools could be implemented to specific disciplines from physics, chemistry and mathematics to poetry, history and human anatomy [7]. Educators should connect computational artifacts development with other disciplines. The variety of different disciplines ensures that students’ interest will be raised, by connecting programming with other well-known to the students’ notions like scientific phenomena in physics and chemistry.

Technical problems: In this category the focus group sorted all recommendations that describe problems with the software or the artefact. For example when the computer crashed, or took a lot of time to perform a task; another example is wrong connections with the boards, functional sensors etc.

This category stresses the importance of a robust software and hardware environment to ensure an uninterrupted progress as well as to support students’ creativity and imagination.

4 CONCLUSIONS AND THE WAY AHEAD

In this paper we presented the results from an investigation of a programming workshop for K-12 students. Our results provide an initial attempt to exploit knowledge from K-12 students and model this knowledge into useful principles for educators and curriculum designers who aim to develop K-12 programming workshops. The study described in this paper has led to a set of guidelines for improving and better designing programming workshops. The guidelines were backed by students’ experience and have been exposed to several stages of validation and organization (focus group, affinity diagram analysis), which should provide some assurance of their validity. Based on this, five have been extracted.

The main principle for facilitating programming workshops for K-12 students is to provide a pleasant atmosphere. Students’ interest rises when they have the feeling that they can playfully interact and explore the functions of the digital artifacts. Educators and curriculum designers should offer practical applications in order to empower students’ interest to programming. They should aim to improve the overall learning procedure of the workshops by reforming the digital artifacts, giving the proper guidance and define the specific goals. This will offer perseverance and reinforce students' passion to deal with challenges, failures, adversity and success with computer science.

We want to emphasize that our findings are preliminary with inevitable limitations. Our future research will concentrate on further refinement of the proposed principles by applying and evaluating them on real conditions. Furthermore, educators, practitioners and researchers in the areas of computer science education should evaluate the proposed principles in order to ensure their understanding and seek suggestions and extensions.

Acknowledgements. We would like to thank all the participants of the study. We also thank Finn Inderhaug Holme, Irene Dominguez Marquez and Ilse Gerda Visser for setting up and running the workshop, P. Bøyesen and A. Eriksen I. for their contribution in the early phases of this project, Eirik Høydalsvik for assisting us with the translation of the cards and the colleagues at the department who work for making Kodeløypa possible.

5 References

1. Buechley, L., Eisenberg, M., Catchen, J., and Crockett, A. 2008. The LilyPadArduino: Using computational textiles to investigate engagement, aesthetics, and diversity in computer science education. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Florence, Italy April 5–10, 2008) CHI'08. ACM, New York, NY, 423–432 DOI= http://doi.acm.org/ 10.1145/1357054.1357123.
2. Buffum, P. S., Martinez-Arocho, A. G., Frankosky, M. H., Rodriguez, F. J., Wiebe, E. N., and Boyer, K. E. 2014. "CS principles goes to middle school: learning how to teach "Big Data". In *Proceedings of the 45th ACM technical symposium on Computer science education* (Atlanta, Georgia, USA March 5–8, 2014) SIGCSE'14. ACM, New York, NY, 151-156 DOI= http://dx.doi.org/10.1145/2538862.2538949 2014.
3. Cassell, J. 2004. Towards a Model of Technology and Literacy Development: Story Listening Systems, *Journal of Applied Developmental Psychology* 25, 75-105.
4. Giannakos, M. N., Letizia, J., and Leftheriotis, I. 2014. Happy Girls Engaging with Technology: Assessing Emotions and Engagement Related to Programming Activities." *Learning and Collaboration Technologies. Designing and Developing Novel Learning Experiences*. Springer International Publishing, 398-409.
5. Hamner, E., and Cross, J. 2013. Arts & Bots: Techniques for distributing a STEAM robotics program through K-12 classrooms. In *Proceedings of the Third IEEE Integrated STEM Education Conference, Princeton, NJ, USA*.
6. Kafai, Y. B., Lee, E., Searle, K., Fields, D., Kaplan, E., & Lui, D. (2014). A crafts-oriented approach to computing in high school: Introducing computational concepts, practices, and perspectives with electronic textiles. *ACM Transactions on Computing Education* (TOCE), 14(1), 1.
7. Maguire, M., and Bevan, N. 2002. User requirements analysis. A review of supporting methods. In *Proceedings of IFIP 17th World Computer Congress*, (Montreal, Canada), 25-30.
8. Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K.. and Kafai, Y. 2009. Scratch: programming for all. *Communications of the ACM*, 52(11), 60-67.

9. Revelle, G.L. 2003. Educating via entertainment media: The Sesame Workshop approach. *Computers in Entertainment (CIE) - Theoretical and Practical Computer Applications in Entertainment* ACM Comput. Entertain. 1(1), Art. 7.

Use of Augmented Reality in terms of creativity in School learning

Karamanoli Persefoni and Avgoustos Tsinakos

Eastern Macedonia and Thrace Institute of Technology
(EMATTECH)
Agios Loukas, Kavala, Greece

{persa , tsinakos}@teiemt.gr

Abstract. Education provides a plethora of tools that can be used (alone or combined) for achieving better results. One of the most recent technological advances that can be used as an educational tool is Augmented Reality, a technology that can combine virtual and physical objects in order to enhance the real world. However, little is known about this technology and its possible applications in primary and secondary education. This paper consists a literature review focused on AR and its current and future incorporation in modern education via various context aware technologies (e.g. tablets, smartphones) which can provide opportunities for more interactive and joyful educational experiences. Also, it is described the possibility of implementing AR in Open Course Project situations, such as the one which is available at the Eastern Macedonia and Thrace Institute of Technology. Its purpose is to inform "creators" and stimulate "users" so that the benefits of this promising technology may be diffused throughout the educational process.

1 Introduction

Education of the 21st century can provide a wide variety of tools that lead towards the achievement of better results. Traditional teaching methods, such as face-to-face instructions, along with some socio-cultural beliefs jointly shape an educational procedure where everything is controlled by the teacher (Nincarean, Alia, Halim, & Rahman, 2013). These educational systems are often described as monotonous, since they do not offer many possibilities for enhancing students' creativity (Tomi & Rambli, 2013).

One of the most recent technological advances that could be used as creativity promoting educational tool is Augmented Reality (AR), a technology that enables users to see and experience the real world mixed with various virtual objects, without losing the sense of reality (Cuendet, Bonnard & Dillenbourg, 2013; Fonseca, Martí, Redondo, & Sánchez, 2014). AR can accord a great potential for engaging, motivating and supporting the creativity of students in a restricted school environment, in ways that otherwise it could not be possible (Kerawalla, Luckin, & Woolard, 2006).

This transformation of learning with technology as a cognitive tool, according to researchers can increase the level of participation, understanding and learning, three

Make2Learn 2015 workshop at ICEC'15, September 29, 2015, Trondheim, Norway.

key elements of all educational systems' targets (Nincarean et al., 2013). Provided that the Information Technology (IT) tools have already been implemented in school class, the incorporation of AR in education is something that can be accomplished easier, as students are familiar with handling IT devices (Chiu & DeJaegher, 2015).

In this paper we present the basic characteristics of AR, the most used AR technologies and AR's incorporation, current and possibilities for future, in education. Also there is an example of AR's educational application that our team constructed. Finally, it must be mentioned that AR, as an educational tool, is being approached under the belief that learning has a strong social nature and the inclusion into human activity of a tool that affects this activity by transforming it, should be treated as something that influences both teams and individuals (Kerawalla et al., 2006).

2 Augmented Reality

The first and basic step for someone in order to follow any science path is the determination of the object under study. Many definitions may be given for Augmented Reality (AR), but the current study will use the following as the more representative (Cuendet et al., 2013):

"Augmented reality refers to technologies that project digital materials onto real world objects. This definition suits a large spectrum of technologies that range from a pure virtual environment to the real environment."

It must be mentioned though that AR applications and systems should have most or all of the above properties (Roesner, Denning, Newell, Kohno, & Calo, 2014):

- *Sense properties about the real world.*
- *Process in real time.*
- *Output information to the user, including via visual, audio, and haptic means, often overlaid on the user's perception of the real world.*
- *Provide contextual information.*
- *Recognize and track real-world objects.*
- *Be mobile or wearable.*

Another important fact related to AR is its origin, as it is considered to be the evolution of Virtual Reality (VR). It could be pointed that the basic difference between VR and AR is the fact that VR does not use at all the camera field, something that AR is based on (Sood, 2012). It would be really useful for the reader the presentation of a schematic classification from Real Environment (RE) to Virtual Environment (VE) in order for him to see the exact position of AR at the Reality-Virtuality Continuum (Salmi, Kaasinen, & Kallunki, 2012). As it can be seen, AR is in the middle of the two edges, which means that it combines the RE with the VE, but it is closer to reality.

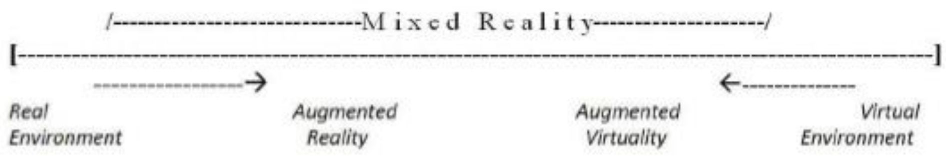

Fig. 1. Figure 1: The Reality-Virtuality Continuum (Salmi et al., 2012).

2.1 Technologies for Augmented Reality

Like every technology, AR needs some devices (hardware technologies) for its application. These devices usually are displays, computes, tracking and input devices. Two of the most common AR systems are: Head Mounted Displays (HMD) and Handheld Displays (Kesim & Ozarslan, 2012).

- *Head Mounted Displays (HMD)*

HMDs are displays that are applied on users' heads and their structure can be compared to this of a helmet. A typical HMD is comprised of one or two small displays that are bonded on a helmet or eyeglasses. They can display computer generated images or a combination of the real world enhanced with these images. They are usually applied in military, engineering and gaming situations. Due to their high cost they are not preferred for educational purposes (Kesim & Ozarslan, 2012; Rolland & Fuchs, 2000). Some basic examples are the Google cardboard, Google glass, Microsoft Hololens etc.

- *Handheld Displays*

Handheld displays are small devices with computer software that a user can handle them with his hands. They can overlay graphical context onto an image from the real world. The most common and easy to use handheld displays are smartphones and tablets. Their greatest advantage is their portability, their significant low cost and their ease of operation. On the other hand users have to constantly hold them in front of them in order to have access to AR content. A handheld device, in order to be suitable for AR applications should have a camera, GPS, digital compass and marker systems. Their advantages render them as the most popular devices for educational applications (Kesim & Ozarslan, 2012; Wagner & Schmalstieg, 2006).

3 Augmented Reality in Education

Since AR is considered to be a relatively new technology, its incorporation in education is in a quite embryonic stage. It was only until 2000 when the first thoughts of applying such a technology started to make their appearance. Sheldon and Hedley explored AR's application in undergraduate education and concluded that it was useful especially for teaching courses that students could not fully understand and experience due to the limitations of the real world (Kerawalla et al., 2006). After this, the way for further more experimentation on incorporating AR in education was opened. Soon primary, secondary education and higher education institutions started applying experimentally AR in order to conclude whether it is really going to help students.

3.1 Current situation

Augmented Reality is available for educators in two different forms, location-aware and vision-based AR. With the location-aware type AR users, via a GPS supporting device, are able to have access to digital media as they move around to the physical world. On the other hand with vision-based type AR a device with a build-in camera can be used for presenting AR content, but only after user has pointed the device at an object that has been linked with digital material. These two forms of AR have been proven a significant helpful tool for educators in their effort to create a more stimulating and creative environment for students (Dunleavy & Dede, 2014). The above mentioned have led to the hesitant but increasing use of AR from educators all around the world and also the ever growing number of researches related to its extensive use in future years. In the next paragraphs, some research examples of AR in different stages of education will be presented.

In 2005 a team of researchers conducted a study in London, UK, for the potential of AR for teaching primary school science in ten year old children. Teachers and children were provided with an animated virtual representation of a spinning earth and a sun that they could rotate to aid understanding of the relationship between sunlight and night and day. Results showed that children taught with this system were less engaged than others that were taught with the traditional methods, teachers that used AR were more likely to ask children to watch an AR animation and describe it and finally teachers recognized the potential of AR technology but they would like it to be more flexible and controllable (Kerawalla et al., 2006).

Also, in 2011 A. Di Serion, M.B. Ibáñez and C.D. Kloos studied the effects of AR on the motivation of students on a visual art course at a middle school in Madrid, Spain. The presented material was relevant to the Italian Renaissance Art and it consisted of images and information of this period's paintings. The experiment included two situations, one with traditional teaching material (e.g. slides) and one with AR material. Results led to the conclusions that though AR is not mature enough for broad application in education the acceptance and enthusiasm of the participants showed that it can be an extremely helpful tool in the next few years (Di Serio, Ibáñez, & Kloos, 2013).

One of the most fruitful years of researches related to the incorporation of AR in education was 2013. A. B. Tomi and D. R. A. Rambli presented the development of a mobile AR application for preschool children related to the teaching of numbers with the use of an old story, *The Thirsty Crow*. The classic book was enhanced by augmenting virtual object like 3D images and sounds, via the use of a mobile device. The experiment showed that the use of AR content turned the whole procedure into a more joyful, creative and interactive learning experience and they unreservedly support the use of such technology in the educational procedure (Tomi & Rambli, 2013). Another AR tool that has been tested, in 2013, was related to teaching chemistry at a junior high school in Shenzhen of China. Students were able to control, combine and interact with a 3D model of micro-particles with the use of markers and also they were able to conduct a series of inquiry-based experiments. Researchers concluded that the AR tool had a significant supplemental learning effect as a computer-assisted learning tool, the AR tool was more effective for low-achieving students, students presented positive attitudes towards AR and that these attitudes were linked to their evaluation of the software.

Finally, a team from Spain studied the possibility of teaching human history with AR in 2014. The whole approach was called REENACT and is based on the exploitation of AR for improving the understanding of several historical events. Results were evaluated as "extremely good" since the participants were able to recall and most important understand more aspects of events like the Battle of Thermopylae. AR provided new experiences that could be generalized in all school courses (Blanco-Fernández et al., 2014).

Above from researches, several AR platforms have been developed in order to facilitate the creation of AR applications. One of the most popular platform is ARlearn. ARlearn was created from the Open University of Netherlands as an AR tool for educators and learners. It supports mobile serious games and can be used for many projects, e.g. organization of a school trip or for the creation of a simple logic game for mobile phones. It is open and free but can only be used from Android devices. Also, with the use of the web based authoring tool someone is enabled to create his own games. As a platform, ARlearn, can support two types of games, games with messages in a list view and view map games. It provides four types of media objects (video, sound, narrative and multiple choice questions), map based positioning of media objects, a notification framework and the ability to download games to PC in order to be reused (Classroomaid, 2013; Open_University_of_Netherlands). Several projects have been made where ARlearn was used as an education tool. Some of these projects are: The *ELENA* project and *"Elena goes shopping"* mobile game for e-learning of languages from young children (4-6 years old) and the *"Emurgency"* program for decision and behavior training for cardiac arrest. (Classroomaid, 2013)

3.2 Future incorporation

Based on the results of researchers related to AR in education and on the fact that most of them agree that when using AR there are significant benefits for students, there are some actions that could be taken for incorporating AR into the modern educational systems (Steve Chi-Yin Yuen, Gallayanee Yaoyuneyong, & Johnson, 2011). These actions can result to the maximum augmentation of both learning and teaching environments, something that has great effects over children's creativity and future academic career (Billinghurst, 2002).

- Use of AR books

AR books can be used even from the primary level of education. They can provide a really good way of combining the physical with the digital world, since they can present interesting digital material (e.g. 3D images and sounds) as an enhancement of the traditional book. Users can create connections with books that may encourage their imagination, creativity and occupation with reading. They are also a cheap way of presenting AR in classroom as there is no need for changes on the school book. In this way students, with the use of a simple handheld display device, can experience knowledge in a more interactive and joyful way (Tomi & Rambli, 2013).

- Use of AR Gaming

One of the most common teaching approaches in primary and secondary education is learning via games. Games have the ability to promote children's collaboration, creativity and imagination but also provide a great source of acquiring knowledge (Moschini, 2008). With the use of AR simple games can be transformed into richer and more appealing for all kind of students. With the use of markers traditional game board games can come alive via digital content and can be used for all kinds of courses, e.g. History, Archaeology, Geography and Art. Another approach is that of virtual environments where students can create their avatars and participate in online games that may have a link with the physical world (use of GPS and location-based AR) (Blanco-Fernández et al., 2014; Steve Chi-Yin Yuen et al., 2011).

- Use for modeling of objects

Another innovative way for inserting AR in classroom is modeling objects. This way allows students to visualize exactly how an item appears and also helps to overcome the boundaries and limitations of a class. Teachers, via AR, can familiarize their students with unknown situations and help them explore the most remote corners of the universe and the most inaccessible depths of the oceans (Chiu et al., 2015).

- Use for discovery learning

An educational approach of learning that stimulates students is the discovery learning. Students get to explore the outdoor environment and get in touch with knowledge at its source. But this way of teaching is not always convenient since it can be really expensive and time consuming. AR applications that provide virtual tours of different places are very easily to be found (Chen, 2014). These applications can be used in class and provide a quick, cheap and easy way to access of letting students interact with the external environment (Steve Chi-Yin Yuen et al., 2011).

- Use at Open Course Projects

One of the most current trends in education is lifelong learning and especially through Open Courses, which enable learners to broaden their research scope according to their interests. This way of teaching may give to its participants "new insights into their fields as well as make the teaching process more rewarding". Also, it can provide the ability to achieve a better level of engaging students with the academic process. AR, as an innovative technology, can boost the performance of these courses, since it is an easy, cheap and extremely interactive way of enriching the curriculum of various Open Course Projects (Dave Cormier & Siemens, 2010).

The Eastern Macedonia and Thrace Institute of Technology (EMATTECH) participates to the National Open Academic Courses initiative (GUnet, 2015) by contributing a large number of subjects taught at the various departments of the institution. The developed courses are distinguished into three categories (A-, A, A+).

- A- Courses: This category provides a description, objectives, keywords, notes and presentation slides, literature and other educational materials, organized into topics.
- A Courses: They contain materials found in A- Courses and additionally include podcasts, synchronized with presentation slides.
- A+ Courses: They provide what has already been reported in previous course categories and in addition they include video-lectures.

As all courses of all categories contain learning material in electronic form, the first step is to acquire this material and upload it to the institutional distance learning platform. The platform that was selected for this purpose at the Eastern Macedonia and Thrace Technological Institute is Moodle. The electronic material can be lecture notes, presentations, exercises or any other material that the lectures wish to be included. As soon as the material for a particular course is received, a corresponding distance learning course is created in Moodle, and the learning material is organized in sections according to the lecturer's requirements. In addition to educational material the electronic form, A+ category also include videos of lectures in high-quality digital form. Recordings of lectures can take place either during the actual lecture delivery to students with the use of portable equipment, or at a time of the lecturer's choice, using a room equipped with a static camera. As soon as a lecture is completed, the resulting video is stored on an FTP server, where it can be accessed at a later time for video editing. When the video lectures are prepared (i.e. processed, edited and converted to an appropriate format), they have to be uploaded to the OpenDelos platform (GUnet, 2015).

AR could be used as an educational tool for improving the results of EMATTECH's Open Course Project, via open source AR software such as Aurasma, ARToolKit, Junaio or Wikitude. The addition of AR components in the output of Open Course project will result to the enhancement of learning content and of the learning process, as the learner should be also able to interact with the video and other leaning material rather than simple download and access it.

The abovementioned ways of incorporating AR in future educational settings provide easy to apply ways that do not consist a financial burden for a country's educational system.

4 Conclusions

As Information Technologies are becoming a part of modern educational systems (European_Commission, 2014; European_Union, 2013) teachers and educators try to find joyful and efficient ways of incorporating them in their classes. AR is one of the most promising technologies for educational applications, and this is why researchers all around the world are experimenting on how its application could reach its full potential on students' progress. Its capability to combine the real world with virtual content presents new possibilities for learning and enhances the quality of the provided education.

AR has the possibility to entirely change the way that people treat education. Students can now interact with digital content that empowers their imagination, creativity and learning. Teachers can incorporate AR via various ways like AR books, AR games, modeling and discovery learning. It is essential to try and adopt technologies and techniques that will improve educational systems and by extension children's experiences.

Acknowledgment

The current research paper is implemented through the Operational Program "Education and Lifelong Learning" and is co-financed by the European Union (European Social Fund) and Greek national funds.

References

Abelson, H., & MIT. (2014). MIT App Inventor 2: MIT. Retrieved from http://ai2.appinventor.mit.edu/

Aurasma. (2015). Aurasma. Retrieved 15/2/2015, from http://www.aurasma.com/#/whats-your-aura

Billinghurst, M. (2002). Augmented Reality in Education. *New Horizons for Learning.* from http://www.solomonalexis.com/downloads/ar_edu.pdf

Blanco-Fernández, Y., López-Nores, M., Pazos-Arias, J. J., Gil-Solla, A., Ramos-Cabrer, M., & García-Duque, J. (2014). REENACT: A step forward in immersive learning about Human History by augmented reality, role playing and social networking. *Expert Systems with Applications, 41*(10), 4811-4828. doi: http://dx.doi.org/10.1016/j.eswa.2014.02.018

Chen, W. (2014). Historical Oslo on a Handheld Device – A Mobile Augmented Reality Application. *Procedia Computer Science, 35*(0), 979-985. doi: http://dx.doi.org/10.1016/j.procs.2014.08.180

Chiu, J. L., DeJaegher, C. J., & Chao, J. (2015). The effects of augmented virtual science laboratories on middle school students' understanding of gas properties. *Computers & Education, 85*(0), 59-73. doi: http://dx.doi.org/10.1016/j.compedu.2015.02.007

Classroomaid. (2013). ARLearn for Authoring Mobile Serious Games. *Mobile Learning* Retrieved 15/2/2015, 2015, from http://classroom-aid.com/2013/03/02/arlearn-for-authoring-mobile-serious-games/

Cuendet, S., Bonnard, Q., Do-Lenh, S., & Dillenbourg, P. (2013). Designing augmented reality for the classroom. *Computers & Education, 68*(0), 557-569. doi: http://dx.doi.org/10.1016/j.compedu.2013.02.015

Dave Cormier, & Siemens, G. (2010). The Open Course: Through the Open Door--Open Courses as Research, Learning, and Engagement. *EDUCAUSE, 45*(4), 8.

Di Serio, Á., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers & Education, 68*(0), 586-596. doi: http://dx.doi.org/10.1016/j.compedu.2012.03.002

Dunleavy, M., & Dede, C. (2014). Augmented reality teaching and learning *Handbook of research on educational communications and technology* (pp. 735-745): Springer New York.

European_Commission. (2014). EU high level group calls for targeted funding to boost use of new technologies in higher education [Press release]. Retrieved from http://europa.eu/rapid/press-release_IP-14-1188_en.htm

European_Union. (2013). Opening up Education: Innovative teaching and learning for all through new Technologies and Open Educational Resources. 2015, from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52013DC0654

Fonseca, D., Martí, N., Redondo, E., Navarro, I., & Sánchez, A. (2014). Relationship between student profile, tool use, participation, and academic performance with the use of Augmented Reality technology for visualized architecture models. *Computers in Human Behavior, 31*(0), 434-445. doi: http://dx.doi.org/10.1016/j.chb.2013.03.006

GUnet. (2015). Open Academic Courses. Retrieved 25/8/2015, from http://www.opencourses.gr/

Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A. (2006). "Making it real": exploring the potential of augmented reality for teaching primary school science. *Virtual Reality, 10*(3-4), 163-174. doi: 10.1007/s10055-006-0036-4

Kesim, M., & Ozarslan, Y. (2012). Augmented Reality in Education: Current Technologies and the Potential for Education. *Procedia - Social and Behavioral Sciences, 47*(0), 297-302. doi: http://dx.doi.org/10.1016/j.sbspro.2012.06.654

Moschini, E. (2008). *The Construction of Knowledge through Gaming. How to Engage University Students in the Understanding of the Historical Developments of Knowledge and Scholarship via Playing and Networking*. http://ceur-ws.org/Vol-398/S2_Moschini.pdf

Nincarean, D., Alia, M. B., Halim, N. D. A., & Rahman, M. H. A. (2013). Mobile Augmented Reality: The Potential for Education. *Procedia - Social and Behavioral Sciences, 103*(0), 657-664. doi: http://dx.doi.org/10.1016/j.sbspro.2013.10.385

Open_University_of_Netherlands. ARlearn. Retrieved 13/2/2015, from http://portal.ou.nl/en/web/arlearn/home

Roesner, F., Denning, T., Newell, B. C., Kohno, T., & Calo, R. (2014). *Augmented reality: hard problems of law and policy*. Paper presented at the Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication, Seattle, Washington.

Rolland, J. P., & Fuchs, H. (2000). Optical Versus Video See-Through Head-Mounted Displays in Medical Visualization. *Presence: Teleoperators and Virtual Environments, 9*(3), 287-309. doi: 10.1162/105474600566808

Salmi, H., Kaasinen, A., & Kallunki, V. (2012). Towards an Open Learning Environment via Augmented Reality (AR): Visualising the Invisible in Science Centres and Schools for Teacher Education. *Procedia - Social and Behavioral Sciences, 45*(0), 284-295. doi: http://dx.doi.org/10.1016/j.sbspro.2012.06.565

Sood, R. (2012). *Pro Android Augmented Reality* Apress.

Steve Chi-Yin Yuen, Gallayanee Yaoyuneyong, & Johnson, E. (2011). Augmented Reality: An overview and five directions for AR in education. *Journal of Educational Technology Development and Exchange, 4*(1), 22.

Tomi, A. B., & Rambli, D. R. A. (2013). An Interactive Mobile Augmented Reality Magical Playbook: Learning Number with the Thirsty Crow. *Procedia Computer Science, 25*(0), 123-130. doi: http://dx.doi.org/10.1016/j.procs.2013.11.015

Wagner, D., & Schmalstieg, D. (2006, 25-29 March 2006). *Handheld Augmented Reality Displays.* Paper presented at the Virtual Reality Conference, 2006.