Empowering the Future of Making to Catalyze STEM Learning Integrations and Innovations Across the Curriculum

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College of Computing and Informatics

Abstract

Growing numbers of learners are engaging in STEM practices and learning through various forms of "Making." The Maker approach is fundamentally self-driven informal learning that centers on personally meaningful projects using physical and digital fabrication tools, such as 3D printers, to design, prototype, and make creative physical products. Making often takes place in social contexts and places – Makerspaces – where learners can find shared tools, collaborators, and mentors. This project will study learning impacts of the recently established CCI Makerspace and related emerging Makerspaces on campus. The research is a re-orientation of perspective in STEM education to focus on student and faculty learning as enabled through the informal learning environment of our on-campus Makerspace. Our vision is to create a sustainable living laboratory for self-guided innovation that transforms students and faculty across disciplines from persons with an interest in individual creative STEM-related projects to persons with a STEM-based affinity identity [7] as Makers. This focus on design thinking will support learning benefits from cross-disciplinary interaction, particularly in interdisciplinary peer learning of STEM concepts, exposing non-STEM learners to STEM concepts, and disrupting traditional teacher-student roles. The project will study the interactions and impacts of an informal learning environment embedded in the campus context of formal learning programs. Results will help catalyze and sustain Maker transitions by identifying design patterns for learning [9] that emerge within the Makerspace, which can be applied more generally to foster synergetic interactions between formal and informal learning on campus.

Budget Request for SOTL Grant
Year 2017-2018

Joint Proposal? ____ Yes __X__ No

Title of Project: Empowering the Future of Making to Catalyze STEM Learning Integrations and Innovations Across the Curriculum

Duration of Project: 18 Months

Primary Investigator(s): David Wilson

Email Address(es): davils@uncc.edu

UNC Charlotte SOTL Grants Previously Received (please names of project, PIs, and dates): N/A

Allocate operating budget to Department of: Software and Information Systems

		Year One
Account #	**Award**	**January to June**
Faculty Stipend	Transferred directly from Academic Affairs to Grantee on May 15	
911250	Graduate Student Salaries	$7,650
911300	Special Pay (Faculty on UNCC payroll other than Grantee)	
915000	Student Temporary Wages	
915900	Non-student Temporary Wages	
920000	Honorarium (Individual(s) not with UNCC)	
921150	Participant Stipends	
925000	Travel – Domestic	
926000	Travel – Foreign	
928000	Communication and/or Printing	
930000	Supplies	
942000	Computing Equipment	
944000	Educational Equipment	
951000	Other Current Services	
	GRAND TOTAL	$7,650

		Year Two
Account #	**Award**	**July to June**
Faculty Stipend	Transferred directly from Academic Affairs to Grantee on May 15	
911250	Graduate Student Salaries	$15,300
911300	Special Pay (Faculty on UNCC payroll other than Grantee)	
915000	Student Temporary Wages	
915900	Non-student Temporary Wages	
920000	Honorarium (Individual(s) not with UNCC)	
921150	Participant Stipends	
925000	Travel – Domestic	$2,050
926000	Travel – Foreign	
928000	Communication and/or Printing	
930000	Supplies	
942000	Computing Equipment	
944000	Educational Equipment	
951000	Other Current Services	
	GRAND TOTAL	$17,350

Attachments:

1. Attach/provide a narrative that explains how the funds requested will be used.

Materials development and assessment / evaluation analyses will primarily be undertaken by a graduate student in the SIS Department, overseen by David Wilson, Faculty Director of the CCI Makerspace, with support from Audrey Rorrer, CCI Center for Education Innovation Evaluator. The graduate student stipend total of $22,950 covers the normal rate paid for a graduate assistantship in the CCI. The graduate student salary will support 20 hours a week during the Spring/Fall 2017 and Spring 2018 terms, when the student will perform material development, data consolidation and preparation, data analyses, and assist with writing methods and results components for dissemination (including presentations and papers). Dissemination of study outcomes include travel for 1 faculty member to the annual conference of the Association for Computing Machinery Special Interest Group: Computer Science Education (SIGCSE). Estimated travel costs are based on the March 2017 conference in Seattle, WA [$410 Registration, ~$700 Travel – Airfare + Ground, ~$940 Hotel/Tax + Meals].

2. Has funding for the project been requested from other sources? ___ Yes _X_ No. If yes, list sources.

Letter of Support

UNC CHARLOTTE
College of Computing and Informatics
Office of the Dean

9201 University City Boulevard, Charlotte, NC 28223-0001
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To: Scholarship of Teaching and Learning Grants Committee

From: William J. Tolone, Interim Dean and Professor: William J Tolone

Date: October 31, 2016

RE: Support for Proposal: Empowering the Future of Making to Catalyze STEM Learning Integrations and Innovations Across the Curriculum

I am pleased to offer my support for the SOTL proposal submitted by Dr. David Wilson, Department of Software and Information Systems, College of Computing and Informatics (CCI). In 2015, the College established a Makerspace as a nexus of STEM learning innovation through Making. Dr. Wilson's proposal takes the innovation to the next level in analyzing and enhancing the Makerspace experience, in order to better connect learners across disciplines through common STEM related goals and activities. Research findings from this proposal will inform CCI-wide educational approaches, both internal and external facing, as well as contribute to academic knowledge at the national and global levels. The College of Computing and Informatics is part of a national initiative to broaden the computing pipeline through multiple efforts that include pedagogy and research initiatives to support increased persistence, success, and diversity in computing and related STEM areas. The proposed project is closely aligned with College goals, and I am pleased to support this effort.

Project Narrative

A. Specific Aims

1. Overall Purpose

The College of Computing and Informatics (CCI) started a Makerspace in Fall 2015. In the spirit of the broader Maker movement [10], it is not a typical academic laboratory. It has a predominantly outward-facing mission – open to all members of the UNCC community – welcoming and encouraging use for self-directed personally meaningful projects. It is a specialized laboratory to support peer-driven informal learning and foster a community of practice [26] around Making.

Through Spring and Summer 2016, we worked to outfit the space, to establish basic policies and procedures, and to begin seeding the community with pilot activities within CCI. We have a space in Woodward equipped with a variety of digital fabrication tools, including 3D printers, 3D scanners, a laser cutter, desktop CNC, sewing machines, hand tools, and a variety of electronics kits such as Arduino and Raspberry Pi.

In Fall 2016, we have started offering open hours for anyone in the UNCC community – students, faculty, or staff – to use the Makerspace. Moreover, we have been working with Atkins Library to help establish a partner Makerspace. We envision a community of UNCC

Makerspaces across campus that are also connected locally, nationally, and globally in support of STEM learning through Making activities.

With increasing Makerspace traction, we believe there is a need to better understand the impacts that such informal learning spaces can have on our campus. This project seeks support to study the use and evolution of our campus Makerspace environment. We want to know how it is being used as a self-directed informal learning space, understand connections with formal learning at the university, document the opportunities and potential impacts for learning, and to help grow, evolve, and shape our campus Makerspace environments to maximize learning impacts.

2. Objectives

As a university-based Makerspace, we seek to contribute to the campus learning environment by providing as many students as possible a unique and enriching informal learning experience. Towards this end, we have identified the following objectives that will help us understand the role the Makerspace plays within the formal learning environment:

- Increase student engagement through novel opportunities for self-directed informal learning in the Makerspace. In doing so, we seek to improve access to digital fabrication tools, for both general availability and engagement with underrepresented groups in STEM learning.

- Facilitate a transition from learner interest in STEM-related projects to a STEM-based affinity identity [7] as a Maker.
- Support and enhance cross-disciplinary STEM learning pathways and connections through multi-disciplinary learner collaborations and encouraging learners to adopt perspectives from outside their own area.
- Increase curricular integration by identifying and leveraging pathways and connections between the Makerspace and formal learning environments.
- Enhance formal learning and improve formal learning outcomes through the informal learning environment and activities within the campus Makerspace.

3. Research Questions

The project is guided by the following primary research questions:

- How does a university makerspace evolve to meet the informal learning needs of members while also addressing constraints of operating within the university environment?
- What kinds of informal learning take place within the makerspace, and how can they best be characterized to help support learning innovation?
- What kinds of interactions take place between the formal learning of university programs and the informal learning within the makerspace, and how can this be characterized toward learning innovation?

- What are the pathways of exploration and discovery that students take during their participation in the space? What sparks their interest? What other interests do they cultivate?

4. Rationale

Using Making to support STEM learning and develop problem-solving skills has exploded in recent years. Nationally, the President's ongoing Nation of Makers Initiative notes that "By helping students experience hands-on science, technology, engineering, and math (STEM) learning and real-world problem solving, making can spark deep interest and develop the necessary passion for students to excel in the 21st century" [22]. But as a 2014 comparative study of makerspaces notes: "Despite a flurry of interest and activity around designing and creating makerspaces, we still know little about the content and processes of learning in makerspaces" [20]. A number of research studies have addressed the *what?* question – that making approaches can positively impact learning outcomes (e.g., [11, 12, 17, 21]). But questions are wide open as to *how?* and *why?* this may happen via informal learning, particularly when embedded within an on-campus formal learning environment. And understanding how/why is critical to learning experience design, both within the makerspace and connecting makerspace learning to support formal classroom learning.

Thus understanding and enhancing Makerspace learning has implications across all aspects of teaching, research, and service in CCI – and beyond. For example, peer-learning and cross-disciplinary interaction embody top-bar skills – collaboration and communication –

of the T-shaped student. And the Makerspace provides a platform resource for students in design oriented courses, such as Rapid Prototyping, as well as the opportunity to bring digital fabrication aspects into other coursework. It also provides an environment and tools that naturally support development for unique individual study and research projects across undergraduate and graduate levels. Moreover, makerspace learning opportunities can serve as a point of contact for outreach and recruitment.

In Summer 2016, an REU project began investigating practices of inclusivity in Makerspaces. It considers populations such as women, racial minorities, and students of low socio-economic status, seeking to understand what aspects might attract/detract them from Makerspace participation; specifically, how perceptions differ across populations about the space itself, its purpose, and who typically participates.

B. Literature Review

Schrock [19] notes that the modern concept of making focuses on activities that are self-directed and hands-on with flexible goals [6, 13, 14]. Anderson points to three distinguishing characteristics of today's maker movement – using digital desktop tools, an online culture of collaboration and design sharing, and common design standards to help enable sharing and rapid iteration [1]. A makerspace, however, is not just a set of tools; rather it is a community that uses such tools [16]. It is a place where people have the opportunity to explore their own interests; learn to use tools and materials, both physical and virtual; and develop creative projects. An on-campus makerspace should be adaptable

to a wide variety of uses, shaped not only by complementary instructor/curricular educational purposes but primarily by students' own creative goals and interests [4]. The maker movement in education has been characterized as "the wave of interest in constructing and sharing personal inventions and creative artifacts" that "reconfigures the learner as a producer rather than a consumer" [15]. There are a wide variety of resources on how to build a makerspace (e.g., [11, 16, 8]), but comparatively little study of Makerspace learning design.

Research shows that integration of making approaches can positively impact learning outcomes (e.g., [11, 12, 17, 21]). This is not surprising, and follows naturally from constructivist [24] and constructionist [23] learning perspectives. Rather than receiving knowledge through instruction, learners build their own knowledge by building external artifacts. Makerspaces embody constructionism by providing a space, the tools, and a supportive community to drive student-led building projects.

The Makerspace approach focuses on informal learning [18]. Our working definition of informal learning corresponds to "out-of-school" learning [3], but also allows for the wealth of informal learning that takes place at the university, which is not intended to address explicit curricular requirements. We consider informal learning within the makerspace context as free-choice learning [2] - "choice" indicates intentional learning - "free-choice" indicates that learning is non-regulated. Our studies will focus on free-choice informal learning activities within the makerspace, specifically learning activities that are not mandated to satisfy institutional course requirements.

C. Methods

To conduct the project, we will need to address the following key steps.

- Consider and finalize specific measures for informal learning evaluation - in consultation with stakeholders, campus evaluation experts, and guided by NSF-identified impact categories [5].
- Develop dual-purpose Makerspace support and instrumentation in service of both Makerspace operation and principled data collection. This includes alignment of Makerspace and equipment access/use, as well as standard platform / support tools for project journaling / portfolio aspects and training / how-to materials.
- Curate, develop, and integrate Makerspace learning materials including training, themed workshops, suggested projects, as well as a library of examples, how-to and reference material.
- Develop survey instruments and necessary IRB applications.
- Conduct interviews with Makerspace participants and stakeholders.
- Collect and analyze data on learning experiences within the Makerspace environment.

D. Evaluation

Project evaluation will incorporate formative and summative evaluation comprised of a mixed-methods design, and be framed within the context of Makerspace users, or 'Makers',

and of the Makerspace lab itself. Questions that guide the project evaluation for Makers are: what are the Makerspace usage trends; what perceptions do Makers have about their engagement in the Makerspace. Questions that guide the evaluation of the Makerspace lab design include: what patterns emerge in Makerspace usage; if cross-disciplinary connections are made, how are they characterized; how does participation with broader networks such as MIT's Fab Academy impact the Makerspace design.

Formative assessment will include collecting feedback from Makers and from the faculty and graduate students who manage the Makerspace. Maker assessment will include collecting demographic data (e.g. gender, ethnicity, major, type of Maker Project), attitudinal data (e.g. reason for using the Makerspace, interest, sense of climate and community) and descriptive information about what activities Makers engage in during lab usage (e.g. products made). Lab design assessment will include monitoring equipment usage, and analysis of Maker usage (frequency and duration of visits, tools used, interactions with other Makers, level of support needed by Makers). The Makerspace faculty and graduate students will be asked to observe lab usage, and asked to describe insights gained from their own experience and from participation in the Fab Academy maker collaboration. Summative assessment will include analysis of Makerspace usage patterns, Maker attitudes and perceptions about the lab, and faculty and graduate student observations of the Makerspace design. Overall assessment of the project will be determined by evaluating activities and tracking participants throughout the grant lifecycle, presented in summative reports, as shown in Table 1.

E. Knowledge Dissemination

Locally, we plan to present findings and their formative implications to our College at a designated Faculty Meeting, as well as through seminar activities through CCI's Center for Education Innovation. We plan to present our summative findings to the University community through campus teaching and learning outlets such as the UNC Charlotte Teaching Week. At the national level, we plan to submit a conference proceeding paper to the Association of Computer Machinery's Special Interest Group on Computer Science Education (SIGCE).

F. Human Subjects

Project researchers are experienced in HCI research, current in IRB certification, and well acquainted with the IRB process. We anticipate many aspects of this research may be considered exempt research. In addition, the CCI Center for Education Innovation has current IRB approval for aspects of learning analytics research. We expect a new IRB application to support Makerspace participant surveys. For the kinds of data we expect to gather, we anticipate IRB approval and will conduct our study in compliance with University policy.

G. Extramural Funding

We are currently exploring extramural funding opportunities to support the expansion of Makerspace activities and to conduct broader and larger scale studies of these interventions in STEM education. Funding opportunities include, but may not be limited to, proposal submissions to the NSF's EAGER MAKER and Advancing Informal STEM Learning (AISL) programs. The first specifically targets Making to support STEM learning and design thinking, while the second more generally targets design and development of STEM learning in informal environments. SOTL funding support of this initial study will greatly enhance our ability to compete for extramural funding opportunities.

Table 1. Project Goals, Activities, Measures and Data Collection

Goals & Desired Outcomes	Activities	Example Measures	Data
Understand Maker attitudes and behaviors Desired Outcome: Set of learner behavior patterns, and pathways to facilitate learning	-Track Maker demographic data - Track Maker experiences	- Maker check-in to space - Equipment reservation / check-out - Maker feedback survey of awareness, interest, sense of community and connection	- Maker usage data - Count of visitors / # visits - Frequency / duration of equipment use - Qualitative and quantitative survey responses
Increase cross-disciplinary Maker projects & collaborations Desired Outcome: More instances of learners from different departments / areas working together	- Hold open-ended facilitating workshops - Propose projects to the community that span disciplines - Participate in MIT Fab Academy	- # projects that have collaborating learners from different disciplines collaborating - # collaborations in workshops - Faculty/GA observations of Makerspace use over time - Dissemination of Makerspace practices and adoption of other practices	- Project journals - Observation - Analysis of observation forms - Questionnaire for Faculty and GA about lab design and practice
Increase cross-disciplinary thinking Desired Outcome: More instances of learners adopting perspectives outside their own discipline	- Interview students about what they are working on, what they like about it, why they - Short workshop sessions after Litts [25]	- # learners who adopt / consider a perspective outside their background	- Project journals - Workshop sessions - Student demographics - Interviews
Help students build interest Desired Outcome: Students who use the space to explore will find things that interest them and be driven by that interest in their formal academic pursuits	- Host a range of workshops that show the flexibility of the space to support pursuit of a variety of topics and interests. - Interview students about the nature of their engagement	- # learners who pursue something new as a result of Makerspace engagement	- Interview data - Classes students take before and after Makerspace participation
Improve access to technical equipment Desired outcome: Learners from disciplines that do not have technical equipment can benefit from it	- Workshops that target the needs of students from non-technical backgrounds	- # learners from technical and non-technical disciplines that participate in the space	- Observation - Student demographics - Interviews
Contribute to Makerspace pedagogy research Desired Outcomes: Document characteristics of the Makerspace and how the effect the learning of different populations	- Gather interview, observation & workshop data - Share findings with UNCC community, other Makerspace leaders, and the education research community	- # venues/ stakeholders sharing results	- Student interest/ demographics/ how they progress through the space

H. Timeline

Timeline	Activities
Spring 2017	Finalize measures to be used for informal learning evaluation. Develop survey instruments and IRB application. Refine Makerspace access/use process for data collection. Develop journaling tools and instrumentation for data collection. Pilot data collection and survey instruments.
Summer 2017	Analyze pilot data and learning outcomes to date. Review of preliminary findings for formative adjustments. Preliminary reports on formative, initial findings.
Fall 2017	Ongoing project evaluation. Conduct open hours, training, workshops, and continue measurements. Conduct interviews with Makerspace participants. Submit SIGCSE Paper Interim reports on data collection, findings.
Spring 2018	Ongoing project evaluation. Conduct open hours, training, workshops, and continue measurements. Conduct interviews with Makerspace participants. Prepare final, summative reports on data collection, findings. Attend SIGCSE Presentations to CCI, UNC Charlotte Community

References

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