Sharing Is Caring: A Proposal for the Development of Shared, Semi-Autonomous, Mobile FabLabs to Overcome Obstacles in STEAM Education

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Abstract

This research originates from previous studies addressing challenges in STEAM education, respectively a lack of knowledge in sciences and mathematics, but also in technology usage and creative skills [1]. We encounter these deficits in university education but are confident that the source of the problem lies in primary and secondary school education. Therefore, we propose a methodology based on the development of novel digital fabrication laboratories, that intend to assist schools to overcome the obstacles associated with STEAM education, due to a lack of technological resources, knowledge, facilities, and appropriate curricular methods. Our previous research already demonstrated the immense effect of digital fabrication technologies onto the ability of undergraduate university students to cope with STEAM related topics. Without a doubt have we seen a very positive impact of these technologies onto the quality of their works, but we also observed a very positive change in their self-esteem, as well as a more positive attitude toward learning. However, the integration of the methodology as a guarantor for successful university STEAM education simply happens too late in time. To be at the forefront of technological advancement, the integration must occur during school education, and must start as early as primary school, with a focus indeed in secondary school. This is challenging since in most cases the regular curriculum is not designed to cater knowledge transfer in these areas, the schools cannot afford the necessary infrastructure, and schoolteachers are not qualified to teach in these domains. Our proposal addresses these issues by changing the way knowledge is transferred (blended and extracurricular instead of frontal instruction) in a non-standard classroom environment with an emphasis on "making". By giving many schools access to mobile hi-tech manufacturing devices situated in a mobile building, that come at zero investment costs for the schools, and at low investment costs for the ministries with a maximum degree of capacity utilization, and by integrating pedagogical approaches that are supported by new algorithms for autonomous, mobile learning.

Keywords: *STEAM Education, Digital Fabrication, Semi-Autonomous Learning*

1. Preamble

The influence of the Covid-19 pandemic onto K-12 education, has shed a new light onto pedagogical research. Our work is not exempt from the fact that the response of many schools around the world toward the challenges of online learning has often been rather dilettantish. We have seen many schools that desperately tried to follow the given curriculum, adopting frontal teaching methods, and transferring them unchanged into the digital realm. We have seen teachers that prepared online content for self-learning without noticing that they entirely disregarded their important role as a mediator in the classroom, a person that a student connects to, not only as a transmitter of knowledge, but also on a personal basis, as "tutors, mentors or role models" [2]. We have also seen approaches where schools obviously forgot about their obligation to teach. Instead they changed their role into something where teachers solely handed out assignments to check upon knowledge the school has never conveyed to the students. We have seen parents that have been forced to take over the role of teachers, which led them into situations where their obligations as mums and dads conflicted with the new responsibilities. Responsibilities they have never asked for, and never been prepared for. We have seen that schools partially came to a standstill regarding their approach to deliver quality education through new means of online teaching. A deep misunderstanding amongst the teachers what online education must entail is evident. We have also experienced, that teachers had a very limited understanding for the actual situation of the students at home. Teaching happened entirely uncoupled from the stressful situation the students were facing. The way students were - and still are - taught often leads them to be demotivated, sad, and spiritless. The schools took away the joy out of learning, and the impact of this is way more far-reaching than trying to keep up with the mandated curriculum. It became evident that many teachers have deficits explaining matters, they use predefined online content that is partially erroneous, they do not answer questions or address concerns, and if they do, they simply defend themselves, but are not open for constructive critique. And for the students, every single day is the same. The slides look the same, the teacher's approaches are the same, and the boring matters are the same. With very few exceptions, there is almost no real interaction with the students, and parents are left to explain what the teachers should have discussed with their classes. The school closure took away the social interaction students enjoyed every day with their peers, and the teachers missed this opportunity to reintegrate interaction into the online classes. In summary, online education around the world has been a disaster for many, but it has also been an eye-opener for those that were under the mistaken impression that education is in good shape. Those are the ones that are worried now. They are worried about the time after the virus, where students go back to school, and face the problems that are so obvious.

2. Introduction

A lack of knowledge in sciences and mathematics, but also in technology usage and creative skills manifest challenges in STEAM education that we encounter in university education today. However, the source of the problem lies in primary and secondary school education. With the experiences made in the past few month, when many schools around the word transferred their classrooms into the digital realm, a lot more aspects became apparent that influence the lack of knowledge in the aforementioned areas. To overcome some of the obstacles associated with STEAM education the following need to be addressed:

- a lack of appropriate curricular methods
- a lack of awareness for global trends
- a lack of facilities
- a lack of technological resources
- a lack of knowledge

As a response to the experiences made in the recent past, aspects that were previously taken for granted need to be reconsidered. K-12 education suffers from underqualified teachers, dated curricula, and more than ever a lack of passion, excitement, and curiosity on both sides, teachers, and students.

3. Obstacles

Dated Curricula

Many schools around the world follow predefined curricula that appear to be set in stone. It is almost sarcastic, but even a pandemic cannot touch the omnipresence of a dated idea that a student must learn a certain topic at a certain time. Neither sooner, nor later. No matter what the actual situation is. It is even worse that occurrences in the real world or things that happen in the classroom often have no effect on what is being taught. Again, simply because teachers feel obliged to teach what they have been told. The pressure that is on the teacher often derives from the pressure external parties put on the school. A school that adjusts teaching to the needs of the students is hard to find.

Negligence of Global Trends

It is paradox, but teachers are often underqualified. Those that are responsible to shape a new generation of learners, thinkers, makers, and leaders, suffer from an education that is as dated as most of the curriculum is. Even though schools have gone through many reforms in the past, the general understanding of what is important as opposed to what is not, hasn´t changed. This is even more astonishing as global trends occurring in the professional world are neglected. Competencies that suit job profiles and requirements of 21st century industries are hardly being addressed in K-12 education. Scenarios of how the curriculum must adopt to these challenges are not implemented [3].

Lack of appropriate Facilities

It goes without saying that the facilities of today´s schools are oriented toward the requirements of dated curricula. Fifty years ago, when the world was facing the recovery and first upturn after WWII, the schools were bursting with facilities such as joineries and metal workshops to meet the demands of the industrialized world. Nowadays, there are no answers as to how the carpentries of the 21^{st} century schools must look like. Schools built in recent years are lacking all kind of facilities, including workshops that would at least give students a sense for craftsmanship.

Technological Resources and their Provision and Use

With no workshops being built anymore, the amount of technological resources available is also limited. Most schools have resources such as computers, chemical or biological samples, which are all stored in dedicated spaces, and this is the crux with this kind of thinking. In today´s world the borderlines between the disciplines diminish, the employee of today and tomorrow has a multitude of transdisciplinary skills that cannot be assigned to a single discipline only. Concepts such as FabLabs or Makerspaces that are already common in many public spaces, but which do not explicitly belong to any of the well-known disciplines, do not have a home in today´s school.

Stagnation in Knowledge and Adaptability

Teachers are detached from the real world. The general education they went through does not leave a lot of leeway for the accumulation of expert knowledge, that is necessary to address the challenges of a globally networked work infrastructure. FabLabs or Makerspaces would require a different teacher. One that feels responsible. Today, no-one feels responsible. It is neither the arts teachers, nor the physicist, nor the chemist that would occupy such a space. But unfortunately, this are the kind of teachers our schools employ. There is no all-rounder, no person that didn´t make it in school, left university, but became a successful businessmen anyways, there is no entrepreneur who failed multiple times but stood up again and again because he learned the lesson from the mistakes he made. Our schools are an assortment of individuals that are oriented toward the past, not the future.

In summary, the challenges that successful STEAM education faces are curricula that are not designed to cater knowledge transfer in these respective areas, schools that cannot provide the necessary infrastructure, and teachers that are not qualified to teach in these domains. We must address these problem domains by changing the way knowledge is transferred (blended and extracurricular instead of frontal instruction), in non-standard classroom environments with an emphasis on making and experimentation. We suggest to give many schools access to mobile hi-tech manufacturing devices situated in mobile buildings, that come at zero investment costs for the schools, and at low investment costs for the ministries with a maximum degree of capacity utilization, and we suggest integrating pedagogical approaches that are supported by new algorithms for autonomous, mobile learning.

4. FabLabs as an opportunity to address STEAM education

The “Zayed University Research Center for Digital Fabrication” is a transdisciplinary research space within which we address the educational challenges and questions that arise from the use of innovative fabrication technologies representing all aspects of STEAM education. Our research results already demonstrate an immense impact of these technologies onto the quality of works produced by university students, and we derived answers from these results that aid us to adjust the direction of current and future university curricula. Without a doubt have we encountered a very positive impact of digital fabrication technology onto these students. Not only is it that the quality of their works improved, but we also observed a very positive change in their self-esteem, as well as a more positive attitude toward learning. However, the integration of the methodology as a guarantor for successful university STEAM education simply happens too late in time. To be at the forefront of technological advancement, the integration must occur during school education [4], and can start as early as primary school, with a focus indeed in secondary school. As a Research Center that caters the needs of a variety of academic disciplines, we also began to open our labs to students from Secondary Schools. The results we gained from workshops with 12-14 years old students matched the results of the university students regarding the pedagogical impact these techniques have. Students were engaged, motivated, and excited. They understood that the objective of the one-day workshops was to produce an object, for which they had to understand how to digitally fabricate the artefact and assemble it manually. A good combination of different techniques had to be tested and applied. Mathematical formulae had been used for a reason, not as a meaningless assignment on paper. Co-working skills had to be developed and honed. Leadership skills evolved naturally from the student´s building an understanding that a group of a dozen students needs guidance. For suchlike scenarios to happen in schools, a range of theses have been developed by the authors [1] that describe the potential challenges university education must deal with. The situation in most K-12 schools is similar but can be extended with the following theses.

Thesis 1: Digital Fabrication is an expensive undertaking. Only few schools can afford this investment. Often, the devices are not used at their maximum capacity. Thus, a shared infrastructure is a valuable alternative.

Thesis 2: A shared infrastructure that is used to its full capacity is an asset with a very high Return of Investment. Thus, sharing is a valuable alternative to an expensive but underused investment.

Thesis 3: It makes no sense to maintain an underused infrastructure. Therefore, either new users must be brought to the infrastructure, or the infrastructure must be brought to the users.
Thesis 4: Digital Fabrication requires expert knowledge that teachers at school can barely provide. Often, the curriculum does not even allow for these methods to be implemented. Therefore, teachers must be supported with appropriate means through which knowledge transfer can be accomplished. Alternative methods of instruction need to be developed.
Thesis 5: Students have a natural curiosity for the unknown. They are also attracted by technology. Therefore, a classroom environment that challenges the existing and is packed with technology will make them interested to explore.
The theses build the framework for the constitution of mobile FabLabs. They derive from more than half a decade of experience with the development of in situ labs. They inform the devices and tools we will integrate into the various systems, i.e. the mobile architecture, fabrication devices, educational technology, and support systems.

5. Shared, Semi-Autonomous, Mobile FabLabs

We propose the development of fully-fledged mobile digital fabrication laboratories that entail novel pedagogical approaches. Once a lab is built, it can be put on a truck, and the lab and the assigned pedagogy can be made available to schools. All elements of the prototype lab are situated in a standard shipping container, and thus can be brought from school to school to be used for a certain period. The container is simply the package that contains all assembly parts, it is not the lab itself. The lab develops through a kinetic structure that can unfold from the container and turn into a fully equipped classroom, with devices that can be pulled out from the container and used in this classroom environment. The mobile lab is ideally located on a school´s parking lot. Thus, enabling schools to train pupils in technologies that they otherwise would never be able to work with, because they simply cannot afford. The pedagogy to be developed enables schools to run the lab with minimal effort and knowledge. Algorithms for autonomous learning will aid students concentrate on the fabrication tasks. These labs intend to raise an awareness and create an interest, a curiosity, in the use of technology. It will be evaluated regarding the effect it has on teachers and students. It is a catalyst that intends to boost STEAM education at K-12 institutions of all ages.

The Architecture consists of a structure that unfolds and turns into a completely autonomous, self-sustained classroom. It comprises of lightweight fabrication devices that can be pulled from the container, used in the temporary environment, and operated through simple means. The Engineering of the device infrastructure with its supply systems will allow for easy and safe operation. The Pedagogy will allow students to learn, create, and successfully develop the anticipated skills and abilities in STEAM. It is based on the design of learning experiences that are student-centered, interactive, promote student autonomy, creativity, collaboration, and real-world engagement. Students will learn how to fabricate artefacts through simple digital means and with minimal effort. The method will enable them to generate objects and develop services they can potentially bring to the market at school age. The pedagogy to support the individual student and teacher in their learning process is aided through means of Digital Technology. Algorithms will be developed to generate software solutions for autonomous Machine Learning through Artificial Intelligence. The methodology can be described as supplemental (if not disruptive) toward regular course offers. Students are taken out of their regular classroom environment, being confronted with an almost autonomous setting that requires them to actively engage to produce results. Technological systems aid them in this process, making use of their native language (amongst others), producing results that can be touched and taken home. The students learning progress is manifested in these outcomes. No grade given for any suchlike task is proof of the achievement, but the artefact produced by the student itself.

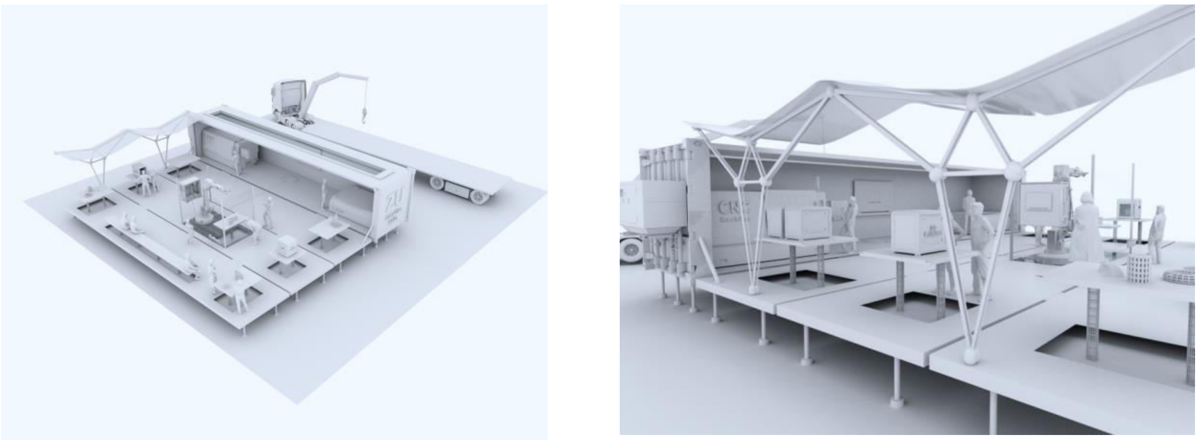

Fig.: 1 Prototypical Visualization of a Shared, Semi-Autonomous, Mobile FabLab

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