Training and Inspiring Educators in Digital Fabrication: A Professional Development Framework

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ABSTRACT
As digital design and fabrication is being pulled more and more into mainstream formal education, there is an urgent need for a comprehensive framework for inspiring, training and supporting educators in curriculum development, integration and alignment, and for assessments that measure mastery of acquired skills, cognitive development, and content knowledge. We, the Fab Foundation and the Teaching Institute for Excellence in STEM (TIES), are working with innovators and educators who are actively using digital fabrication and experiential, project-based learning, and who have a stake in supporting and implementing this kind of STEM and arts-integrated education to:

- Design the foundations of a national, customizable digital fabrication STEM professional development framework
- Design the foundations of a standards-based digital fabrication STEM curriculum framework.

In this paper we review the professional development framework that has been assembled by this community of practitioners and reflect on the work that still needs to be accomplished.

Categories and Subject Descriptors
Documentation, Management, Performance, Standardization

General Terms
Management, Measurement, Documentation, Performance, Design, Standardization

Keywords
Digital Design and Fabrication Education, STEM Education, Arts Integrated Education, Informal Education, Formal Education, Teacher/Educator Professional Development, FabEd

1. INTRODUCTION
Many of the current exciting and innovating programs focused on STEM and arts teaching and learning leverage the digital fabrication environment and DIY movement as creative foundations. Innovations are emerging from informal education environments such as community centers, Fab Labs, maker spaces, hacker spaces, libraries and museums. Formal educational institutions are increasingly pulling for these innovations, in great part due to the lack of effective curricular and teaching tools to support a growing demand from industry and government for STEM literate graduates. Despite progressive efforts on the part of individual pioneering educators, US K-12 schools are not graduating a sufficient number of students who pursue further education or careers in STEM to fulfill the technical workforce demand [1].

In order to increase the number of STEM literate and capable students needed to fill growing workforce demands, it is necessary to create an environment that empowers students to own their learning by engaging in authentic projects driven by real-world problems [2,3,4]. This can be accomplished, very effectively, using some form inter- or transdisciplinary project/experiential/problem based learning [2,3,4]. Introducing digital fabrication and other making techniques can amplify the effects of project based learning through an enhanced learning environment that provides the opportunity for learners to imagine, design, prototype, make, and collaborate [4]. In this environment the learner is immersed in the content material that they are responsible for mastering, leading not only to learners internalization and applied understanding of the concepts (as opposed to memorization) but also to learners reaching for information above and beyond the educator's planned learning outcomes. This just-in-time learning is reminiscent of how technicians, engineers, and scientists operate in the workforce, in stark contrast to the "traditional" classroom learning.

Educators desperate for new approaches and solutions are reaching for digital fabrication and making, which currently reside mostly in informal education. The innovations coming from informal education are partially due to the agile, flexible, and unconstrained environments from which they emerge. These same advantages are perceived as disadvantages in formal education, making the DIY culture that inspires innovation a mismatch for formal educational institutions. There are examples of formal education integrating digital fabrication into project-based learning environments, with great success. MC2STEM High School in Cleveland, OH, Marymount Catholic Day School in Manhattan, NY, and Incite Focus in Detroit, MI utilize trandisciplinary projects that cut across the boundaries of traditional subject area classes to create authentic student driven learning experiences. Mahtomedi High School in Mahtomedi, MN, High Tech High in San Diego, CA, and Castilleja High School in Palo Alto, CA have implemented an engineering class with transdisciplinary projects that reach out to the subject area classrooms. Unfortunately these examples are the exception, not the rule. The lack of a national consensus regarding standards for teaching or learning with digital fabrication in the classroom severely inhibits formal institutions from adopting a potentially powerful toolset for engaging students in STEM and the arts and providing hands-on, authentic learning opportunities in a transdisciplinary learning environment. Due to this, adoption of digital fabrication in formal education has been inconsistent. Digital fabrication continues to be perceived as an after-school opportunity rather than a formal educational platform for STEM learning. Formal education, while pulling for this transdisciplinary platform, has not yet devised large-scale strategies to empower and support educators in implementing digital design and fabrication in the classroom. Effective teachers are one the main factors affecting student success rates (NTP). Therefore training, development, and support of educators responsible for facilitating student learning are critical to the successful integration of digital design and fabrication into formal education.

In response to this increasing demand for digital fabrication in the classroom, stakeholders in the digital fabrication community have formed a collaborative educational network called FabEd to address the needs of formal educators interested in using a digital fabrication approach in the classroom. The network collaboration, led by The Fab Foundation and TIES, is developing tools to inspire, train and support educators in migrating digital fabrication tools and curricular strategies into formal education - first through a comprehensive educator professional development framework and later through additional community shared resources and innovations. FabEd is a coordinated national effort—providing guidance and fidelity for a network of educators as digital fabrication moves into formal education. FabEd strives to hold on to the magic and joy of what making and digital fabrication bring to youth and harness it to transform learning.

2. Framework

2.1 Framework Categories of Knowledge

Digital fabrication laboratories in formal education environments bring the ability to make physical and conceptual models, to engage in computer aided design, to design and fabricate electronics, to create and implement computer programs, to communicate and collaborate with other digital fabrication labs around the world, and to print, mill, and cut a large variety of materials. Both the soft skills and the interdisciplinary learning that can be achieved in digital fabrication laboratories are highly valued by industry. However, without supporting frameworks for teaching and learning, a digital fabrication lab is akin to a door stop, a technological artifact, a place in school where powerful potential exists, similar to a computer lab, but is only useful with competent, thoughtful guidance and mentoring. With a framework that provides the necessary support and guidance to an educator, the digital design and fabrication lab becomes a place where learning happens, evidence of that learning is generated, and learners are challenged and inspired to reach for the content necessary to complete their projects. In July of 2013, The Fab Foundation, TIES, and the Chicago Museum of Science and Industry convened a group of experts and practitioners of digital fabrication in education to develop an educator professional development framework for digital fabrication and the design principles surrounding it.

This group identified critical categories of knowledge that an educator needs to successfully integrate digital design and fabrication into a learners' formal educational experiences.

These categories included:

- Digital design and fabrication techniques
- Engineering fundamentals
- Application of the design process
- Project design and management
- Strategies to align student learning to benchmarks and to leverage standards for assessment
- Partnership and asset building and alignment
- The larger context of digital fabrication in the making, tinkering, and fabbing communities as well as the interests of industry and national economy-- The BIG Picture

As a result of the Chicago Digital Fabrication Professional Development Design Studio, the group formed a continuing collaboration and designed a basic educator professional development framework from which FabEd will pilot training programs around the country as it continues to iterate the work. The design process will broaden in scope in August at the annual international Fab Lab gathering, FAB9, where the collaboration will begin to incorporate an international cohort of digital fabrication educators and practitioners. Below we describe in more detail the core categories of knowledge identified in the professional development framework.

2.2 Digital Design and Fabrication

To facilitate a learner's use of digital fabrication tools as part of an experiential/project based curriculum, an educator must have some personal working knowledge and understanding of the software and physical machines to be utilized by learners. Instruction in basic design software, safe use of equipment, awareness of machine capabilities and design methodologies that allow for fluid transition between analog and digitally created forms is essential. An educator with this knowledge can guide beginners in digital design and fabrication and is better able to integrate digital design and fabrication techniques into their curriculum.

2.3 Engineering Fundamentals

It is necessary for educators intending to use digital design and fabrication in the classroom to have a basic understanding of engineering and science fundamentals--for safety reasons as well as to facilitate cross-disciplinary learning and leverage the full potential of the digital fabrication environment for STEM. It is not necessary for every educator to become an engineering expert, but basic understanding of mechanical/electrical/physical properties will greatly enhance an educator's potential to catalyze learning in a digital fabrication environment. A grasp of engineering fundamentals also supports educators in identifying and recognizing evidence of learning in fields that may not be their primary expertise. This knowledge also supports educators in guiding students and learners through product and project designs.

2.4 Design Process Application

Educators need to understand and utilize the design process in a digital fabrication environment. The design cycle of imagine, prototype, test, reflect and iterate is used by engineers, industrial designers and product innovation teams worldwide and can greatly enhance an educator's ability to guide and mentor students successfully through their projects and creations. The iterative nature of the design and prototyping process facilitates a student's pull for knowledge and encourages him or her to stretch the boundaries of their capabilities. Educators who have a working knowledge of the design process are better able to create an environment in which students own their learning processes and are equipped with the tools and self-efficacy for lifelong learning. The design process itself also provides opportunities for integration of standards and benchmarks, including the national Common Core Standards in math and language arts and the Next Generation Science Standards. (NGSS).

2.5 Project Design and Management

As many educators are discovering, classrooms that integrate project-based learning require a very different management system. This system encompasses not only how an educator facilitates the needs of several groups or individuals working on potentially disparate topics, but also how "class" and "classroom" are defined both in space and time. Educators and their supervisors must understand how to implement and manage this very different learning environment. Strategies for management include developing logistics skills, facilitation skills, and understanding how to organize systems and collaborative or team projects. Effective project framing and design skills are important tools for educators embarking on the digital fabrication path. Poorly designed projects can be overly formulaic, negating the advantages of project-based learning. Likewise, overly open-ended designs can discourage learners to the point that they disengage and fail to meet learning goals. Developing project design and management skills is an essential element of the FabEd educator professional development framework.

2.6 Aligning with Standards

As digital design and fabrication migrate into formal education, a critical consideration is the alignment to local, state and national standards. Adoption of these tools and processes in formal education requires their integration into curricula in an authentic manner and the ability to assess learning outcomes. Without this alignment, digital design and fabrication will continue to be leveraged in informal/out of school time and space but not in formal education environs. Educators must to learn to design projects with rubrics that contain learning outcomes aligned to standards. It is essential to identify desired learning outcomes for projects and be able to collect evidence of learning outcomes over the course of student projects. For educators to accomplish these two things, they should develop the skills to map requisite standards to a comprehensive list of learning outcomes. This list can then used by educators in the original design and implementation of projects in their classroom. The FabEd framework incorporates standards alignment as a core element of training.

We are uniquely poised at this time to create a national language for digital fabrication standards as a number of states in the country are adopting new standards, and developing new strategies for teaching, learning and assessment, specifically: the Common Core Standards (including math and language arts) and the Next Generation Science Standards. As we equip educators to use digital fabrication in the classroom we can also shape the form and content of digital fabrication more broadly in US education.

2.7 Partnership and Asset Building

Garnering the resources, both intellectual and financial, required to build and sustain a digital design and fabrication lab in a traditional formal school setting can seem like an overwhelming and unattainable challenge for individual educators who want to bring digital fabrication into a school or district. In addition, the expertise and mentorship that learners need as their projects delve deeper into authentic, real world problems is rarely present in the staffing of K-12 educational institutions. It is essential that digital fabrication training programs include strategic lessons in identifying local and regional assets and the process of developing supportive, sustaining partnerships through these assets. Educators working in states with functioning STEM networks face less of a challenge, but at this point in the growth of digital fabrication in education, all educators entering the field need skills to garner resources and to form mutually beneficial partnerships.

2.8 The BIG Picture

Fabbing, making or tinkering rarely happen in a vacuum, especially in this age of blogs, wikis, Google hangouts, and maker spaces. The community that has formed around fabbing things, analog or digital, is a powerful resource for educators and learners as expert technical and instructional support. The framework includes strategies for connecting to the larger community. It is vital as we move informal spaces into formal education that we keep them connected to the surrounding communities and ensure that the spirit and magic of these groups are not lost. It is also essential that educators understand the skill needs and technology trends of industry and how our national and global economic interests are intimately tied to the emerging digital fabrication economy.

3. Empowering Educators

The framework will be designed to be useful for a variety of informal and formal educator groups, each with its own system of developing and training its human capital. The piloting, vetting and sharing of the framework through the FabEd network will reach a subset of informal and in-service formal educators. However, in order to create the human capital resources for digital design and fabrication labs in formal education, the education of pre-service teachers must be considered. Teaching programs at places such as Purdue University, Virginia TECH, Stanford, and the Curry School of Education at Virginia, are providing innovative pre-service training for educators in STEM and project based fields, with Stanford and the Curry school beginning the process of integrating digital fabrication [5,6]. These programs provide a starting point as we try to integrate the educator professional development framework into pre-service training for educators.

4. CONCLUSION

This first iteration of the educator professional development framework will be piloted by a number of organizations collaborating with FabEd in the coming year. The development group will iterate improvements on the framework based on feedback from educators who learn through this framework and use their skills in the classroom. Through the process the Fab Foundation and TIES will collect data and process information on these pilots in order to create successive forms of the framework and facilitate the eventual sharing of the framework with the network. Our hope and expectation is that crowd-sourcing with an international cohort of digital fabrication practitioners in education will allow us to develop a relevant and effective framework for leveraging digital fabrication in formal education, and will eventually assist in blending formal and informal education environments. Our next challenges are to develop strategies to better integrate digital fabrication into curriculum, to develop aligned assessment strategies, and to evaluate and share successful programs and activities that emerge from our communal work with the formal education sector.

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6. REFERENCES

[1] Committee on Science Engineering and Public Policy. (2007). *Rising Above the Gathering Storm:Energizing and Employing America for a Brighter Economic Future Engineering in K-12.* Retrieved March 3, 2011 from: http://books.nap.edu/openbook.php?record_id=11463&page=R1

[2] Janice Morrison.(2006). *TIES STEM Education Monograph Series: Attributes of STEM education*. Retrieved August 19, 2013 from: http://www.tiesteach.org/assets/documents/Jans%20pdf%20Attributes_of_STEM_Education-1.pdf

[3] National Research Council. (2011). *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics. Committee on Highly Successful Science Programs for K-12 Science Education*. Board on Science Education and Board on Testing and Assessment, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press. Retrieved August 19, 2013 from: http://wolf.house.gov/uploads/Fall%202011%20NSF%20Report.pdf

[4] Vanessa Vega. *Research Based Practices for engaging Students in STEM Learning*. Retrieved August 19, 2013 from: http://www.edutopia.org/stw-college-career-stem-research on

[5] http://curry.virginia.edu/research/projects/childrens-engineering-initiative

[6] https://tltl.stanford.edu/projects/fablabschool