Junior Journal

Learning through Making – with Relevance to Robotics Education

Autonomous Projects

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Abstract

Through the past years, we have seen the development of the Maker movement, and the increasing involvement in the field of robots. More school teams have been joining Robotics competitions like the Botball competition and the First Lego League (FLL). Moreover, more makerspaces and hacker-spaces are being founded all around the world.

This paper will explore what a maker is (with relevance to making robots), and define some of the important terms and concepts of the Maker Movement and Robotics Education. Then, the paper will explore the importance of integrating both 'learning through making' and robotics into educational systems, and how the implementation of that could occur.

Keywords Maker Faire, Fab Lab, 3D Printing, Botball, Education

1. Introduction

As part of our school's Botball Robotics team in its fourth year, and with members involved in Fab Lab Egypt, we have understood the importance of being involved with such activities, and have realized to what extent our involvement in Robotics has helped us develop and grow both as individuals and as members of our community. We firmly believe that more schools should aim to involve their students in robotics activities on a larger scale, and that school curricula worldwide should teach students the fundamental skills needed to be 'makers'. Schools should encourage their students by giving them the tools and knowledge to be makers and doers, as a way to educate and encourage them. More importantly, the educational system should support students who have a passion for robotics, as a way for them to improve, develop, and become makers and doers in their societies.

2. Making

The maker movement, as defined by Maker Faire's website, is "a tech-inspired DIY community" and includes amateurs, students, enthusiasts, and hobbyists. Makers are people who would rather innovate and create themselves, than consume and depend on others to do the task. Essentially, a maker could be anyone, young or old, a craftsman or a robotics engineer. Dale Dougherty, founder and CEO of Maker Faire and Make Magazine has previously said in his TED talk [1],

"My goal is that all people, young and old, come to see themselves as makers, creators, and doers, because I know that the people who have the skills and knowledge to make things, have the power to make the world a better place".

Making could be through technological tools such as, but not limited to, 3D printers, milling machines, and laser cutters, which have recently become a lot more accessible. It can also be making robots, or any other innovative projects through microcontrollers such as the Arduino board or the Raspberry Pi. While a making is a rather general term, what brings makers together is creativity, resourcefulness, and innovation.

Making has been recently celebrated and promoted through different means, including the growing Maker Faire, and the increasing number of Fab Labs throughout the world.

2.1 Maker Faire

Maker Faire is 'the largest Show and Tell on Earth', it is an event for makers to showcase their projects, for the community to connect, and for people to become inspired. In 2014, over 130 Mini Maker Faire's have been held worldwide [2].

2.2 Fab Labs

Figure 1. Fab Lab Logo

The first Fab Lab was founded by Dr. Neil Gershenfeld, a professor at Massachusetts Institute of Technology (MIT) and the Director of its 'Center for Bits and Atoms'. Fab Lab was formed under the slogan that 'You Can Make Almost Anything'. Gershenfeld described Fab Labs as "high tech, low cost workshops, equipped with the tools to make almost everything…" [3]

Since then, numerous Fab Labs have been formed all around the world; independent yet part of the global Fab Lab network. Fab Labs aim to provide the tools and machinery needed to make your ideas a reality, the needed working space, and a collaborative community to learn from and share your ideas with. According to Fab Academy, there are now over 460 Fab Labs located on all six continents.

3. Robotics and Botball

Robotics is a field which requires design, mechanical, electric, and computer knowledge; all what you need to be a maker. Making robots provides people with countless opportunities and opens the door to abundant possibilities. Robots can be made out of any material, and to perform any function, all depending upon what the robot's maker intends of it to do. There are racing robots, robots which play football, robots which help at manufacturing, and robots which participate in competitions like Botball. The Botball Educational Robotics Program is a robotics competition that requires of teams consisting of Middle and High School students to independently design, build, and program autonomous robots to perform certain tasks, depending on the year's game mission.

Botball has proven to not only be a competitive competition for school students, but an inclusive STEM (Science, Technology, Engineering, and Mathematics) Educational program, teaching school students some of the fundamentals of each subject. In order to build and program the robots, students need to learn a lot about technology, for instance servos, motors, and sensors, which they use to complete the mission. Moreover, they put some of the mathematics and scientific concepts into use as they try to achieve optimal effectiveness through measurements, calculation, and scientific concepts, specifically mechanics. Example: our team has previously used the Pythagoras theorem to know the right measurement for building a robotic arm, and keeps in mind methods to reduce friction while building the robots. Through being problem-solvers, students also gain the necessary experience to prepare them to be able to start thinking like engineers at an early stage in their education.

Aside from it being a STEM educational program, Botball, or Robotics competitions in general, provide students with many other skills which are necessary for them to obtain through their educational and work experience. Botball students work within a team, developing their ability to work cooperatively with others, throughout a period of 6-9 weeks, and teaching them commitment. Through aiming to complete tasks which will almost never work the first time, students learn perseverance, problem-solving, and critical thinking.
Caroline Hanson talks about her experience with robotics' effect on her students saying, "I'm trying to create deep thinkers who will consider complex problems and recognize that they usually cannot be solved in one attempt. I love observing the tenacity of a group of students working for hours on a single robotics challenge, a behavior I do not see with a paper and pencil task!" [4]

4. Learning through Making (In Schools)

The importance of learning through making and robotics lies in all the benefits of making and robotics education through programs such as Botball, outlined above. More importantly, learning through making provides students with an education that the standard schools' education

system fails to provide.

With an education system that is more focused on memorization of knowledge that could usually be found on the Internet, students become more of programmable machines than creative innovators. As a result, we find that many students rapidly forget the information they memorized after the test, or come out of a class with no real added value to their character. While the importance of teaching the standard core subjects and usual curriculums is undeniable, it is definitely not enough in a world that is growing and developing at an exponentially increasing rate.

Middle School teacher Julia Rea said, talking about her experience with learning through making and doing,

"And for a brief moment, students were directing their own learning and they were excited about it. It is this moment that I try to replicate every day in the classrooms I am in with students: let's find a problem we care about, let's create some solutions, and let's learn by making and doing. And it's why I am working with a group of teachers who think that designing a school around a makerspace and a maker mentality is an idea whose time has come." [5]

Through working for solutions that they have to find, and through taking the responsibility of their own projects, students become personally involved in their learning process, greatly increasing their drive towards learning and causing education to be a more valuable experience rather than an unwanted burden on the students. Our education curriculums might give students the knowledge they need to have memorized in order to pass exams, fill applications, and excel at interviews. It does not, unfortunately, always give them the skills needed to actually develop and grow, nor to be creative individuals. Through standardized tests and exams, students fail to realize their value as individuals, their capacities, and their abilities. On the contrast, teaching students to make, to do things themselves lets students know that they could be creators and doers, that they could make a change, as valuable individuals.

The Hayah International Academy Robotics team conducted an online survey for Middle and High School students to collect more information about their involvement in the topic. There were over a 100 replies, with the majority of the students from Egyptian schools, although there were replies from the UK, Qatar, the United States of America, and Bahrain as well. Outlined below are the results gathered from the survey.

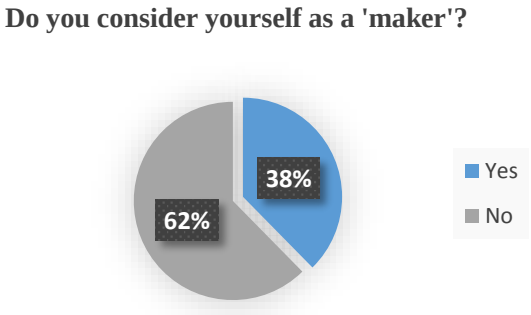

Figure 2. Results of survey's first question

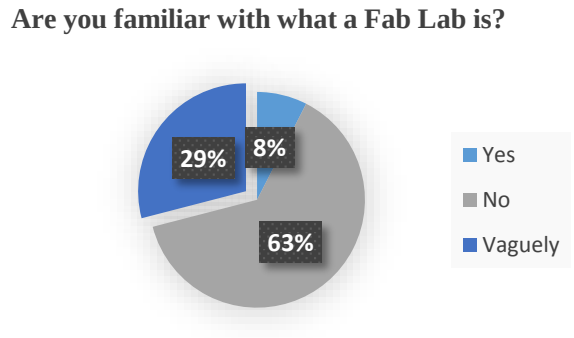

Figure 3. Results of survey's second question

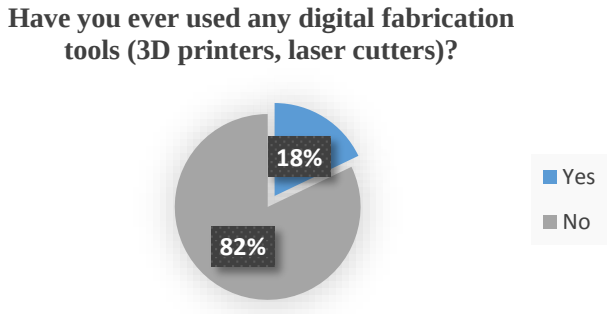

Figure 4. Results of survey's third question

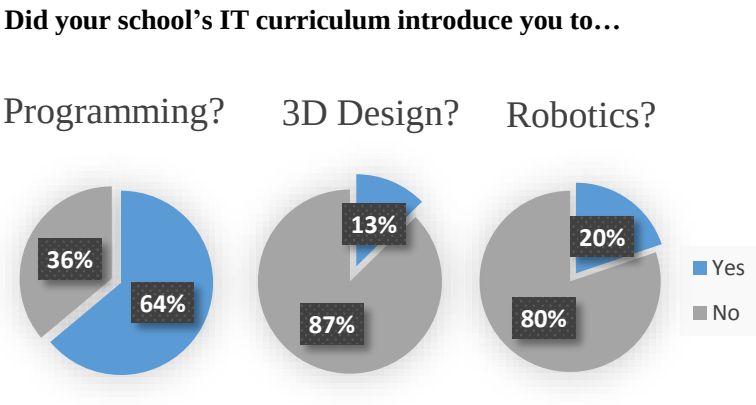

Figure 5. Results of survey's fourth question

4.1 Data Analysis

Through observing the data gathered from the survey, we can notice that the majority of the students do not identify themselves as makers, do not know what a Fab Lab is, have never used a 3D printer, and have never learned 3D design or been introduced to Robotics**.**

5. Combining Making, Robotics, and Schooling

By now it is undeniable that students need to be given the opportunity to make, to turn their ideas into a reality, and definitely to participate in activities such as robotics, through means such as the Botball Educational Robotics program. Such opportunities could be present through having the resources available at school and teaching students DIY and making through IT curricula. It could also be available for students with a higher interest in making and technology through optional activities, school teams, and after-school activities.

5.1 Fab Labs at Schools

FabLab@School is a project organized by Stanford University's Transformative Learning Technology Lab (TLTL) and directed by Stanford professor Dr. Paulo Bilkstein. It aims to provide schools around the world with low-cost digital fabrication labs for Middle and High School students. Since Stanford's TLTL have successfully installed several Fab Labs around the world in different schools, other schools could aim to connect with the Stanford TLTL faculty, learn from their experience, and either join their project, or work independently to achieve the same goal.

An ideal Fab Lab at school would be following the same idea and concept that regular Fab Labs are built upon, but catered towards the younger audience; school students. A Fab Lab could either be hosted by one school, for the students of the specific school, or even as a joint Lab for students of several schools, as to encourage co-working and an open-source mentality. The Fab Lab, or maker lab, would provide students with:

Equipment:

1) The machinery needed (digital fabrication tools): 3D printers, Laser Cutters.
2) LEGO: as a way to build robots, join competitions, and work on many projects through student-friendly materials
3) CBC/NXTs: The CBC or NXT are controllers that make robotics simpler for students, allowing them to program motors, servos, and sensors easily. They are also used in Middle/High School robotics competitions such as the First Lego League (FLL) or Botball Robotics.
4) Micro-controllers: Micro-controllers, such as the Arduino board or Raspberry Pi, are a more advanced way to control electronics than the CBC or NXT, and give students the capability to work on a limitless number of projects, from amateur level to engineering-level.
5) In order to make use of such boards, the Lab will need to include all needed wires and connections, as well as an electronics set, which could include resistors, LEDs, servos, motors, sensors, etc.

People:

1) Community: It is essential for students participating more actively in makerspaces to feel like a part of a collaborative community, which could happen through holding group projects and events/activities in the Lab and for its active students.
2) Instructors: Teachers and/or students who have been previously trained to use the resources in the lab, and understand the purpose of the lab and its goals.

Working Space: an open yet supervised working space which allows students to use it to pursue their own creative projects, yet ensuring a safe environment for them.

5.2 Schools' Robotics Teams

Perhaps the most prominent way to encourage students to participate in robotics' related activities is for schools to encourage and sponsor their Robotics Team(s), and to help them in joining local and regional Robotics competitions. Schools could seek to give such teams as much support and recognition as needed, as much as it would give any sports varsity team on campus. Rather than having a team with the sole purpose of attending a competition, schools could encourage the students of such teams to be the pioneers of the maker movement at their school, potentially teaching new students the design, programming, building, and documentation skills which they have gained through their involvement with the robotics competition they have participated in.

At our school, Hayah International Academy, the Robotics team participates annually in the Botball Robotics competition. The Botball team at school is permanent, meaning that the same students get to carry on as part of the team in the following years, if they choose to. New members of the team are chosen by the students themselves, based on an application process and a criteria, which gives the students a sense of belonging to the team.

The advantages to that are the immense commitment that the team members develop, and the sense of responsibility which grows with them as they realize that it is their team, not the teachers' or anyone else's. The disadvantages to that, however, is that only a very limited number of students in school participate in Botball, or Robotics in general. There is no problem in having robotics teams for students who are passionate about the subject, but in the case where there are many students who are not part of the team, then the school could try to gradually host more than one team (as some schools already do at Botball), or teams attending different competitions.

Figure 6. Hayah Botball students at the Botball Qatar Competition [6]

5.3 I.T Curriculum That Encourages Making

Many or most schools already follow an IT (Information Technology) curriculum, which usually teaches students the basic skills needed to interact with a computer. Although many schools already do that, it is important to also integrate programming platforms such as Scratch and Small Basic through the curriculum. Such platforms teach students at a very young age the fundamentals of programming and its logic, while keeping the learning experience simple and entertaining.

Another way is to introduce students to 3D designing programs such as Google Sketch up and AutoCAD. Students usually do not realize the power of such programs, if not introduced to 3D printing, and if not aware that they are capable of turning these designs and ideas into real-life 3D designs.

It is crucial that schools do not force students who have had no prior interest in programming into finishing complicated programming tasks or sophisticated digital fabrication projects. The goal should be to encourage students to independently develop and grow as makers and doers, and to support students with a passion for technology and computer science to join robotics activities and competitions, but definitely not to force it on them, making it seem like just another burden enforced by the education program.

5.4 School-Sponsored Trips and Activities

Even if schools fail to provide students with makerspaces inside school, do not have robotics teams, or their curriculum does not give students the tools and skills needed to become makers, there still is a way. Schools could plan to send students to day-trips to local maker spaces and Maker Faire events.

Fab Foundation provides a database for all Fab Labs located around the world, their location, and their social media contacts at:

http://www.fabfoundation.org/fab-labs/

Maker Faire also provides a list of all the Maker Faire/Mini Maker Faire events around the world at:

http://makerfaire.com/map/

Trips to Maker Faire events will definitely inspire students. To build on that, schools could even host making fairs, just like science fairs, to honor the most innovative, resourceful, and proactive students.

6. Conclusion

It is apparent through the collected data that many schools, in many locations, specifically Egyptian schools, fail to give students the resources they need to become makers and doers. Most students have never used a digital fabrication tool, in an age that is that of the digital fabrication revolution. Many students have also never been introduced to robotics, despite their potential and its benefit.

By encouraging students to become makers, and to join Robotics competitions, schools support students interested in a STEM-related career. More importantly, schools would be giving students a more inclusive educational experience, which would result in more creative, innovative, and resourceful individuals. Schools could achieve that by supporting robotics teams, introducing students to the Maker movement through trips and activities, and by ensuring that their Information Technology curriculum gives students an insight into the worlds of programming, 3D design, and robotics.

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