Makerspace Curriculum Development and Implementation Toward Cross-Cultural Integrative STEM Learning: A United States and China High School Collaboration

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Abstract

The Chinese Ministry of Education is being intentional regarding efforts toward the development and modernization of the country's education system. This modernization, in part, encompasses the need to establish technological literacies within the classroom. Chinese students often are unprepared to be successful in American universities as a result of minimal exposure to educational activities that embrace critical thinking, problem solving, and innovative group design projects[1]. Makerspace utilization aims to answer the nation's demand for curriculum that is rich in integrative Science, Technology, Engineering, and Mathematics (STEM) activities, thus establishing a platform for Chinese nationals to experience authentic classroom activities that are student inquiry centered and problem based[2].

Keywords

Makerspace, International Collaboration, Engineering Education, Curriculum Development

Introduction

The Chinese Ministry of Education is being intentional regarding efforts toward the development and modernization of the country's education system. This modernization, in part, encompasses the need to establish technological literacies within the classroom. The United States experienced a similar demand that birthed the Standards for Technological Literacy circa 2000. Enhanced technological literacy prepares students to become more competitive global citizens.

Makerspace utilization aims to answer the nation's demand for curriculum that is rich in integrative Science, Technology, Engineering, and Mathematics (STEM) activities. The design and implementation of a maker education curriculum to assist instructors with the facilitation of integrative STEM activities provide the platform to introduce Standards for Technological Literacy (STL) to the Chinese school system.

This paper discusses and outlines the Makerspace curriculum development, implementation, and STL alignment within the Suzhou North America High School (SNA) in Suzhou, China. The vision for SNA, in part, is to develop global citizens and to have a classroom environment with a pronounced focus on inquiry and collaboration. The identified resources needed to support this vision include teacher professional development with American and Chinese student collaboration[2].

Background

Suzhou North American High School

The Chinese Ministry of Education has embraced the widespread and growing understanding of the role creativity and problem solving and how both can positively affect the country's economy regarding innovation and entrepreneurship. International collaborations are a response to this growing demand for innovative and globally-minded opportunities for Chinese nationals within their education system. Mr. Wang Bintai, CEO of Suzhou North American High School and the Wuzhong Group approached Dr. Hiller Spires at NC State University in 2014 to help create a state-of-the-art high school, including a new facility and innovative curriculum. "Through strategic planning and continuous improvement, SNA seeks to integrate dynamic curricula and pedagogies, digital learning, and global collaborations on the school's state-of-the-art campus"[2].

Drawing on the best of Chinese and American education standards and using an iterative design process, the NC State team, led by Dr. Spires, created the SNA curriculum framework for the school to use as a guide for developing the school culture and teaching and learning program. The framework was based on curriculum principles and philosophies from the: (a) U.S.-focused Common Core State Standards, (b) College Board Advanced Placement, (c) Partnership for Twenty-First Century Learning, and (d) Chinese Ministry of Education Policies and Reform Standards. A key feature of the school is to focus on creativity and innovation, and to be a model for Chinese education.

Makerspace

A Makerspace is a physical place where students engage in "hands on learning through designing and building things"[3]. Makerspaces can be anywhere from large rooms with cutting edge technology such as CNC machines, Laser Cutters, Plasma Cutters and Industrial 3D printers to the corner of a classroom or in box that can get stored away. The use of simple materials such as white glue, cardboard and recycled plastic bottles can be used to facilitate the learning of complex design. A Makerspace is a combination of the shop class, home economics class, the art studio, and science lab that allow for the skill sets required for each to be used together[4].

A physical makerspace draws upon a student's desire to create things using their hands, minds, and tools. The space invites curiosity and wonder, when students are digging deep into themselves to engage with the unexplained world around them[5]. When students are constructing their own knowledge in a makerspace, they are using tools, materials, and their prior knowledge to develop new understandings of the laws of the universe through active experiences[3]. It is a place where the tools and materials combine with a collaborative community atmosphere to empower students to take ownership of their learning by physically building products.

Maker Education

Maker Education is a pedagogical structure behind a Makerspace. Through the physical hands-on building of products students learn construction principles, engineering mindsets, and technological literacy. Maker Education sets a framework for building technical skills and knowledge to construct prototypes of products toward solving societal needs. Maker Education focuses on the skills and methodologies of taking an idea and turning it into a real-life product. These projects teach traditional content and ultimately skills that students can transfer to different challenges that arise throughout their lives.

In addition, Maker Education develops students' traits beyond technical knowledge, including personal grit, interpersonal skills, and critical thinking. Maker Education engages students in empathy based and personalized learning experiences to develop real world skills and characteristics they need. John Dewey concluded that "The process of intelligent use of materials and the imaginative development of possible solutions to problems issuing in a reconstruction of experience that affords immediate satisfaction[67]."

Maker education curriculum follows a process including: identifying a problem or situation, empathizing with a group of people experiencing that situation, brainstorming solutions for that problem, best possible solution selection, planning out the idea through sketching, practicing with materials, determining specific requirements, (specifications and constraints), prototyping a solution, implementing the most viable solution, testing and evaluating the effectiveness with people whom it was created for, then thinking deeply about redesigning and improving the solution. Students work through this process which is similar to the design thinking process in order to create products that are solutions to real world problems. Students create physical products within makerspaces where tools, materials, and knowledge are available to create the best possible solution.

Standards for Technological Literacy

The Standards for Technological Literacy (STL's) is a document aimed to establish benchmarks indicating technological literacy for students relative to their grade level. The document outlines 20 standards that focus on the knowledge of technology as a teachable field of study. The document makes a strong case for technology education being an integral part of curriculum with special emphasis on the design process within classroom projects[8].

Integrative STEM

Science, Technology, Engineering and Mathematics education and activities within aim to address the complex problems in our world such as climate change, personal security, medical issues, and energy demands to name a few. These problems are not single subject specific and require scientists, technologists, engineers, and mathematicians to work together toward creating acceptable solutions. Collaborative learning spaces were an intentional design of SNA that provide platforms for contemporary theories of teaching and learning[2].

Big Idea

Chinese Basic Education Curriculum Reform (2011) calls specifically for innovative, creative, and student inquiry centered learning activities within the classroom. In response to this call and to address the growing demand for creativity and innovation in the classroom maker education has become a focus of curricular design within SNA.

Inquiry based, and student-centered approach is the foundation of Maker Education pedagogy. Maker Education build skills in students which are vital for the 21st century. These skills include critical thinking, problem solving, communication, collaboration, technological literacy, adaptability, innovation, creativity, and globally competency[9].

Benefits of Maker Education

In a Makerspace, students develop their critical thinking skills of effective reasoning and judgement when determining the viability for the best possible solution to a problem they are working on. A Maker Education curriculum has students' analyzing how different systems and process work together in order to build products and understand systems. For example, when using a 3D printer, students need to understand how the CAD design software works with the 3D slicing program and how that program directs the 3D printer resulting in a built product. Often times in Maker Education curriculum teachers challenge students with non-familiar problems that require students to access past knowledge and transfer their skills to new projects.

Students are required to articulate their thoughts in a Maker Education project so that others can understand the products purpose and benefits. They must communicate in various ways with diverse groups of people in order for their product to be displayed to the world. When developing a product, students must learn to listen with empathy toward others to understand their needs and wants so they can create the best possible solution to their problems.

When students act as Makers, they develop students character strengths of grit, perseverance and self-reliance[10]. When students learn new skills in a supportive environment it makes them better prepared for the uncertainty that accompanies innovation[10]. One of the key characteristics for a teacher to develop in a Makerspace is supporting students as they revise and redesign their solution ideas. As students succeed through perseverance their self-reliance and determination increase leading to more involved and engaged students.

Problem Solving through Design Thinking

Design thinking is a problem-solving method that has students designing creative solutions to problems that people face in their daily lives. Using the design thinking approach within a makerspace setting helps students develop their problem-solving skills. It helps students identify a problem and methodologically identify the best possible solution. Maker Education encourage problem solving methods in a supportive environment that include self-discipline and ambiguity tolerance. Design thinking also encourages innovation which provides a platform for students to adopt a human-centered perspective in creating innovative solutions while also integrating logic and research[11].

A makerspace naturally leads to community building and teamwork. Within this supportive community students are able to get input on projects through all phases of its creation[10]. These phases include the reflection and redesign of work, the transferable knowledge of tools and technologies, empathy toward others, and the collaboration and teamwork skills needed to work with others. Students who have similar passions often work together on projects to create more complex and thoughtful projects.

Plan of Action

The overarching area of interest is intentionally moving from basic education where knowledge acquisition is the primary focus to learning that is centered on analytical knowledge and the creation of such knowledge. This interest frames the question of "How to help teachers and students identify problems in their local community or within their current content that they can design and create solutions for in a Makerspace through the Maker Education perspective?"

To address this question and provide a framework toward answering how this creative problem-solving initiative can be implemented, the following areas of focus have been identified accompanied with action items.

Current Equipment

SNA currently has a Modela - CNC machine, an XYZ - 3D printer, an Epilog - laser cutter, and 15 Makeblock - robots. The action item is to build curriculum around each piece of current machinery toward the development of a general STEM course for all students to enroll in. This course will outline the framework and become an example for SNA instructors regarding the implementation and collaboration toward integrative STEM units within their respective content areas.

Professional Development

SNA's philosophy of professional development encompasses three pertinent ideas: (a) the teacher is the single most important factor determining the success of the student, (b)professional development needs to be ongoing and embraced by teachers, and (c) educational systems need to support the idea-driven economy regarding the global citizenry of the student[2].

This professional development collaboration aims to prepare teachers to be effective in building a sustainable Maker Education curriculum and STEM program within SNA's existing course offerings. SNA teachers will collaborate and discuss how to create projects that focus around design thinking and that embrace integrative STEM activities. Teachers will use the world around them to create curriculum that is rich in opportunities for design thinking-based projects.

Through this guided collaboration, teachers will identify and develop a unit of study into a design thinking project that facilitates learning guided by the existing standards in place at SNA including the Common Core State Standards, College Board Advanced Placement, Partnership for 21st Century Learning, and the Chinese Ministry of Education Policies[2] with a new and centered focus on the following Standards for Technological Literacy:

STL 03. The relationships among technologies and the connection between technology and other fields. STL 08. The attributes of design. STL 09. Engineering design. STL 10. The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. STL 11. Apply the design process. STL 17. Information and communication technologies[8].

Webinar Series

A webinar series addressing the nature of technology with the guiding belief that technology will always change allows for ongoing curricular collaboration. The focus of each webinar is to facilitate the technology education needed to further curricular development toward establishing integrative STEM lessons throughout each content area and to support the development of a general STEM course. Teachers will discuss the appropriate steps when encountering a new technology or tool in their classroom and how to facilitate learning using that technology or tool.

Current Status of Collaboration

The researchers are currently designing professional development material, building curriculum, and continuing meetings with SNA instructors and administrators toward establishing a Makerspace curriculum. Two trips are scheduled to facilitate the researcher being onsite at SNA in late November of 2018 and in early April of 2019.

Initial Visit (November 2018)

A STEM Foundations course is currently being developed to ensure SNA students are part of the technical literacy for all vision which drove the STL's[8]. This course will be required for all 10th grade students at SNA to take. The course will introduce students to two areas of STEM education: a) the conceptual understanding of technological literacy; and b) safety, proper use, and application of the current technology available within the Makerspace at SNA.

A professional development objective of increasing the STEM presence within existing lesson plans is also underway. Teachers who choose to participate in this professional development submit current lesson plans to their supervisor at SNA. These lesson plans are evaluated and annotated by the researcher aiming to suggest intentional ways to bring STEM teachable moments into the classroom lesson and activities.

Follow-up Visit (May 2019)

This visit will aim to finalize the STEM Foundation course development document and to develop an ongoing support plan to enhance the STEM presence within the existing SNA curriculum.

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Liz is an adjunct lecturer at the Hynes Institute at Iona College and a Technology & Engineering educator with a passion for helping people become better problem solvers and design thinkers. Liz believes that the future of education is centered around design thinking. She teaches the Designing 4 Humans process which combines the engineering design process and empathy-based problem solving. Liz also serves on the executive board of the New York State Technology and Engineering Educators Association and is very active in WhyMaker, a design company she started.