CULTIVATING THE 21ST CENTURY SKILLS IN THE MICROCONTROLLERS LAB

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1. Introduction

- This paper is a case study on the educational policies and learning methods used by the Computer Engineering and Information Science Dept. of the Hellenic Air Force Academy.
- In order to build the background, the underlying learning theories will be mentioned.
- Next, the so-called 21st century skills will be presented.
- A few words about the operation of the Microcontrollers Lab will follow.
- Then we shall describe the policies used for cultivating the 21st century skills.
2. The Arduino platform

- In the Microcontrollers Lab of the Computer Engineering and Information Science Dept. we use the Arduino board as an educational and experimental platform. Arduino is a series of low cost, free and open source software (FOSS) and open hardware microcontroller boards.

- Arduino provides an inexpensive, easy and fast way for novices and professionals to create devices that interact with their environment using sensors and actuators. Common examples for beginner hobbyists include simple robots, thermostats and motion detectors.
The first Arduino was introduced in 2005 and since then, its spread worldwide was unprecedented. The open-source Integrated Development Environment (IDE) includes a large number of FOSS working examples.

The board can be connected to a computer via a USB port. Through this port and the IDE, the code may be uploaded to the Arduino board and the microcontroller can send results back to the computer.
Arduino board
void setup() {
  while (!Serial); // wait for leo to be ready

  Serial.begin(9600); // this baud rate doesn't actually matter!
  //mySerial.begin(9600);
  delay(2000);
  Serial.println("Get version!");
  //mySerial.println(PMTK_0_RELEASE);

  // you can send various commands to get it started
  //mySerial.println(PMTK_SET_NMEA_OUTPUT_RMCGGA);
  //mySerial.println(PMTK_SET_NMEA_OUTPUT_ALLDATA);

  //mySerial.println(PMTK_SET_NMEA_UPDATE_1HZ);
}

void loop() {
  if (Serial.available()) {
    char c = Serial.read();
    Serial.write(c);
    //mySerial.write(c);
  }
}
Due to its FOSS nature, user-friendliness and wide range of automation applications, a vast community of Arduino enthusiasts has been created and includes region specific groups and special interest groups.

The official Arduino forum hosts posts in many languages but many more local national user communities also exist. International Arduino day was celebrated in 2014 and 2015.

Figure 2 shows a map of events held worldwide on the International Arduino day 2015 (March 28th, 2015).
Arduino is a good candidate platform for introductory programming as well as technology courses, such as those of the Greek Lyceum curriculum.

The wealth of available information about Arduino on the Web covers any possible problem, supports many topics, covers many ambitious projects and is therefore offered for learning by discovery. MOOCs about Arduino are also available.
Events held worldwide on Arduino DAY 2015
3. The educational scenario

- In our Microcontrollers Lab the exercises are implemented in groups of three students, using Arduino and a set of cheap, off-the-shelf components such as LEDs, resistors, sensors, speakers, etc. (Andreatos, 2015). The first educational examples are demonstrated by the instructor on a projector, and junior students, typically 20-21 years old, have the possibility to reproduce the experiments step-by-step, in real time. The instructor also demonstrates a technique for recording the whole experiment in a brief video, using the laptop's webcam and a set of FOSS tools. Students are supposed to use this technique in order to record their own videos.

- According to Vygotsky's social constructivism, this process develops the student's ability to do the same tasks on their own, without help or assistance.
3.2. Student identification issues

- One of the major reforms in modern formal education is the infusion of face-to-face instruction with technology-enhanced learning. The proliferation of Web 2.0 tools and low-cost portable computing devices enables teachers to assign project work to students, to be fulfilled outside of the classroom. In our case, the lab hours are not enough for the students to complete the lab curriculum, which also foresees a complex team project in the end.

- Project-based learning (PBL) is being used systematically by our Division because it has proven to be a great way of learning. Given that all our students are given laptops and can acquire an Arduino board at low cost, they can work on their own out of the class schedule. Moreover, students which were absent during the lab hours, are given the opportunity to complete the missed exercises at their own convenience, either in the lab or even at home, without supervision by the instructor. In both cases, the students have to prove:
  - a) their identity; b) that they were able to complete the exercise.
3.3. Proposed solution

The instructor has chosen to solve the above two problems in the following way: by the end of each exercise, students have to deliver two things: a) a report in digital format containing a description, their code, links and photographs taken by their smartphones, and b) a video taken by their laptop's webcam, demonstrating the stages and the completion of the exercise, the date, the code and the students' faces. The instructor selects the best video for each exercise and uses it as educational material for the following academic years.
4. Underlying learning theories

- Constructivism is being used systematically by our Division because it has proven to be a great way of learning. Learning is an active process.

- Bruner proposed that learners construct their own understanding of a subject by engaging in activities and building on past knowledge and experience. A lot of modern learning theories such as active learning, problem-based learning, experiential learning, learning by discovery, collaborative learning and computer-supported collaborative learning have been influenced by constructivism. Therefore, today's constructivism is not a single theory but rather a number of related theories and perspectives associated with ideas of active learning.

- Vygotsky put the bases of social constructivism in his theory of the "Zone of Proximal Development". Vygotsky stated that a child following an adult's example or working in collaboration with an adult, gradually develops the ability to do certain tasks without help or assistance.
4.1. Constructivist learning theories

- By having the instructor demonstrating the use of the Arduino board and IDE on the one hand, and the process for creating educational videos using common equipment on the other, we apply Vygotsky's social constructivism. By having the students work together in teams we apply social constructivism and collaborative learning. Learning by discovery, as well as, PBL, are used in the project.
4.2. Application of Constructivist learning theories

- By having the instructor demonstrating the use of the Arduino board and IDE on the one hand, and the process for creating educational videos using common equipment on the other, we apply Vygotsky's social constructivism.

- By having the students work together in teams we apply social constructivism and collaborative learning. Learning by discovery, as well as, PBL, are used in the project.
4.3. Social capital

- During the past four years a considerable social capital has been created in our Lab, shared among students and staff. This consists of imported sources such as books about Arduino, as well as, in-house educational material such as the Lab handout, the educational videos and past projects. In 2013, our lab organised an introductory Arduino seminar during the FOSSCOMM 2013 conference.

- Students have access to the educational material produced around the Arduino during the last four years; they also discuss various issues with their senior fellows (which have completed the course a year ago); in these ways, they access the lab's social capital. Their work will feed and enrich the social capital. The best projects are described in the lab handout which is revised and extended every year.

- Due to this process, each year the experiments and the projects get more and more complex; it has been observed that each new academic year, newcomers in the Lab get exposed to an increased social capital and are therefore capable of implementing more complicated projects than past years.
5. The 21st century skills

- The 21st century skills are a set of abilities that students need to develop in order to succeed in the information age. In order to prepare today's children for tomorrow's world, the Partnership for 21st Century Skills and the International Society for Technology in Education have drafted frameworks and guidelines that outline what our students need to know to meet the challenges of the modern age.

- Mastery of core content areas, such as language, mathematics, science and history, remains the centerpiece. But these two organisations emphasize the importance of cultivating interdisciplinary themes, such as global awareness and financial, civic and health literacies, and weaving key skill areas (creativity and innovation, communication and collaboration, research and information fluency, and critical thinking, problem solving and decision making) into core subject matter.
Beyond the 3Rs - the new skills the world is looking for.

- Leadership
- Digital literacy
- Communication
- Emotional intelligence
- Entrepreneurship
- Global citizenship
- Problem solving
- Team-working
Ten primary 21st century skills

- 21st century skills are critical for innovating and for operating more effectively and at lower cost. Therefore, 21st century skills are an important consideration for every educator striving to prepare today’s students for the competitive global market of tomorrow.

- Care and Griffin (2010) identify ten primary 21st century skills organised within four thematic areas:

  1. Ways of Thinking (Creativity and innovation; Critical thinking, problem solving and decision making; Learning to learn and metacognition);
  2. Ways of Working (Communication; Collaboration);
  3. Tools for Working (Information literacy including research on sources, evidence, bias, etc.; ICT literacy);
  4. Living in the World (Citizenship - local and global; Life and career; Personal and social responsibility including cultural awareness and competence).
### Ten primary 21st century skills

**Table 1**: Ten key 21st century skills organised within four thematic areas  
Source: Care and Griffin (2010)

<table>
<thead>
<tr>
<th>Thematic areas</th>
<th>Primary 21st century skills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1/ Ways of Thinking (3)</strong></td>
<td>Creativity and innovation</td>
</tr>
<tr>
<td></td>
<td>Critical thinking, problem solving and decision making</td>
</tr>
<tr>
<td></td>
<td>Learning to learn and metacognition</td>
</tr>
<tr>
<td><strong>2/ Ways of Working (2)</strong></td>
<td>Communication</td>
</tr>
<tr>
<td></td>
<td>Collaboration</td>
</tr>
<tr>
<td><strong>3/ Tools for Working (2)</strong></td>
<td>Information literacy including research on sources, evidence, bias, etc.;</td>
</tr>
<tr>
<td></td>
<td>ICT literacy</td>
</tr>
<tr>
<td><strong>4/ Living in the World (3)</strong></td>
<td>Citizenship - local and global</td>
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<tr>
<td></td>
<td>Life and career</td>
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<td></td>
<td>Personal and social responsibility including cultural awareness and competence</td>
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6. Skills cultivated by the proposed scenario

<table>
<thead>
<tr>
<th>Primary 21st century skills</th>
<th>Method used</th>
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<tbody>
<tr>
<td>Creativity and innovation</td>
<td>Final project; project-based learning</td>
</tr>
<tr>
<td>Critical thinking, problem solving and decision making</td>
<td>Final project; project-based learning</td>
</tr>
<tr>
<td>Learning to learn and metacognition</td>
<td>Final project; project-based learning</td>
</tr>
<tr>
<td>Communication</td>
<td>Team work</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Team work; social constructivism and collaborative learning</td>
</tr>
<tr>
<td>Information literacy including research on sources, evidence, bias, etc.;</td>
<td>Search for information about project, etc. Collaborative learning. Learning by discovery</td>
</tr>
<tr>
<td>ICT literacy</td>
<td>Learn by discovery how to find and process information, analyze &amp; synthesize</td>
</tr>
<tr>
<td>Citizenship - local and global</td>
<td>Arduino is supported by communities and individuals worldwide; our lab constitutes such a community; thus students feel part of the international community of Arduino users</td>
</tr>
<tr>
<td>Life and career</td>
<td>Develop professional skills in the lab and in events</td>
</tr>
<tr>
<td>Personal and social responsibility including cultural awareness and competence</td>
<td>Our lab frequently participates in social and cultural events such as the FOSSCOMM conferences, where students present seminars and projects.</td>
</tr>
</tbody>
</table>
Photos from FOSSCOMM 2013
Photos from FOSSCOMM 2013
Educational videos (demo)
7. Conclusion

• By applying modern learning theories in the lab practice, we manage to enhance the educational process, produce technically and educationally remarkable results and cultivate the 21st century skills.

• Using modern learning theories and practices, we strive to prepare our students for living and working in the information era.

• This is achieved at low lost with the use of cheap components, as well as, available equipment such as laptops, webcames and smartphones.
Contribution to Distance Learning

- We presented a way for creating educational videos using free tools;
- We also presented a way to check learners' ID in e-learning courses;
- We also presented a cost-effective way of implementing Microcomputer/ Electronics labs in distance learning courses.
THE END!

Thank you for your attention.

– Any questions?

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