The Makers’ Movement and FabLabs in Education: Experiences, Technologies, and Research

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ABSTRACT
In this paper, we introduce the origins and applications of digital fabrication and “making” in education, and discuss how they can be implemented, researched, and developed in schools. Our discussion is based on several papers and posters that we summarize into three categories: research, technology development, and experiences in formal and informal education.

Categories and Subject Descriptors
K.3.1 [Computers and Education]: Computer Uses in Education; J.6 [Computer-aided engineering]

General Terms
Design, Human Factors, Experimentation, Theory.

Keywords
Digital Fabrication, Making, FabLabs, Constructionism, Education.

1. INTRODUCTION
Every few decades, a new set of skills and intellectual activities become crucial for work, conviviality, and citizenship. For example, in the early seventies, computer programming emerged as one of those new foundational skills. But computers in those years were large and awkward machines, and the idea of using them in K-12 education was unconceivable: programming was too difficult for children and too disconnected from school curricula.

The Logo computer language [17] started to change that mindset. In recent years, easier to learn programming tools such as Scratch [22], Alice [5] and NetLogo [30] achieved unprecedented popularity and made coding accessible to a large number of students and teachers. They also made schools expand their curricular boundaries to include new skills and abilities, such as engineering, design, and computer coding. The world caught up with the idea that computational media could be a vehicle for powerful ideas in mathematics, engineering, and science.

Digital fabrication and ‘making’ is a new and major chapter in this process of bringing powerful ideas and expressive media to schoolchildren [2]. The analogy with programming is clear: the technology became better and more accessible, and the skills more valued and important. What Logo did for programming—bringing complex mathematics to the reach of schoolchildren—fabrication laboratories (FabLabs) can do for design and engineering.

1.1 From technology “skills” to computational literacy
Traditionally, at a policy level, engineering and technology were considered as important “workplace skills” that needed to be included in school curricula. However, in 1999, the National Research Council issued a landmark report stating that technology was changing too fast for this skill-based approach to be effective, and called for a fluency approach. They suggested technological education to include the development of adaptive, foundational skills in technology and computation, in particular “[intellectual] capabilities [to] empower people to manipulate the medium to their advantage and to handle unintended and unexpected problems when they arise” [15].

The same concerns were echoed in later reports [16] which confirmed the demise of the “computer skills” approach and recognized that decades had been lost teaching them to millions of students. It called for a move from computer skills towards computational fluency or literacy [6; 19] and broadening “technical literacy” to include basic engineering knowledge, the nature and limitations of the engineering design process, and critical thought about the trade-offs of technology development and implementation.

The report also introduced an important distinction, which resonated with the concerns of Papert [18] and diSessa [6]: the recognition of a difference between technological literacy (a general set of skills and intellectual dispositions for all citizens) and technical competence (in-depth knowledge that professional engineers and scientists need to know to perform their work). It identifies fluency with technology not anymore as a vocational skill or a way train future workers, but knowledge valuable for every citizen. Since then, several other developments in research, technology and policy have further supported this vision. The once dismissed idea of children programing computers was not only embraced, but developed into a much larger vision of students conducting sophisticated activities that were before restricted to specialized professionals, such as robotics, environmental sensing, data analysis, advanced science, and engineering design. Thus, rather a sudden revolution, the now widespread acceptance of “making” and digital fabrication in education owes much of its popularity to these developments.
1.2 The Digital Fabrication Lab: the re-intellectualization of the shop class

Notwithstanding the natural content overlaps amongst science and engineering disciplines, they are fundamentally different. While a scientific investigation is typically concerned with finding the one law to explain many natural phenomena, a technological investigation typically finds many solutions for the same problem [1]. A typical school science lab is designed for rigorous, disciplined, and scripted experiences in which students are guided towards the re-discovery of a unifying principle. School science labs are architected to facilitate and optimize such a process—but would those spaces be appropriate for engineering and design?

Despite engineers’ dependence on basic scientific knowledge to do their work, their epistemology even precedes science; humans have been creating tools and altering their environment much before the inception of the scientific method. In fact, engineers’ ‘ethos’ as inventors and tinkerers, in both K-12 and college education, survived up to the fifties and sixties, after which there was a significant push towards analysis and mathematics, and away from traditional “shop work” [11], which was overwhelmingly present in curricula during the first half of the 20th century [7]. The professional engineer of the first half of the 20th century became the scientific engineer of the second half [29], partly motivated by the end of the Apollo era funding – less expensive theoretical classes prevailed over engineering labs or design work [9]. Over time, this resulted in the removal of the engineering design experience from not only college curriculum, but also from K-12 education. Shop class became “vocational education” for those who supposedly could not handle ‘serious’ math or science.

Two independent processes started to reverse this trend. First, around the eighties, faculty and employers started to feel that the design-deprived engineering graduates were not well prepared to do any real engineering design work, which had started to become more important [25]. Second, in the early 2000s, prototyping equipment, such as laser cutters and 3D printers, dramatically dropped in price, and open source hardware further popularized these technologies. Suddenly, corporate product development showed that it was possible to engage children in complex uses of technology, that those same children could actively construct with interactive textiles [4], electronic jewelry [20; 28], the creation of advanced scientific explorations [3], low-cost robotics [26; 27], and the creation of low-cost materials to engage children in the creation of tangible creatures [21; 24]. These toolkits and technologies prepared the ground for the popularity of the ‘maker’ movement and digital fabrication. They showed that it was possible to engage children in complex uses of technology, that those same children could actively construct with technology rather than just consume technological products.

These theoretical and pedagogical principles have also pervaded the creation of the Interaction Design for Children community, so bringing the “maker” movement, FabLabs, and digital fabrication to the center stage of IDC is a natural fit. In fact, many developments in the IDC community enabled or amplified the maker/FabLab movement, such as hardware and software for advanced scientific explorations [3], low-cost robotics [26; 27], interactive textiles [4], electronic jewelry [20; 28], the creation of videogames [12; 14], and new types of cybernetic creatures [21; 24]. These toolkits and technologies prepared the ground for the popularity of the ‘maker’ movement and digital fabrication. They showed that it was possible to engage children in complex uses of technology, that those same children could actively construct with technology rather than just consume technological products.

2. WORKSHOP CONTRIBUTIONS

In this workshop, we revisit the theoretical underpinnings of constructivism, constructionism, and how they inform research and development in the realm of digital fabrication in education, “making,” and the “makers’ culture.” The papers and posters analyze current initiatives in the field, examine the literature, and create initial theoretical frameworks for research, assessment, and design in this area, with roots in the learning sciences, HCI, critical theory, and the cognitive sciences. The submission connect the explosive on-the-ground work that is happening in schools, museums, and after school programs, to theories, literatures, and research around hands-on learning, project-based learning, tangible interfaces. The contributions can be grouped into three different categories. The first is mostly about how scholars and practitioners are collecting data and doing research in this field. The second is about narratives of experiences that are taking place in schools and informal educational settings. The last category of papers and poster is about new technological developments in hardware, software, interface design, and system integration. In what follows,
we will describe each of the categories and their corresponding submissions.

2.1 Technologies and human-computer interaction in digital fabrication

The first contribution of this category is “Considering Constructionism for Digital Fabrication Software Design” by Zeising, Katterfeldt and Schelhowe. They argue for a new approach for 3D-modeling applications for digital fabrication in educational contexts. Based on playful constructionist learning, they propose an initial framework to design such kind of software applications.

The second contribution, “The Spiro Inquiry,” by Hooper and Freed, presents the design and implementation of a new software tool called “Spirogator” for exploring the properties of “spirograph” geometry, both on-screen and with digitally designed and physically fabricated gears.

Also in the technology/HCI track, another contribution is the “MakerCart” by McKay and Peppler. They present a mobile FabLab for the classroom that is designed to address the space and funding constraints of schools. They claim to improve the integration of FabLabs to schools’ instructional and curricular frameworks.

Sipitakiat, in his poster submission, discusses a new paradigm and hardware platform (“PiTopping”) developed to highlight a new physical computing programming model made possible by miniature single-board computers such as the Raspberry Pi. Ri Que presents the design of workshops to engage parents and their children to “make” together using creative tools such as Scratch and MaKey MaKey, and shares preliminary findings and lessons learned from these experiences.

Chan and Pondicherry present LightUp, a constructionist toolkit for learning about electronics, and explain in detail their design principles for making electronics transparent and easy to understand for children.

2.2 Experiences in formal and informal education

In this category, one of the main contributions come from Wanyiri and Ombatti, who discusses the impact of the “FabLab Robotics Outreach Programme (FROP)” in marginalized areas in Kenya. The aim of this project was to teach girls simple, basic and elementary electronics, robotics, programming and automation in different workshop sessions.

Telhan, Kafai, and Elinich’s poster present eCrafting Circles, a platform for design, sharing, and learning built to support craft communities. Milne introduces the Future Science Leaders, a high school enrichment program run out of a science museum, which uses project and problem-based learning to teach science and technology. The poster describes successes and challenges from the first two years of the program.

Druga and Kera describe a research framework for inquiry-based learning activities for middle-school children, focusing on motivation and knowledge transfer. They have designed several activities, such as the “Wiki of Making” and “Challenge Hub,” and use self-determination theory [23] as one of their theoretical basis.

Buckley’s poster describes a design-inspired project (“Tools for Schools”) in which The School at Columbia University partnered with a furniture manufacturer to implement a fabrication project in an 8th grade classroom. Forty-four students were asked to create the “classroom of the future” using their daily school environment as a launching pad.

Zamarano and Jenkins present their CoLaboratory project at the United Nations International School, focusing on ways to integrate making and constructionism into teachers’ traditional curriculum.

2.3 Research

In the research cluster, Martin and Dixon report on how young people involved in an out-of-school maker club think about making, the maker movement, and themselves as makers. In their paper “Youth Conceptions of Making and the Maker Movement” the authors identify three general themes and present a description of future research plans.

Flores and Springer describe research in the school fabrication lab (iLab), and how they are trying to introduce self-directed, peer-organized learning across several age groups. Norris’ poster discusses a case study with nineteen 10th grade girls who worked with their Geometry teacher to design artifacts that would assist them with the development of positive self-perception. She frames this design-thinking curriculum in terms of a constructionist roots, and examines the process of identity formation through the construction of physical artifacts.

Worsley presents three case studies of youth in a digital fabrication lab, illustrating how such spaces must address a wide range of interests and motivation levels. He describes in detail the learning trajectories of different students, showing how even students from the same school and same grade levels would behave very differently in an open-ended environment, calling for careful activity design in order to accommodate individual differences.

3. CHALLENGES, OPPORTUNITIES AND CONCLUSION

3.1 Opportunities and possible actions

Starting from the submitted contributions and poster session, the objective of the workshop is to discuss concrete next steps for community building and dissemination of this work, such as:

- Tools for exchange of experiences between participants.
- A crash-course in some of the theoretical foundations in the field.
- A web-repository of relevant literatures, research methods, instruments, and institutions working in this field.

Digital fabrication and “making,” and the positive social movement around them, could be an unprecedented opportunity for educators to advance a progressive educational agenda in which project-based, interest-driven, student-centered learning are at the center stage of students’ educational experiences. However, we are still in early stages of implementation of these technologies and spaces in schools, and soon the “honeymoon” period will be over – results will be demanded, evaluations will take place, and schools will carefully analyze the cost-benefit of such initiatives. Educators and researchers should be prepared for this next phase with good activities and generative themes, sound research instruments/methods, and comprehensive professional development programs. The goal of this workshop is to start this discussion and plan next steps in that direction.

4. REFERENCES


