A Maker Approach For The Future Of Learning

FRANCESCA FIORE, ALBERTO MONTRESOR, and MAURIZIO MARCHESE, Department of Computer Science and Engineering, University of Trento, Italy

Cross-disciplinarity and active learning have been recently recognized as fundamental educational tools to enable the understanding of our complex reality. For this reason, educational models are shifting from a traditional approach to an integrated one, where Science, Technology, Engineering and Mathematics are merged with Arts (STEAM), acknowledging the fact that future citizens and workers will need not only technical skills, but also imagination, creativity, design and critical thinking.

This paper describes an effort to design, develop and evaluate novel educational models based on the integration of ICT skills with the "makers" philosophy, both inside and outside the University of Trento. For this purpose, we have created two FabLabs, one static at University, the other on wheels called ApeLab. The goal is to activate informal learning processes, empowering our students through learning-by-doing methodologies, but also exploiting them to bring this educational models to the general public, fulfilling the "third-mission" of our university.

CCS Concepts: • **Social and professional topics** → **Informal education**; *Computational thinking*; *FabLab*; *STEAM*.

Additional Key Words and Phrases: STEAM, education, FabLab, maker, ICT, citizen science

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1 INTRODUCTION

The digital revolution has brought a profound transformation of the job market, a transformation that is still ongoing [23]. This shift requires policy-makers and businesses to respond immediately and far-sighted to avoid missing the wave of the fourth industrial revolution. According to some estimates [14], 65% of children who enroll in primary school in 2019 will be employed, at the end of their studies, in jobs that do not yet exist. Preparing young people for this change requires the modernization of education at all levels, from primary school to university and beyond, in order to provide students with the skills they need to work in the digital age. Only with the appropriate public education and training policies the next generation of students and citizens will be able to leverage the digital revolution to create new businesses, generate jobs in cutting-edge technology sectors and solve local problems in alternative and innovative ways. Particularly in the STEAM disciplines, there is the need to question the actual curriculum and formal education, in order to better prepare students to the world of tomorrow.

A particularly promising direction with regard to 21st century skills [11] is the integration of the *maker approach* into the school curricula. This approach allows students to be active users and digital creators, rather than mere passive consumers of digital services. Technical skills are not an end in themselves, but rather become a lever to build

new business solutions, improve their surroundings and respond to the complex problems of our times. Well-known educational approaches like *learning-by-doing* or *learning-through-making* are enriched with with new important applications, like the possibility of digitally manufacturing objects.

The integration of the maker approach in primary and secondary school is relatively recent, but this teaching methodology has already been shown to support the development of a range of 21st century skills among younger students, including resourcefulness, creativity, teamwork and adaptability [3, 17–19, 21]. Indeed, the idea of "playful experimentation" with tools and materials is powerful in the context of learning; when children create something with their hands they are engaged in active learning and at the same time have fun [22]. Recent studies on introducing a maker culture into schools through laboratories and updating the academic curriculum suggest that students develop skills, as well as interest, in STEAM subjects [2, 13], but also critical thinking and the ability to solve complex problems [16]. Furthermore, the realization of projects through digital manufacturing also often implies an interdisciplinary approach, another important element in the training of future workers and citizens, who will face increasingly complex and transversal challenges compared to the most various branches of the know.

Even though the need to promote new skills at school appears as a clear goal, just few countries have actually developed strategies to promote their acquisition in formal education [15]. In Italy, for example, the curriculum of most schools has not undergone radical changes in recent decades (1990-2020), despite the profound changes in the economic and social fabric; local initiatives abound, even funded by the government, but what is missing is a clear and integrated strategy that includes all educational levels [7].

In this context, the Department of Information Engineering and Computer Science at the University of Trento has recently started an effort to bring the maker approach to the local autonomous province of Trento, from primary schools to the university and beyond. The effort is going in two directions:

- *towards our students*, we have created an internal FabLab that aims at being a central hub for all extra-curricular and interdisciplinary efforts, in all the departments of the University, from humanities to mathematics, from social to economical sciences, with a special attention to engineering and sciences;
- *towards the external population*, we have created a mobile FabLab, hosted in an iconic Ape Car, that aims at carry out the so called "third mission" of the University, bringing maker activities to schools and citizens.

The goal of these FabLabs is to break barriers: between the disciplinary silos constituted by the departments, and between the university and its territory. While university FabLabs and mobile maker vans have already been proposed and discussed, the novelty of our approach stays in the integrated approach inside and outside the university. Our vision is to create an "educational supply chain" centered around university students that extend its reach towards lower school levels and lifelong-long learning activities, as well as professional development courses for teachers.

The goal of this paper is the present the problem we want to solve, our vision, our initial efforts in spite of the pandemic, as well as raise several research questions that we plan to answer in the coming years.

2 PROBLEM STATEMENT

FabLabs are often referred to "places where people have access to low-cost digital production tools and come together face to face to create anything" [6, 8–10]. This definition often leads people to focus primarily on the social aspects of FabLabs and the technological tools that are made available. When talking about university FabLabs, instead, there are important aspects that should be emphasized:

- understanding and evaluating the *educational process* adopted by students in their projects, based on *learning-by-doing* and *learning-through making*;
- promoting *interdisciplinarity* – which occurs naturally in a FabLab, but is often in contrast with the rigidity of study curricula;
- fostering *creativity*, i.e. train students who are creative thinker, cognitively adaptable and flexible, ready to meet the needs of the future job market – thus acquiring the 21-century skills necessary for the new generations.

In this project we will focus on two research questions. The first one is the following: *what novel educational models and methodologies our FabLab should adopt, also considering the unique characteristics of its members, i.e. a substantially resident but transient population of students, coming from all disciplines but often trapped in their curriculum?*

Recently, there has been a lot of discussion about the "third mission" of academia, to emphasize that universities must take on a new fundamental objective alongside the traditional ones of higher education and scientific research: dialogue with society. This is particular important in a local province like Trento, where the ties between the University and local administrations and schools are particularly strong.

Thus, the second research question is: *How can we transfer outside our university the educational model and knowledge produced in our FabLab? How can we make the public aware? How can we contaminate local schools with a more active educational approach*?

The sample of our study will be represented by all the students of the University of Trento, but also primary and secondary school students and teachers in the Province of Trento. Furthermore, with the dissemination activities, the objective will be to speak directly to the citizens, moving to unconventional places such as squares and parks where to carry out our activities. A blend of quantitative and qualitative methods will be utilised in this research to seek answers to the key research questions.

3 VISION

To answer our research questions, we have conceived, designed and built two laboratories: one static and one mobile.

- The static FabLab UniTrento, inside the University of Trento, will allow students to have a place of meeting and exploration. A place in which they could drop by between lessons but also where they could carry on long-term projects - on the side of standard classes and assignments.
- The mobile ApeLab, on the other hand, will allow us to reach other categories outside the institutional academic walls, and therefore to address all citizens with a real purpose of information and scientific dissemination, in a slightly more pop key.

3.1 FabLab UniTrento

The core mission of our FabLab is to create an open learning space, focused on interdisciplinarity, practice and legacy.

In the last decade, FabLabs have been established as places in which different expertises, backgrounds and ambitions collide. The combination of crafts with high-tech offered by FabLabs brings together a diverse crowd which, in the case of university FabLabs, translates to students coming from different degrees. Because of this, the lab context can be seen as a first proxy of the "outside world", or the working environment. Indeed, workplaces are becoming increasingly interdisciplinary, and more and more fields are affected by the presence of digital technologies. Universities, then, need to equip themselves with contexts that combine the "safety" of a learning space with a realistic proxy of what is to come for their students.

In this view, the FabLab UniTrento can be seen as a privileged place where interdisciplinary synergies can be created, leveraged and orchestrated in order to create new value as well as foster creativity and innovation. School maker spaces, in fact, more than other Fablabs of the network, are considered as instruments for developing student's agency and identity [5]. Indeed, very few students are experienced in both technology and crafts, and even fewer have competences to both "make" and generate value from what is made. The FabLab, then, is a leveling ground where nobody can work on their own, and skills are learned inductively in a collaborative fashion. We envision that UniTrento students will be involved in our FabLab as members of a community of practice in various types of interactions: as learners, as mentors and teachers - in some specific domain - and also as supporters of the management tasks of the FabLab. To enable this, the FabLab should be a space of open experimentation, where the cost of failure and iteration is as low as possible. User accountability should be minimized to a responsible use of the space and of its infrastructure, and "failed" endeavours should be embraced and made sense of, with the goal of generating value and learning from them.

Finally, the FabLab should be a space of serendipity. All of the above should be quietly phased down by those that simply want to tinker or pursue their own interests, without discrimination. If the space works as intended, then, new opportunities can arise even from "out-of-the-box" uses of the lab. In this view, a project-based learning approach would be encouraged. If it is true that it might be difficult to predict what students will learn, it is also true that the users of the lab might develop projects according to their passion and interests, leading them to an open-end design experience. Seymour Papert [1, 20] pushed his students to have "hard fun". In his vision, this could lead to an eagerness to work even harder, because when motivation is guided by passion everything changes. The FabLab, therefore, has to become the playground of our students, where they can feel comfortable in exploring, building, creating and experimenting. Being in a familiar university setting, they could combine a sense of mastery and self-confidence with creativity and open-exploration. This could be done using familiar materials and spaces in unfamiliar and novel creative ways.

3.2 ApeLab

In the last few years library, school, as well as university settings have begun to incorporate open learning spaces and maker technologies among their facilities. In these labs, users can learn through experimentation and play, not necessary in standard educational settings.

But what if we could create a mobile *makerspace* on wheels that can reach people beyond the traditional learning settings? Now more than ever we need to shift our approach and vision on education. There is the need to break down barriers across disciplines creating multidisciplinary teams, across age and cultural backgrounds, across time (allowing students to work from wherever they are and when they want) and, in particular, across spaces.

For an academic institution like the University of Trento, it is always complex to break down structural barriers and really embrace the third mission in its core: dissemination. We argue that for a creative society, people need to learn to learn but also learn to adapt. To achieve this goal, it is fundamental to put together different voices and reach new audiences, integrating them in the discussion.

"ApeLab" is a mobile FabLab, a travelling experimental lab for social innovation at the service of the local communities. This project wants to encourage the empowerment of citizens and, consequently, the horizontal subsidiarity and active citizenship. The mobile laboratory allows citizens (children, young people, students, schools, families, the elderly) to see and try the tools and work machinery present in a FabLab to experiment, self-produce and prototype, create and innovate.

In line with the UNESCO Open School model [4], the goal is to create a real experimental laboratory for innovation at the service of the territory, capable to activate formal and informal learning processes, creative and innovative

co-planning among citizens usually not involved in the formal learning spaces. In this context, technology becomes an educational tool capable of creating connections, innovative models and developing ideas at the service of the well-being of the community and the territory, enabling everyone access [12]. All set up on an iconic Ape Car, properly prepared to host digital fabrication machines and tools. All activities are aimed at supporting the well-being of the community by training and informing it, so as to contribute to the empowerment of citizens through the use of the STEAM disciplines. Going town to town, valley to valley, we aim at providing citizens with tools for experimentation, innovation and creativity but also with an informal meeting space, where everything they can imagine and design can become "possible".

4 CURRENT STATUS AND OPEN QUESTIONS

The current status can be briefly described as "ready, but almost empty". The project started just before the pandemic and during this year it has been possible to renovate and equip the rooms where that static FabLab is going to stay, buying the appropriate fabrication tools and hiring part of the staff. In parallel, the renovation of the Ape Car is completed and we are now designing its interior to host tools and devices that can be easily brought around.

The activities have already started, but for now they are limited to students working on their thesis and Ph.D. candidates. It is important to note that we are already serving a quite diverse set of disciplines, including computer science and engineering, industrial engineering and mathematics. Unfortunately, the restrictions originated by the Covid emergence prevent us to open our premises to a larger public; for the same reasons, we are not currently able to bring our labs outside the University, so we are not able to report extensive results about the outcomes of the activities or the effectivness of the educational methodologies.

Yet, the contingency can be translated in a unique opportunity to reflect on our goal and to design the methodology we want to adopt; this activity has already raised a large amount of key points but also questions that are worth sharing.

- *Sustainability over time*: In our experience, public makerspace have a core of passionate members, who stay constant over time; their problem is to engage a larger public. Our population is the opposite; students are "resident", in the sense they spend most of their day at the university, but are bound to leave in 3-5 years. How do we create a community out of a such a transient population? How do we ensure that appropriate mindset is passed from one cohort of students to the next?
- *Promoting an open mindset*: The FabLab is located closer to the scientific faculties. Our first experiences with this population of students is that their mindset is quite bound to the curricula; they are focused on the next exam to complete, rather than the next concept to learn. How do we foster a change in mentality? How do we make them understand that tinkering and playing in a serendipitous manner can promote more important skills than rote learning?
- *Involving students in the educational process*: The regular staff posses pedagogical skills and technical competences in the use of the machines, but clearly the amount of knowledge they will be able to share will be finite. How do we get students involved in the educational process? How do we make them propose courses and activities to enrich the educational offer of the Fablab?
- *Involving schools*: Our department is already the hub of several initiatives for the professional development of teachers of the local province, in the field of active learning and computational thinking. The amount of activities that we organize could be much larger if we involve our students in them as tutors of less experienced

teachers. How we can promote the learning-by-doing and learning-through-making approaches? How can we help students to develop the skills to act as effective tutors?

- *Involving the society*: As part of the ECIU consortium of innovative universities (https://www.eciu.org/), UniTrento is involved in citizen science with challenge-based projects. How do we make science interesting for citizen without trivializing it or making it look like magic?
- *Impact*: As argued above, we know that academic makerspaces can create meaningful experiences for students, we are already seeing this. Yet, how do we measure our impact? What kind of learning outcomes can have everyone involved? How were learning outcomes assessed during and after the process? To what extent are students developing skills and competences related to the design process (e.g. exploration, language, judgement, reflection, etc.)?

5 CONCLUSIONS

This work illustrates some preliminary work that has been carried out to establish the University Fablab at UniTrento and its mobile counterpart, the ApeLab. We really believe that an integrated approached, involving the university, the students, the schools as well as their teachers and pupils, and finally the local administrations and their citizens, can really enable our territory to embrace the digital revolution and project itself in the 21st century.

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