Using Web Collaboration to Create New Physical Learning Objects

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Abstract. This paper describes the construction of a technological and collaborative infrastructure for the creation of physical learning objects. The solution uses a social network, digital fabrication lab and wiki page as an way to propose, build and publish educational objects. The idea is to create an innovative solution to get together a multidisciplinary team of students, teachers, professors and researchers that can propose, define, coordinate, build and publish these objects. The structure is presented and also the first objects and results.

Keywords: Digital fabrication · Social networks · Learning objects

1 Introduction

The reduction of the costs and consequent popularization of electronic equipments allows the creation of new technological solutions outside of the mainstream development industries. This new scenario creates a new generation of people motivated by the do-it-yourself culture, also known as the maker generation.

The expansion of the maker community results in the creation of collaborative spaces named: makerspaces - to develop any kind of object, technological or not; hackerspaces - with a more technological approach; and fablabs - a global network of collaborative digital fabrication labs created by the Center of Bits and Atoms of MIT [1].

Collaborative spaces for digital fabrication has a fundamental role in the creation of new objects because, despise of the reduced cost of the fabrication equipment (like 3D printers and laser cutters), the makers use the collaboration in order to increase the knowledge needed to make something. In these spaces, the users share specialized knowledge and techniques like design, software modeling, machine use, electronics, etc., in order to build new complete solutions. The users normally depend on each other and they grow in knowledge with the collaborative process.

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This paper presents the description of a collaborative web based technological infrastructure capable of produce a collection of educational tools in a digital fabrication lab. This collection is composed by physical objects coupled with sensor, actuators and network capabilities to be used in educational experiments. The propose and definition of the objects are made through a collaborative virtual social network and, after the definition process, the fabrication is made in the lab. At the end of the process, the final object is published in the web to be reproduced by anyone.

With this structure, we can use the object in classroom experiments, allowing the students to construct the relation between theory and practice, experimenting collaboration through the fabrication of the object and creativity to use and modify the object.

The authors intend to share the objects so that they can be recreated, used and modified in collaborative educational spaces by students, teachers, researchers and professors in educational and creative activities.

This project aims to build the needed infrastructure so that the collaborative learning process can occur, in a multidisciplinary fashion, through the creation of new physical learning objects.

2 Digital Fabrication and Education

The use of creation/fabrication spaces and the concept of "learning by doing" is aligned with the constructivist theories of Piaget. To Piaget, the "...use of active methods which give broad scope to the spontaneous research of the child or adolescent and requires that every new truth to be learned, be rediscovered, or at least reconstructed by the student and not simply imported to him." [2] apud [3]. To Piaget, teachers at the university and secondary levels should known their subjects and also make an interdisciplinary approach.

To researcher Seymour Papert: "In our image of a school computation laboratory, an important role is played by numerous controller ports which allow any student to plug any device into the computer... The laboratory will have a supply of motors, solenoids, relays, sense devices of various kids, etc. Using them, the students will be able to invent and build an endless variety of cybernetic systems." [2] apud [4].

The use of new technologies in education environments is not something new. The use of low costs electronics, sensors and controllers started with Papert, Michel Resnick and Fred Martin in the 90's using the Lego Mindstorm Kit [5]. Starting from these initial experiments, the increase in the availability of new low cost technologies normally brings new studies in how to use them in learning activities.

The specification and design of new objects normally takes place inside educational institutions, with the teacher acting as the starter of the process. The students engage in the fabrication and experimentation in local labs. Our goal is to expand this process making the specification step more embracing and allowing the share of the creations.

In order to achieve this goal the implemented infrastructure should allow that anyone with basic technological resources (internet connection, some form of fabrication and basic electronics) can study and build the available learning objects. Anyone should be able to add, recreate and modify the objects.

3 Creation and Publication of the Objects

The creation process follows three phases which are presented in Fig. 1.

In the first phase we have the proposer of the object, which describes the objectives of some learning experiment. He/she describes these objectives, publish this information for a community of teachers, students and researchers and invites some other specialist users.

All the people involved in this first definition phase create a micro-community inside our infrastructure. This micro-community collaborates through an "object space" created by the proposer, inside a virtual social network environment. They use this space to post comments, files and ideas in order to make the specification of the proposed object.

The objectives of the new learning object should consider: the theory involved; some initial ideas about the design; if electronic components should be used; and some initial ideas about the educational experiments that can be performed with this object.

Starting from this initial description, the micro-community collaborate through posts and files, discussing and presenting ideas about the object. In this phase, the micro-community should define the design attributes that the new object should have such as [6]:

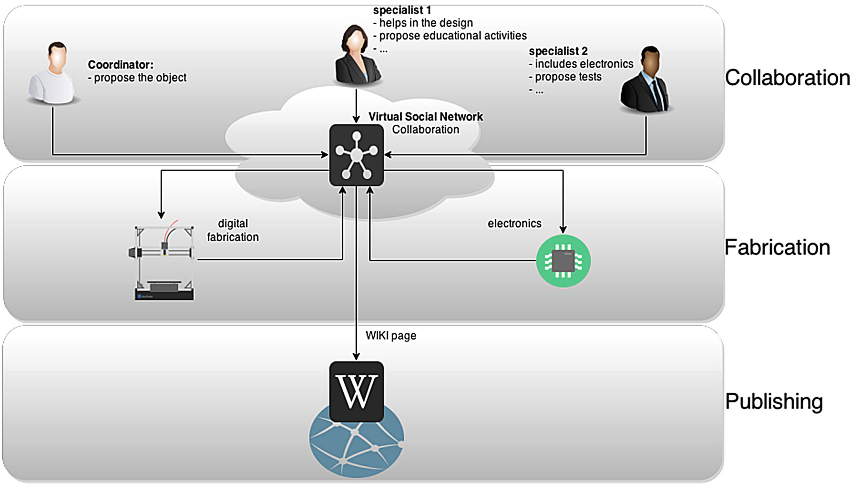

Fig. 1. Creation and publishing process

- **Affordances** - the shape of the object regarding the way that it should be used. The right shape leads the user to the right use of the object;
- **Signifiers** - signals in the object to lead the user like icons, buttons, colors, text, etc.;
- **Discoverability and Feedback** - the user should figure it out how to use the object and have the right feedback to each action performed.

The same process happens with the electronic parts needed in the object. The electronic specialists should interfere in the design process, indicating the restrictions and considerations regarding the electronic aspects of the object.

The construction of the educational aspects and the global/abstract development of the new object happens through collaboration inside this object space. All the creative process will be available and public to the community, serving as a new case for other object spaces.

We used the HumHub system as our virtual social network [7]. This system has a familiar user interface (similar to other social networks, like facebook) and allows the creation of discussion "spaces" among users. Each user can create a new space, publish it and invite other users to participate in that space. Each new object is proposed in a new space and the users collaborate in the space, forming the micro-community.

The Fig. 2 presents a object space in the social network interface. The users can publish posts and files, create wiki pages (through HumHub plugins), create collaborative text files, etc. In Fig. 2 the object space defines an eolic turbine to be used in environmental classes.

The object proposer is responsible for the coordination of the object space, guidance and allowing the collaborative process among the micro-community. Whenever necessary, the proposer can schedule meetings (virtual or face meetings).

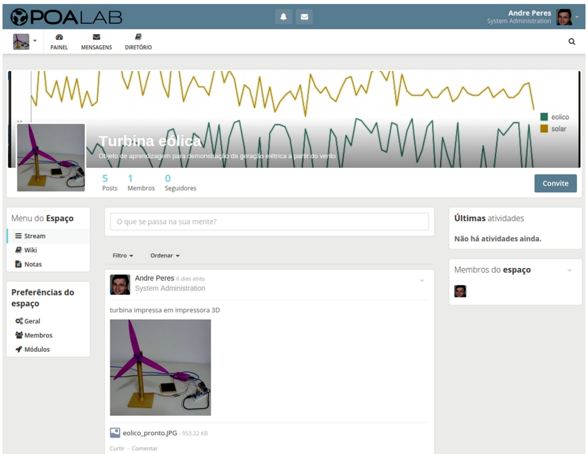

Fig. 2. Object space in the project social network

When the object is defined in its design, functionality, use and electronic requirements, we start the second phase: the fabrication.

In the fabrication phase, the team responsible for the fabrication of the object meets up at the digital fabrication lab. At this point, the collaboration is made in the lab and all the work is documented in the object space at the social network. Also, all the files generated in the softwares used to the design of the object (vector files, 3d files, computer code, etc.) are also stored in the object space.

The fabrication lab that we used has: three simple 3D printers (RepRap based); 1 vinyl cutter; 1 laser cutter; 1 cnc precision mill; arduino boards, sensors and other electronic equipment.

The object space is now used to post questions about the fabrication process, register use cases and to post proposition about modifications in the object.

When the object presents a positive history of use within the community, the final layout and files are published in an external repository in the internet. This publication is the third phase of the project.

For the third phase, we choose to use a wiki page to store the description, specifications, instructions and files of the objects that presents a positive history in the community. We used the MediaWiki system [8].

The wiki page serves as a repository for the files, and also as a way for users outside of our social network to interact with the objects designs. Anyone can edit the wiki, modify the pages and even create new pages (with new objects).

Each object should have published: its description and objectives; the list of electronic components needed; the electronic circuit description and schematics; images/photos; digital fabrication files; code; and examples of use in educational activities.

The Fig. 3 presents a wiki page that describes how to create the eolic turbine. In the page there is the description of: all the parts needed; how to change a computer fan in order to make a turbine; the 3D printer files to make the tower and helices of the turbine; code files to connect the turbine to an Arduino board [9]; and some PHP code to present the generated energy to an end user through the web.

4 First Results

The fabricated objects serve as a base for educational activities in different fields of knowledge. We present the first five objects in the next subsections.

4.1 Electromagnetic Sensor

The Electromagnetic Sensor object was proposed by one of our students based on the similar project published in [10]. The definition and design was made by 2 students in the social network.

The object goal was to be used in physics educational experiments, detecting the intensity of electromagnetic emissions and displaying this information in the computer screen.

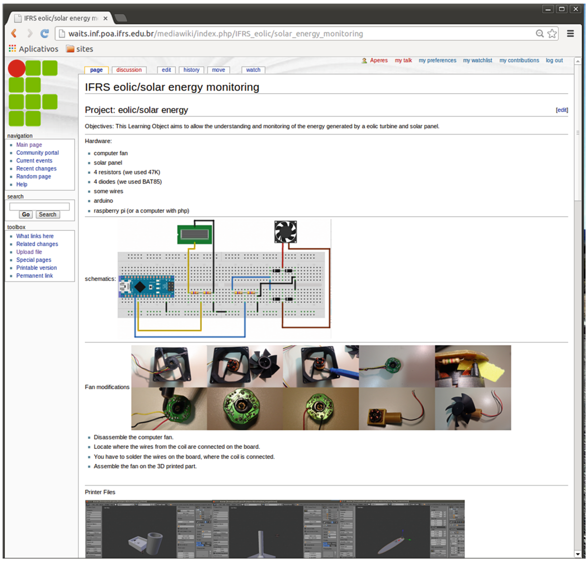

Fig. 3. Project wiki page

The electromagnetic interference is caused by the electron propagation in a conductor. The electric current in this conductor generates the electromagnetic field around it.

The sensor node quantifies the intensity of the electromagnetic field received by an antenna and plot this value in a graphic interface. In order to do so, the antenna is connected to an Arduino Uno board and the data received is send to a computer through the Arduino's USB interface. The computer generates the graphic interface in real time.

This object can be used to demonstrate the concepts of induction, interference and electromagnetism. The Fig. 4 presents the object, circuit layout and graphic interface.

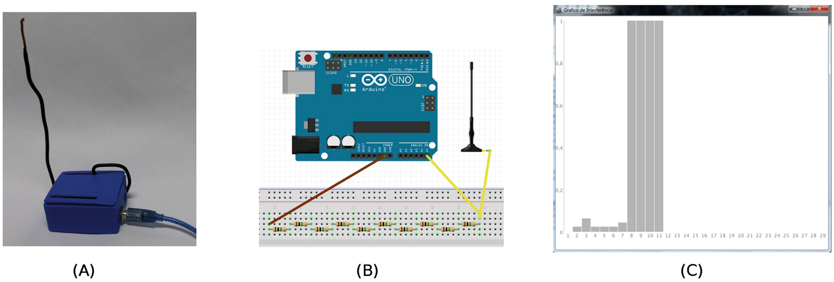

Fig. 4. (A) Electromagnetic measurement object (B) Circuit and (C) User interface

4.2 Water Conductivity Sensor

Similar to the Electromagnetic Sensor, the Water Conductivity Sensor also was proposed by 2 students based on [10]. After proposing the object, the students contact researchers from the Environmental courses in our institution. They contribute to the development of the object and in the lab tests.

The electrical conductivity is used to measure a material's ability to conduct an electric current. In aquatic environments it can be used to identify the presence of extra volume of ions (in polluted water with inorganic matter, for instance).

The authors of this paper has already worked with the Environmental researchers in a water quality project [11]. This new sensor aims to reduce costs in this type of environmental monitoring.

In this object we used an Arduino Uno board and connected two cables in 2 analog ports. We measure the conductivity in water sending 5 V to one of the cables and analyzing the current received by the other cable. With this values we can determine the resistance of the water.

In the same way as the Electromagnetic Sensor, we connected the Arduino board to a computer and generate a real time graphic with the values obtained by the sensor. The Fig. 5 presents the object, circuit layout and graphic interface.

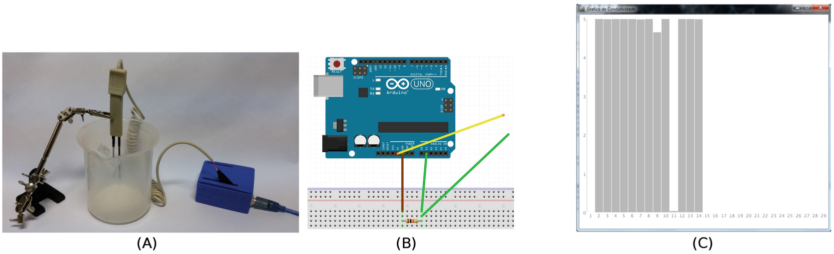

Fig. 5. (A) Water conductivity sensor object (B) Circuit and (C) User Interface

4.3 Greenhouse Monitoring and Control

Getting together researchers from Computer, Biotechnology and Environmental area, the Greenhouse monitoring and control is a web system developed to control a small greenhouse in the institution.

The object was proposed by one computer science student as its final project and evaluated by one computer science and one environmental professors.

This object controls the humidity, light and temperature of the greenhouse and has the ability to change these parameters by turning on led lights, water pump and fans.

The humidity, luminosity and temperature influence in every stage in the agriculture production. The construction of greenhouses helps in the control of these parameters and, the use of automatic resources increases the efficiency of the production.

It was developed a computer system capable of monitoring and controlling these factors using sensors and actuators connected to an Arduino board. The Arduino has an ethernet shield that allows the remote communication. The board collects data from sensors and send the data to a remote database through the Internet. The system has a defined policy regarding the expected humidity, light and temperature based on the specific plant needs.

The user can remotely monitor and interact with the board and the data is kept in the database for historic proposes.

The greenhouse is used by the environmental researchers in order to monitor the soil and make experiments with it, and by the biotechnology researchers to study plants reaction to specific chemicals. The automation of the greenhouse allows a better control over the plants which reflects in the quality in the results (the assurance that the results are not compromised by mistakes in the culture of the plants).

The Fig. 6 presents the arduino board, the sensors and the graphic monitoring interface.

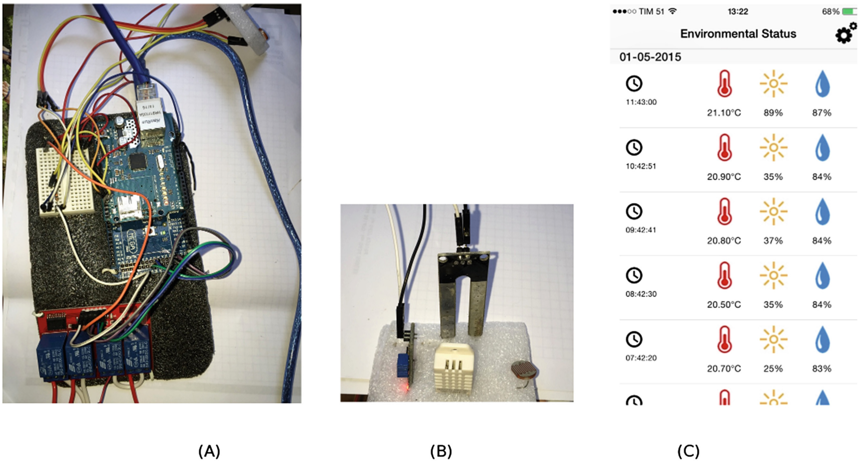

Fig. 6. (A) Arduino controller (B) Object sensors and (C) User interface

4.4 Air Quality Monitorining

Another final project proposed by one of the computer science students was the construction of a node for air quality monitoring. This object was evaluated by one computer science and one environmental professor.

It was created an object that is able to obtain data about the air quality using sensors and publishing it in order to be used in educational activities.

The object uses the National Council of Environment (CONAMA - Conselho Nacional do Meio Ambiente) air quality reference data in order to indicate the air quality.

The collected data is stored in a database and published as: raw data for scientific use; geographic data presenting a map with the sensor location and the air quality digest information; and in an educational interface, displaying the physiological effects of concentrations of obtained compounds data in humans.

The collected compounds are: Methane Gas Sensor - MQ-4, Carbon Monoxide Sensor - MQ-7, Hydrogen Gas Sensor - MQ-8, LPG Gas Sensor - MQ-6 and Optical Dust Sensor.

4.5 Eolic Turbine and Solar Panel

An eolic turbine was proposed by one computer science professor together with one environmental professor. The environmental course has an electric generation lab that is used by its students in order to understand the energy generation.

The lab has some energy generation kits capable of demonstrate how battery and solar panels works. Other objects were created by students using alternative materials.

Using the lab objects as a starting point, the professors proposed the construction of an eolic turbine made with a computer fan, connected to an arduino board. The computer fan was modified in order to generate energy. The arduino board monitors the amount of generated energy and sends this information to an raspberry-pi board through the USB port. The raspberry-pi has an LAMP (Linux, Apache, Mysql and PHP) environment and plots the received data in to a graph.

It was also connected to the arduino board one solar panel. The graph plotted by the raspbberry-pi shows both graphs - the eolic turbine and solar panel.

The eolic turbine tower and solar panel base was fabricated using an 3D printer. The Fig. 7 presents the object, the circuit and the web interface generated by the raspberry-pi.

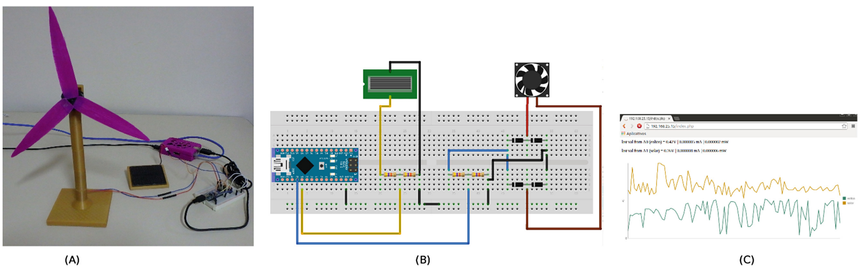

Fig. 7. (A) Eolic turbine and solar panel object (B) Circuit (C) User interface

5 Conclusions

This project put together a set of technological solutions in order to allow a better interaction and collaboration among students, professors, teachers and researchers in the development of new objects that can be used in educational activities.

We created this infrastructure with: social networking as a platform for proposition, definition, coordination and collaboration in the construction of innovative educational objects; a digital fabrication lab to construct the proposed object and be a place to meet and talk about the objects; and a publication platform in a wiki page, that can publish all the objects created together with their files, photos and description, allowing anyone to build, modify, increment or adapt the objects.

We consider that the collaboration process was successful during the proposing and fabrication of the first objects. Also, the authors consider that this first objects can serve as a base for the expansion of the infrastructure through the inclusion of new collaboration mechanisms in the social network and the increase in the number of its users.

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