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Design as a Catalyst for STEM

EXAMINING THE IMPACTS OF MAINSTREAM DESIGN EDUCATION

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The integration of Design Thinking/Design based learning/STEAM into secondary education has impacted the understanding of the role of design as a field. These effects show up in multiple ways; first through students' confusion around the relationships between STEM and design disciplines, second the role of design education within academic curriculum development, or policy issues, and lastly, the impact of an ill-defined inter/cross disciplinary interaction has resulted in potential funding gaps for the arts vs the sciences.

This study examines the trajectory of design thinking and its use in secondary STEM education, revealing that while design thinking enhances student engagement and experiential learning, its inconsistent application across traditional engineering programs can result in frustration and attrition for students. Rather than advocating for further disciplinary silos, this paper promotes interdisciplinary collaboration, emphasizing the need for equitable recognition of all fields within research and education. Design, as a discipline, plays a critical role in shaping our world and must be valued accordingly.

The author advocates for design educators to serve as stewards in creating interdisciplinary pedagogies that respect disciplinary histories and embrace diverse forms of knowledge, fostering problem-solving skills for the future.

Keywords: Design, Pedagogy, Interdisciplinary, Engineering, STEM, STEAM

INTRODUCTION

This paper aims to examine the outcomes of integrating design into STEM disciplines. It will analyze pedagogical trends spanning the past two decades and gather information through classroom interactions, including informal interviews with students enrolled in Industrial Design programs. These interactions reveal a discernible pattern of confusion regarding the relationship between Design and STEM (Science, Technology, Engineering, and Mathematics). As students transition from design-focused STEM programs to traditional engineering programs in college, they are encountering a stark contrast in pedagogy that fuels frustration and often attrition.

These pedagogical differences extend beyond student engagement and have implications for design educators within institutions. The extent to which design is acknowledged and honored as a discipline has consequences for institution wide curricula and strategic planning, and internal funding opportunities could be negatively impacted by the (in)visibility of design as discipline.

The objective here is to foster a deeper understanding of the relationship between design and other academic disciplines. By conducting this line of inquiry, we can gain a better understanding of how these changes have influenced design literacy and pedagogy, both within academic institutions and beyond. This paper concludes by proposing ways to increase the visibility of design through the promotion of creative research, developing internal cross-disciplinary partnerships, and nurturing a community of practice within academic institutions that support design led research and dialog.

As an educator with 15 years of experience teaching art and design at various institutions, including small private art and design colleges, as well as large R1 state universities, the author has acquired a broad and pragmatic perspective on design education. Working with students from diverse backgrounds and academic programs has provided valuable insights into the influence of secondary education on students' understanding of various fields of study, their preparation for college, and their expectations of what a disciplinary area of study will contain.

STEM

As population growth and technology driven global interconnectedness spur the demand for innovation, the consequences of this growth and its effects on our environment present large-scale, complex problems. Addressing emergent challenges demands increasingly sophisticated problem-solving skills. Many STEM educators view the future as presenting new problems that will require a cross-disciplinary approach and new tools that exist outside of isolated disciplines (Connor, et al 2015). More traditional methods of science education are good for training the scientist but do little to build cross-disciplinary creative problem identification and solving skills (Maddena , et al. 2013).

In the past 20 years, STEM educators have sought to invigorate curricula through expanded learning opportunities that have helped make STEM subjects more engaging. Additionally, alongside commercial industry and government organizations, educators have begun to recognize the importance of creativity and flexible, adaptive thinking strategies to meet present and future challenges.

Educators recognize that approaches to STEM that integrate other disciplines can improve learning and prepare students for complex futures (Ankiewicz, and Hallstrom. 2023). This includes developing 21st century skills, such as creativity, innovation, collaboration, and critical thinking abilities (P21, 2009). Initiatives such as increasing the time students study STEM subjects, or combining topic areas that structurally align (math, engineering) have been explored as tools to increase student engagement and learning. These tactics were limited and did not show a dramatic increase in student engagement. However, as new pedagogical approaches were developing to include design thinking strategies, educators were discovering the impacts of design on STEM learning, and student engagement (Doppelt, Mehalik, et al 2008).

WHY DESIGN?

Design pedagogy teaches skills that are desirable in STEM fields for increasing a student's capacity for problem solving in an ill-defined problem space. Students learn to apply creativity, with flexible and adaptive thinking to iterative solution building, integrating different forms of knowledge with creative and adaptive modes of thinking. Design as a discipline offers diverse ways of thinking with a structure that equally engages the analytic and the intuitive; it requires observation, analysis, synthesis, and transformation to materialize solutions (Costantino, 2018). Design is not a science yet has its own rigorous processes and prioritization for problem solving which is less focused on the desire for repeatability to validate its finding. Students build understanding and test ideas through active learning that involves hands-on exploration.

DESIGN BASED LEARNING

Perhaps the earliest iteration of integrating design into education as a method emerged in the 1980's, when a Los Angeles elementary school teacher named Doreen Gehry Nelson pioneered a new method for helping students process and retain information through hands-on experiences that focus on problem identification, critical thinking and creative problem solving. What emerged was Design based learning, a new pedagogical approach that allows students to experience the construction of knowledge through individual, inventive and creative projects that support individual preferences, learning styles and skills (Doppelt, Mehalik, et al 2008). Design based learning can involve both problem- and/or project-based learning, centering students as the agents of knowledge formation.

DESIGN THINKING

In the 1990's, scholars and practitioners began to apply design tools and thinking strategies to problems outside the realm of design as a practice. The term Design Thinking had already emerged in research circles and had appeared at conferences, but was popularized by Tim Brown at IDEO, promoting it through TED talks and in his 2008 article in the Harvard Business Review. Brown framed an urgent need for transformative thinking that would tackle the world's complex problems through innovative, human centered designerly practices to develop and refine practical solutions (Brown, 2008).

Design thinking offered a marketable process that sought to deliver creativity and increase innovation to corporate and academic environments through the introduction of designerly ways of thinking and doing. The excitement and rapid adoption of design thinking was inspired by the potential for anyone to learn these methods outside of design and employ them towards educational or institutional goals. (Goldman, Kabayadondo).

Emerging from diverse interpretations, incorporating recycled concepts and adaptations of Design as a "cognitive style" (Kimbell, 2011), Design Thinking often appears as a collage of borrowed techniques, applied inconsistently. This misapplication, compounded by a widespread unfamiliarity with design as a

discipline beyond the superficial signifiers of aesthetic decision making, has led to the rapid proliferation of simplified workshop techniques.

STEAM

Along with Design Thinking, the Arts Integration movement (which began in the 1990's) brought art and design principles and pedagogies into classrooms, integrating creative thinking into a range of disciplines. This initiative went beyond skill building in the production of art and worked to develop habits of mind that involve observing, envisioning, expressing, and reflecting, as well as deep engagement and persistence through problems (Harvard Project Zero, 2003).

The Arts Integration Movement sought to create synergies between arts and design and STEM subjects by introducing transformative learning experiences through "the infusion of art and design principles, concepts and techniques into STEM instruction and learning using creative problem solving." (Liao, 2016).

In 2006 Georgette Yakman, a secondary school instructor for Engineering and Technology, developed the term STEAM and the educational framework to follow that sought to integrate the arts back into the STEM curriculum through the application of various thinking skills and project-based learning tools. STEAM education emerged as a pedagogical model for dismantling boundaries between traditional academic subjects. It envisioned the integration of science, technology, engineering, arts, and mathematics into a cohesive and interconnected curriculum (Connor, et al, 2015).

This idea gained popularity with academic institutions such as Rhode Island School of Design (RISD) adopting and championing STEAM as an institutional principle. Former RISD president and designer John Maeda wrote in 2010 that STEM subjects alone would not meet the demands of the 21st century, and that design brings the innovation that not only inspires economic growth but asks the challenging question of where we want to go as a society (Maeda, 2013). With the language of innovation as a driver for economic growth, and the view of the US as lagging in STEM globally, the momentum grew (Anthanasia,Cota 2022). In 2013, Congresswoman Suzanne Bonamici (D-OR) and Congressman Aaron Schock (R-IL) announced the formation of the Congressional STEAM (STEM + Arts and Design) Caucus. This new initiative focused on developing briefings and advocated for policy changes to encourage educators to integrate the arts (broadly defined and inclusive of design) into STEM education with a goal of driving economic prosperity through innovation. In 2015, President Obama signed Every *Student Succeeds* act, which includes mandates, and funding, to provide STEAM education in schools, into law.

Educators quickly saw the potential of integrating these methods into the STEM curriculum to develop more active, inquiry-based learning opportunities (Doppelt, Mehalik, et al.2008) for students in grades K-12. (Connor, et al 2015). The growing acceptance of STEAM and Design Thinking within secondary school curricula was supported by the rise of informal learning opportunities for students, such as

specialized afterschool STEM or STEAM programs, science or children's museum programs, summer camps, and online programming (Bequette, and Bequette, 2012).

OUTCOMES

As the students who studied engineering, math, and science through these expanded curricula transition into college programs, some of the unexpected consequences of this educational shift are becoming clear. Through informal interactions and classroom discussions, students have shared their educational experiences. Having grown up learning design out of context, these students are surprised to learn that the engineering programs they have joined are nothing like the design driven curriculum of their secondary school experiences. They are finding less opportunity for inquiry-driven exploration, limited opportunities for hands-on learning, and less active learning through the prototyping of ideas. Instead, they find themselves ensconced in STEM programs focused on tables and figures. It has become increasingly apparent that there is a causal relationship between secondary school STEM education and students' proficiency in Design literacy. Many students enrolled in design classes express frustration with traditional lecture-based approaches commonly found in STEM classes, where hands-on, experiential learning is often lacking. When students are presented with opportunities for active hands-on, student-centered learning, engineering the author has often heard them express that “this is what I thought engineering was, this is what I came here to study….”

This confusion has brought many students to faculty or academic advisors seeking to add a design-based track of study, or the transfer into a design program. These changes can cause the student to lose time in a degree program or require extra time in college to meet requirements in additional areas of study. There are financial implications for students and a lack of clarity in future professional opportunities. Also, there is an impact on faculty and advising staff to help students coordinate course registration and degree advising.

Both design thinking and STEAM seek to integrate the arts and design into new domains. However, this often means cherry picking from design as a process, without acknowledging (the arts and) design as a larger, more comprehensive discipline. For faculty in design programs situated within larger universities, this can impact the visibility and understanding of design as a discipline in the context of adjacent or related professional STEM based fields, particularly Engineering. This in turn shapes the faculty’s status and standing within the larger institution. When subject areas are integrated without consideration, there is risk of one area being paid lip service (Bequette, and Bequette, 2012). While disciplines may be counted as included, their true value may not be honored or recognized. Design programs are often at risk of being relegated to service branches within a university, particularly in relation to STEM-based programs. This role could be reflective of an outdated perspective of design as a purely technical or vocational education, focusing solely on training students in specific processes related to design production (Cross, 1982).

Design is often seen as simply an aesthetic endeavor. Design faculty and students are all too familiar with ‘collaborations’ in which they are expected to make things *look good*, but not to play a substantive or transformative role in a project’s direction. One scenario the author encountered saw two Industrial Design students invited to join a team of students working on a federally funded student research project. The two ID students we asked to reformat the slide deck/presentation to make it more visually appealing with animations, graphics, and layout being the focus. Although this task falls within design, it is not all that these students can offer.

On another occasion, the author attended a three-day workshop on project-based learning at a prestigious engineering school. At this workshop, the keynote speaker made a case for expanding students' learning experience through design focused project-based learning. They went on to list skills, attributes, and methods that all described design as a process and discipline, yet design was never mentioned as part of the process. Throughout the workshop design thinking was present, as a skill being taught through various workshop activities, also as the very foundation for the facilitation of the workshop itself. A room full of engineers spent days learning about ways to invigorate STEM, and design was a foundational tool for these interventions, and yet it was rarely acknowledged.

Design’s visibility is essential in institutional contexts. We must cultivate awareness of the contributions design has made in shaping education and the world around us. This visibility increases opportunities for everyone in design, especially the graduating students, and works to elevate the discipline to be a significant contributor to the formation of knowledge among liberal arts and STEM.
On a research level, lack of design literacy and visibility could lead to limited access to funding opportunities. Many federal funding opportunities that outline specific design related skills sets do not recognize or include design as an applicable discipline within most fields of study. One only needs to search the National Science Foundation (NSF) database using keywords such as design, design thinking, and STEAM to reveal several grant programs whose descriptions reveal an awareness and interest in design pedagogy and design processes (NSF, 2024).
The borrowing of art and design principles for STEM, including an appropriation of language and cognitive skills, has generated funding opportunities in which it is difficult for designers to participate, even though they may be design centered initiatives.

THE STEWARDSHIP OF DESIGN AS A DICIPLINE

The integration of Design Thinking/Design based learning/STEAM into secondary education has impacted the understanding of the role of design as a field. These effects show up in multiple ways; first through students’ confusion around STEM and design disciplines, second the role of art and design education within academic curriculum development, or policy issues, and lastly, the impact of an ill-defined inter/cross disciplinary interaction has resulted in potential funding gaps for the arts vs the sciences.

It falls on faculty to do the work of increasing design literacy within an institution. Design literacy, namely an awareness of the impacts of design as a field and/or a familiarity with the skills applied through design (Pacione, C. 2010), can increase recognition of the role that design has played in shaping our current innovation driven economy. It can also draw attention to the complex nature of real-world problems, and how designerly ways of engaging with complex problems enable individuals to act as agents of change and creators of preferred futures.

Design educators should advocate for academic institutions to add design courses to general education requirements. Adding design as a form of literacy among liberal arts and STEM implies that students should develop basic design abilities, such as inquiry, ideation, and externalization. Design has distinct areas of knowledge, and methods of research, and is concerned with the conception and realization of new things, through thinking, planning, making, and doing. (Cross, 1982)
These designerly ways of thinking are examples of aspects of design from which everyone may benefit when interacting with the world (Christensen, et al 2016). Since Design educators are hired and evaluated as content experts in subjects focused on developing design skills including creativity, problem solving, as well as critical and reflective thinking, it follows that they should be involved in shaping curriculum at a foundational level to support the development of these crucial skills.

Increasing the visibility and understanding of research in design and creative fields is an integral part of this strategy. Design educators are often required to maintain an independent research practice as part of institutional expectations for advancement. When designers share creative research within academic institutions, they help elevate design research and illuminate the role of design in society. This can help expose students to a wide range of research methods utilized in design as practice. Additionally, when shared within an academic institution this could help generate cross disciplinary dialog, highlighting practices unique to design, or shared ideas that could inspire collaboration.
While cultivating interdisciplinary collaborative projects increases visibility, there are many obstacles that can make this difficult for faculty seeking collaborators. Many Universities lack institutional structures to facilitate faculty collaborations. Some have internal grant opportunities to promote cross pollination through interdisciplinary collaboration, but few have pathways or structures in place to support this work such as peer mentorship in navigating the time-intensive, logistical, and administrative hurdles of interdisciplinary practice.

One solution would be to formalize a community of practice within a university, inviting students and faculty to participate in rigorous multidisciplinary dialogs that facilitate understanding of design as a disciplinary practice. Including faculty from diverse disciplines represents an opportunity to uncover shared values while fostering dialog around professional identity and disciplinary practice. Such a center could support collaboration across the institution, co-sponsor and promote visiting design scholars and practitioners, and facilitate connections between various disciplines such as human rights,

environmental sustainability, and global studies, among others. This interdisciplinary approach enriches the discourse surrounding design and its intersection with broader societal issues.
This would contribute to a student's professional development and encourage students to become future stewards of design.

In closing, this paper acknowledges that in some respects, these pedagogies which borrow from design increase design literacy. But, it argues, this comes at a price. In some cases, a lack of understanding within institutions impacts students and faculty alike.

This paper is not intended to advocate for further siloing of disciplines. On the contrary, it supports interdisciplinary collaboration and cross pollination, but stresses the importance of an equitable, non-hierarchical accounting of the different disciplines that comprise research. Design must be recognized as a discipline that has a high impact, and which helps to shape the world in which we live.

We can do this without siloing disciplines. Rather, by naming different strategies and fields of knowledge, we gain a deeper understanding of the tools we have at our disposal. We recognize the work that has preceded us, acknowledging the importance of interdisciplinary practice and the value of integrating different forms of knowledge gathering and synthesizing into solution building. Instead of paying lip service to design, we should aim to both honor the specialization of disciplinary tools and integrate them by recognizing the meaningful yet contingent applications and connections between fields (Alliance for the Arts in Research Universities).
We can honor specialization, disciplinary history, and practices as we build new interdisciplinary pedagogies that support complex problem solving for the future. The intention here is to empower design educators to find ways to advocate for design literacy within their respective institutions. In the end, this will benefit the students who will be graduating and moving out into the world as practitioners and the future stewards of Design.

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