



## **Fab Labs: Re-envisioning Innovation and “Entrepreneering”**

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### **ABSTRACT**

Can Fab Labs provide the impetus for systemic change in education and entrepreneurial environments? Fab Labs, small-scale workshops using off-the-shelf, industrial-grade technologies, are being used to bring prototyping capabilities to underserved communities around the world. The Massachusetts Institute of Technology uses Fab Labs and information technologies to enable individuals to define problems, prototype solutions, and encourage the start of local micro businesses (Lassiter, 2009).

The Fab Lab concept may reflect a new manufacturing paradigm where individual “entrepreneers” (individuals who perform both engineering and entrepreneurial tasks) define problems, create solutions, and market products. A community workspace is created that serves as an incubator for research, creative endeavors, and business incubation. The Fab Lab removes barriers such as start-up funding, access to equipment, and access to expertise, thus encouraging systemic change to educational and entrepreneurial environments.

Speculation on a process for developing a Fab Lab that is based on the Midwest Fab Lab Network’s eleven step model is detailed and followed by a brief discussion of findings to date.

Keywords: STEM, FabLab, Agile production

### **INTRODUCTION**

This paper is divided into five sections that explore the viability of developing a Fab Lab at the University of Wisconsin- Stout. The background section includes a description of Neil Gershenfeld’s Fab Lab project and his vision for social change within a context of digital fabrication. The methodology section describes an eleven-step process used for developing a Fab Lab. Suggestions for curriculum models, project development models, and teaching strategies are indicated where appropriate. A non-linear model that includes planning and implementation phases is proposed in the findings section of the paper. Perceived tensions between structured environments of educational institutions and the creative environment of a Fab Lab are also noted. After a short summary section, suggestions for best practices are



made. The paper concludes with a section briefly recapping future work needed to develop a Fab Lab at UW-Stout.

## **BACKGROUND**

Fabrication Laboratories (Fab Labs) began as an educational outreach project from MIT's Center for Bits and Atoms in 2002, with funding from the National Science Foundation. Fab Labs combine open source software with commercially available, industrial grade, rapid prototyping equipment such as computer controlled laser cutters, scanners, and milling machines. Internet and broadband conferencing capabilities link over 40 Fab Labs in 11 countries (Sun 2009; Lassiter, 2009) to enhance information sharing and informal educational opportunities. Fab Labs allow individuals to construct prototypes as long as users learn how to do the fabrication on their own and share the lab with others. Clients are expected to work safely, clean up and assist with maintenance, repair, and supplies (Fab Charter, 2007). Fab Labs employ a new manufacturing paradigm where ordinary people "create rather than consume technology" while "locally design(ing) and produc(ing) solutions to local problems (Gershenfeld, 2007, 14:11 – 15:48). A pilot's control yoke made from old electronic toys, a telecommunications network to track sheep in northern Norway, and measurement tools to ensure a safe milk supply in India (<http://www.wired.com/science/discoveries/news/2005/11/69495>) are a few examples of Fab Lab projects designed to meet local and personal needs. The Fab Lab community workspace removes barriers such as access to equipment and access to expertise. The Fab Lab's grassroots environment serves as an incubator for creative endeavors, job creation, economic development and research. Individuals applying scientific and mathematical principles to the practical design, manufacturing and operation of products (engineer, 2011) engage in engineering activities. Some individuals become entrepreneurs (entrepreneur, 2011) as they create businesses related to marketing and selling their newly engineered creations. Thus Fab Labs help create "entrepreneers" -individuals who design as well as market their own creations.

Fab Labs are designed to be more than elaborate workspaces. Labs are built in underserved communities that experience "a fabrication and instrumentation divide bigger than the digital divide."



Fab Labs serve as “social engineering” agents that encourage systemic change in education and entrepreneurial environments (Gershenfeld, 2007).

A Fab Lab currently exists at Century College, in White Bear Lake Minnesota. The Mahtomedi Public School District is in the process of installing a Fab Lab in its school district. Both of these sites are within 75 miles of the University of Wisconsin-Stout campus. With the establishment of a Fab Lab at UW-Stout an infrastructure would be in place to support and enhance collaborative endeavors between K-12 schools, community colleges, and the university.

Outreach efforts, teacher preparation in STEM (Science, Technology, Engineering, Math), verifying research-based “best practices” related to engineering education/assessment, and the impact on student recruitment and retention represent a sampling of topics that may be investigated as UW Stout’s Fab Lab is developed. A STEM agenda related to education would be advanced as a result of these activities.

## **METHODOLOGY**

UW-Stout has begun the process of developing a Fab Lab that supports the institution’s commitment to technology transfer, entrepreneurial support, and outreach to K-12 schools. The Fab Lab concept fits with the university’s emphasis on real-world experiences for students and faculty with applied research directly impacting the regional economy. (Midwest Digital Fabrication Partnership, n.d.).

This paper integrates information from existing Fab Labs, UW-Stout’s progress to date, instructional design processes, and agile manufacturing concepts to explore the viability of a model for Fab Lab development. The chosen model uses the Fab Lab lifecycle outlined by the Midwest Fab Lab Network (MFLN), which includes the following: research, interest generation, planning, justification, commitment, training, installation, implementation, enhancement, maintenance and sustainability. (Midwest Fab Lab Network, 2008; FabLab Dev Process (US), n.d.). The project has gone through the research and interest generation stages. Planning and justification phases are scheduled to occur. The balance of the project lifecycle will continue as resources and support are obtained. It should be stressed that the model presented here outlines one hypothetical strategy and is not necessarily indicative of how the project will



actually unfold. It should also be noted that the author is interpreting the Fab Lab lifecycle process within the context of personal experience related to a specific project.

## **Research**

Research and participation in NSF-funded Fab Lab activities have been ongoing for several years. Researchers at UW-Stout demonstrated that digital fabrication capabilities can be integrated into engineering technology courses using equipment found in Fab Labs. Sabbatical leave allowing faculty to investigate Fab Labs in other countries has been supported by the university. Professors working with students on special projects identified a need for access to labs that are stand-alone entities not tied to any department. Lab access facilitates applied learning with students working in interdisciplinary teams and fast turn-around times. Easy access to labs fits with agile production principles and removes barriers needed to implement UW-Stout's 2015 goals to "expand early and ongoing experiential learning opportunities including undergraduate applied research and entrepreneurship" (UW-Stout, 2009). Data of student use of labs could be correlated with recruitment and retention data to examine the impact Fab Labs have in attracting and keeping students interested in STEM-related careers.

Designing prosthetics, designing packaging, and designing for technical competitions have been identified as potential activities for the Stout's Fab Lab. By targeting needs of university students, surrounding communities and K-12 schools, the Fab Lab project has the potential to provide an avenue for economic development and serve as a showcase for individuals interested in accessing science, technology, engineering and mathematics (STEM) within their communities. Schools lacking resources could bring students to UW-Stout to expose them to STEM activities. Integrating Fab Lab experiences into pre-engineering courses allows K-12 students to use digital fabrication equipment that a single school district might not be able to afford. Additionally, the Fab Lab could provide communities with implementation guidelines and consulting help, thereby enabling them to create their own Fab Labs and spur economic development. Curriculum describing "how to build anything" combined with instruction on "reimagining your community" may facilitate locally-driven, innovative solutions to economic growth in depressed communities. These concepts can be tied to UW-Stout's goals and include activities not limited to:



- Designing classes and seminars asking students and community members to “Create a company that will support your family and employ at least one other person within a three year period of time.”
- Providing capstone experiences, such as machining and robotic projects, to K-12 students and teachers.
- Utilizing K-12 partners in conjunction with Fab Labs to create student teaching experiences for pre-service teachers seeking dual Science and Technology Education licensure or exposure to integrated STEM curriculum.

Data collected relative to these activities may help to determine the success of K-12 outreach efforts, examine best practices in creating education pipelines to STEM careers, and examining “best practices” related to experiential learning.

### **Interest Generation**

Interest in the Fab Lab project is generated through formal and informal networks. The Director of UW-Stout’s Discovery Center plays a central role in generating project interest. As co-principal investigator of the NSF’s Project, the Director is able to identify potential partners, participants and key stakeholders interested in Fab Lab development. The Director is able to gain project support from university administrators , as well as identify individuals with the requisite skills necessary for project implementation.

Personal contacts, conversations, and telephone calls are some of the informal processes used to augment project development. Over time feedback from personal and professional contacts helps project coordinators gauge interest in the Fab Lab project. A core group of leaders is identified to help develop the Fab Lab concept. An invitation to serve as a key leader for the project is based on expertise, interest, and the ability to commit to the project. The planning phase of the project begins in earnest as project coordinators focus on specific goals, refine the size and structure of leadership teams, and develop the Fab Lab mission relative to the needs of the surrounding community.

### **Planning**

A small leadership team representing multiple stakeholders is assembled to work on the Fab Lab’s mission, objectives, and goals. All Fab Labs adhere to The Fab Charter, whose



mission is to join “a global network of local labs, enabling invention by providing access for individuals to tools for digital fabrication” (Fab Charter, 2007). Some Fab Labs construct their own mission statement relative to local needs that may focus on architecture, art, computing, and technical trades (Champaign-Urbana Community Fab Lab, n.d.) or on empowering individuals to create practical and economical smart devices (ARO Fablab, 2010). The mission of the Fab Lab is established early in the process to align with university goals, requirements of the participating partners and the target audiences. Leadership teams identify the goals and objectives that support the project’s mission. In this project the leadership team is being asked to consider a “collective impact initiative” that involves a centralized infrastructure. A common agenda, ongoing communication, mutually reinforcing activities, and systematic and shared measurement (Kania & Kramer, 2011) are integrated into the project.

It is suggested that a version of Scrum methodology, an agile project management strategy used in the software industry, be adapted for this project. Scrum methodology dovetails well with a collective impact initiative. The Scrum approach divides larger projects into smaller steps requiring regular communication among team members, frequent progress reports, and collective planning of “next steps” (Scrum Methodology, n. d.). Utilization of this method helps keep the project on track as key leaders work independently with sub-groups on different, but connected parts of the Fab Lab project. Tasks for key leaders and sub-groups is not limited to justifying Fab Lab need, identifying existing curriculum, developing instructional models, locating funding sources, assessing community needs, and procuring Fab Lab facilities.

## **Justification**

Justification for the existence of a Fab Lab at the university is in its formative stages. Economic development, access to labs independent of university departments, and access to expensive equipment allowing for the integration of STEM activities in K-12 settings have been identified as needs. Project interest has been generated among potential stakeholders. It is the task of the leadership team to determine the mission of the Fab Lab relative to the geographical area served.

Determining who has access to the lab, the location of the lab, and financial issues need to be considered (FabLab Dev Process (US), n. d.) This part of the process is critical as it lays the foundation for Fab Lab implementation. Sun’s 2009 annual report to the NSF regarding the



installation of the Jalalabad Fab Lab in Afghanistan sheds light on critical issues regarding Fab Lab location.

Considerations in site selection include easy access for key stakeholders, the ability to maintain control of equipment, the availability of volunteers to help run the lab and ownership of the facility. Considering these questions before a Fab Lab is set up helps to alleviate problems that arise regarding maintenance, safety, liability and accessibility.

### **Commitment**

Obtaining a commitment from key stakeholders to support the Fab Lab initiative helps the project in several ways. Existing resources are identified and help to reduce start-up costs. Conversations regarding human and material resources help reaffirm stakeholders' willingness to utilize the Fab Lab and its resources. Discussions regarding resources and their allocation help keep stakeholders informed about project progress.

A number of resources are required to implement a Fab Lab at the University. A current inventory of equipment and supplies needed for a Fab Lab can be found at <http://fab.cba.mit.edu/about/fab/inv.html>. Identifying available resources for the fab lab may result in reduced implementation costs. It is important to determine if existing resources need to be repurposed and appropriate permissions need to be obtained. Potential resources for a Fab Lab are not limited to reallocating grant funds, reallocating machinery, locating existing but unused equipment, soliciting contributions from college deans or asking local industries to supply "scrap" material for Fab Lab use.

The unseen infrastructure also requires a commitment from stakeholders. Web page development/upkeep, marketing initiatives, technical support and the ongoing costs associated with these activities needs to be considered (Sun 2009). Clear delineation of responsibilities related to the unseen infrastructure should be specified before the Fab Lab is installed.

### **Training**

Instructional design and training model(s) for the Fab Lab project have not been selected or scheduled for implementation. Comprehensive models to consider include the Morrison, Ross and Kemp model, the Three-Phase Design model, the ADDIE process, Instructional Development Learning System model, and the Dick and Carey model (Tan, n. d.; Instructional



Design, n. d). Wiggins and McTighe's *Understanding by Design* (McTighe & Associates, 2011) focuses on developing units of instruction aimed at applying knowledge and skills in meaningful contexts. Teaching model(s) (Learning Technologies at Virginia Tech, 2011) and suitable approaches for delivering content may be explored to determine the best instructional approaches to be used in a Fab Lab setting. The selected model(s) need to be responsive to the interactive and learner-centered nature of the Fab Lab. The type of delivery method, whether instruction is delivered face-to-face, distance delivered, delivered synchronously or delivered asynchronously are some of the issues to be considered. Lessons from Sun's (2009) experience with the Jalalabad Fab Lab indicate that some teachers may not be comfortable learning in front of students. Project-based learning strategies proved to be a successful instructional approach. It is not clear if this will be the case in context of a Fab Lab based at UW-Stout.

Training related to lab implementation will occur in conjunction with site installation. Training for Fab Lab visitors will occur after the Fab Lab is operational. The selected model(s) need to be comprehensive enough to address curriculum development at the system level while providing suitable design structure for unit development and lesson delivery. A balance must be reached between an instructional design model based in research that provides structure for curriculum developers/researchers and the need to provide just-in-time, flexible instruction for Fab Lab clients.

Before instructional design and training occurs it will be necessary to identify roles and responsibilities of individuals providing instruction, maintaining facilities and equipment, and those who are reporting data. A need analysis identifying what training is indicated will be completed. Training documents will be obtained or created for policies, procedures, safety, maintenance, liability and instruction. Initial efforts will be aimed at finding existing curriculum such as MIT's "How to Make Almost Anything". Vendor created curriculum for machine operation, published curriculum, library resources and Internet resources will be tapped for use in the Fab Lab. The second step will be creating curriculum to fill gaps in training documentation. The training materials will be designed to fit an instructional template so that materials have a consistent format.



## **Installation**

Fab Lab installation at Stout includes making sure hardware, material storage, utilities, and furniture is in place. Software, information technologies, and computing resources will be installed. Operating procedures including staff descriptions, budget processes, inventory procedures, data collection procedures and items identified in the planning and justification steps will be implemented (Sun, 2009). Strategies helping make the process progress smoothly include talking with others who have installed Fab Labs, referencing existing publications describing Fab Lab implementation, and referencing existing material and equipment lists. A clear idea of the Fab Lab goals, measurement indicators, and marketing strategies will guide the implementation of web pages, assessment systems, policies and procedures.

## **Implementation**

The implementation phase of the Fab Lab project is straightforward in that the services of the Fab Lab are marketed, clients visit the Fab Lab, instruction is provided, and products result. It is expected that the progression of personal empowerment to technical education to problem solving as described by Gershenfeld (2007, 10:57 – 13:16) will occur during the initial stages of the implementation phase of the project. It is also expected that that issues, like those described by Sun (2009), including quality of products, peer mentoring, lab governance, communal lab issues, and training effectiveness will need to be addressed.

The implementation phase may offer an opportunity for researchers to study the impact of instructional strategies within the context of a rapidly changing, user-driven environment. This phase of the project may also provide opportunities to adapt agile production systems and principles from lean manufacturing to a constantly changing educational teaching-learning environment (Patton, J. 2009).

## **Enhancement**

The enhancement portion of the Fab Lab project is designed to be a long-term, ongoing process. If Gershenfeld's (2007, 10:57 – 13:16) observations about the progression of activities occurring within a Fab Lab are applicable, job creation from Fab Lab spinoffs, inventions and supporting research will occur. The resulting activities will challenge typical organizational and



educational boundaries providing opportunities for research, “entrepreneering” and social reform.

### **Maintenance**

Maintenance strategies will be developed during the planning and justification phases of the project and modified over time to assure that the Fab Lab remains functional. Relying on volunteers alone to maintain facilities may not be reliable and are problematic in terms of liability and safety issues. Finding a funding source to supply maintenance fees, charging user fees, course fees, and consulting fees are being considered.

### **Sustainability**

UW-Stout’s Fab Lab will be sustainable over time if it adds value to the key stakeholders. Marketing efforts and web sites showcasing engineering and entrepreneurial activities will help generate a critical number of clients interested in utilizing the Fab Lab. The importance of easy access for community members, students and researchers is vital and includes keeping the lab independent of specific colleges and departments. This structure will help promote agile systems capable of keeping up with a rapidly changing world independent of university constraints. Clear outcomes tied to collective impact initiatives (Kania & Kramer, 2011) with ongoing data collection and impact analysis will provide data for researchers and demonstrate the lab’s effectiveness.

### **FINDINGS**

Two major insights resulted from speculating on the eleven-step Fab Lab development model. There is a perceived tension that reoccurs through most phases of the Fab Lab project. Fab Labs are inherently designed to be responsive to clients’ needs. Equipment use, tools needed, materials allocated and instruction required all vary with each individual user in the Fab Lab. The Fab Lab emulates agile production methods, just-in-time delivery of instruction, and flexible manufacturing systems. At the same time, the Fab Lab project is being developed by individuals within organizations that require structure, planned processes, and demand accountability on multiple levels and across institutions. It may be difficult to find ways to provide a well-planned, structured environment that can accommodate, embrace and nurture creativity

at the individual level. Gershenfeld (2007) describes how his Fab Lab model challenges everybody's boundaries and this project will not be an exception.

The eleven step model for a Fab Lab lifecycle was presented in a linear format in sources found by the author (Midwest Fab Lab Network, 2008; FabLab Dev Process (US), n.d.). Experience to date indicates that Fab Lab development occurs in a non-linear fashion that includes two project phases. The planning phase is implemented by a small group of individuals who identify a need, find resources, and develop interest in the project. As the project grows nearer to implementation, more individuals with varying skill sets are needed to carry out different parts of the project. The author indicates the transition point from planning to implementation using a dashed line in Figure 1.

FIGURE 1:

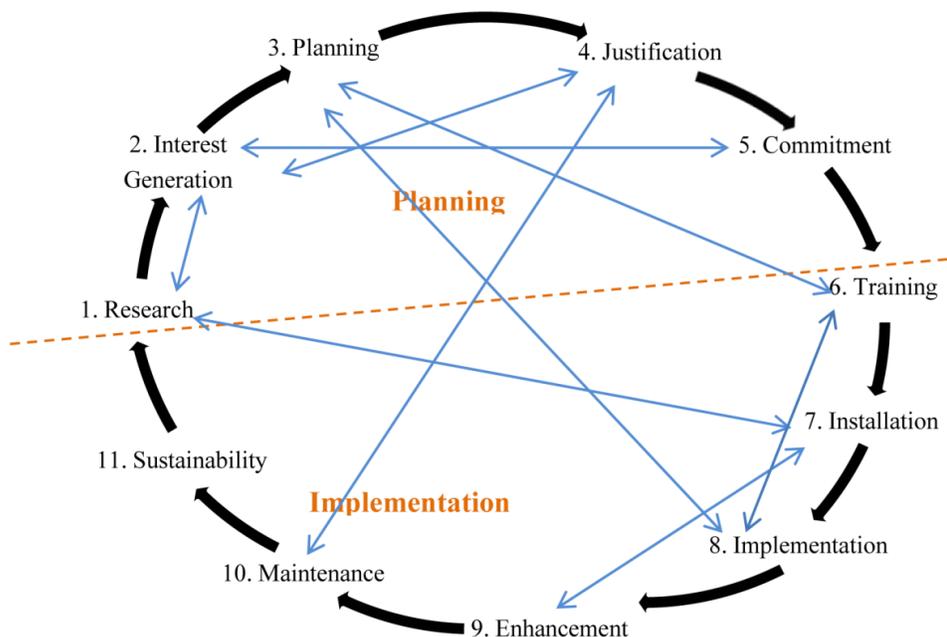


FIGURE 1: Midwest Fab Lab Network's 11 step fab lab lifecycle revisited



Figure 1 shows steps in the lifecycle model arranged in a circular fashion with arrows drawn between elements indicating interconnectedness in a non-linear model. For example, during the project planning stage research into the viability for a Fab Lab meshes with efforts to generate interest in the project that in turn requires one to be able to justify a need for the Fab Lab. As interest in the Fab Lab increases, so does the commitment of stakeholders. Thus the steps found in the planning phase of the Fab Lab seem to be interconnected in a non-linear fashion.

A similar pattern is found in the second phase of the project. Stages from the implementation phase are connected with one another as well as being connected with items from the planning phase of the model. For example, training occurs before and after the Fab Lab is installed to two different groups of people with differing needs. Implementation is impacted by the planning phase. Each time a new piece of equipment is installed, a piece of equipment breaks, or individuals change roles within the lab, there may be a need to plan revisions and conduct training. Before this occurs a justification of expenditures and changes will be required.

## **SUMMARY**

The Midwest Fab Lab Network's lifecycle model (Midwest Fab Lab Network, 2008; FabLab Dev Process (US), n.d.) is viable for developing a Fab Lab at Stout. Project managers, faculty members and key stakeholders possess the requisite knowledge, skills and dispositions to bring the project to fruition. The Fab Lab will provide a space where university faculty/staff can engage in teaching and research activities. The envisioned Fab Lab will also serve students completing undergraduate or graduate degree programs, high school students, and interested community members. The lab will provide individuals with the ability to conceptualize, design, develop, and fabricate almost anything at the local level. The Fab Lab promotes collaboration and access to a worldwide network that builds connections, using common tools and free software applications to facilitate the exchange of ideas of and designs. The Fab Labs provide an avenue for individuals to engage in "entrepreneurship" activities, provide an impetus for economic development and expose K-12 students to digital prototyping activities that include STEM concepts. The outcomes are expected to be the development of new technologies and



patents, the spawn of new businesses, and a model for Fab Lab development that rural communities can replicate.

## **SUGGESTIONS FOR BEST PRACTICES**

Stout's goals relative to the Fab Lab project are focusing on a collective impact initiative (Kania & Kramer, 2011) that creates systemic change. It will be critical for the key stakeholders to have a clear understanding of the project goals and clearly defined outcomes that participants support. Project planners and key leaders are encouraged to identify and use design processes, curriculum development models, and assessment techniques that are supported by a research base. It will be best if these models and processes are identified and included in project implementation from the initial planning stages and moving forward. Identifying processes that facilitate ongoing and regular communication between key leaders will set an expectation for active participation and should be encouraged. Finally, it will be critical to find a project implementation model that addresses institutional needs while honoring the fab lab's mission to embrace and nurture individual creativity.

## **FUTURE WORK**

Much work is needed to bring the Fab Lab to UW-Stout. Short term goals include identifying key stakeholders who will develop the Fab Lab mission and the associated goals. Agile project development models will be identified and adopted providing a framework for individuals' ongoing participation and active engagement. Key stakeholders will identify additional participants who will help identify instructional models, assessment models, data collection strategies, facility location, and address issues related to project infrastructure.

Long term goals include developing entrepreneurial activities that spur innovation resulting in the design of new products and the creation of new businesses. Developing partnerships with K-12 institutions that include STEM initiatives with outreach activities will be implemented. Creating systemic change in regions with depressed economies will be an additional focus of the project.

The Fab Lab project will provide the ability for researchers to focus on engineering – related activities and product development. Other opportunities are available for student and faculty members to investigate issues such the impacts of micro financing or social engineering



related to the clustering of resources. Research related to teaching and learning in formal and informal settings may be conducted. New models for teacher preparation in STEM fields and the potential to influence teacher licensure at state and national levels may occur. If Neil Gershenfeld's experiences with MIT's Fab Lab apply to Stout's Fab Lab, other opportunities will present themselves over time (Gershenfeld, 2007).

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### **AUTHOR INFORMATION**

Sylvia Tiala is an assistant professor at the University of Wisconsin- Stout in the School of Education. Her current research efforts focus on digital media and manufacturing for social change. Developing a Fab Lab within a community and investigating the resulting impacts on education-related environments is a current emphasis.

### **NOTE**

This paper was originally presented at the 2011 Advancing the STEM Agenda Conference. <http://asq.org/edu/2011/07/innovation/fab-labs-re-envisioning-innovation-and-entrepreneering.pdf>

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