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WIP: Scaffolding the Design Process for Undergraduate Biomedical Engineering Students: Towards a Self-Regulated Design Learning

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ABSTRACT

This is a work in progress. Biomedical engineering undergraduates use the design process to solve open-ended problems in studio-based courses, cornerstone design experiences, or senior capstones. Some professional skills that are acquired through these ABET accredited courses are: the abilities to design a technology-based product or service, to address a real-world problem, and to communicate effectively. The forced transition to online education due to the COVID-19 pandemic exacerbated the fact that higher education students need more self-regulated learning (SRL) skills to engage in effective time management, prioritize their tasks, watch lectures, and complete assignments. Most literature concerning self-regulated learning has not acknowledged the underpinnings of how design pedagogy and the studio culture can play significant roles in achieving these important skills in engineering design. As in many other subdisciplines, the deployment of design education is often informed by folk pedagogy, rendering it limited in scope, non-replicable and difficult to transfer to other disciplines and areas. This article looks to explain some of the theoretical and practical underpinnings of Self-Regulated Learning Design and to describe techniques implemented in 2021 to scaffold the design learning process in our well-known *Design Teams* biomedical engineering course. We use a Design Based Research approach to describe some of the scaffolding techniques and to assess and propose possible improvements to these teaching practices. Future work will include thorough qualitative assessments of the experiences of past and current students as well as an expansion of the theoretical framework and literature involved.

Keywords: self-regulated design learning, biomedical engineering undergraduate, design learning, design teams

1. INTRODUCTION

In 2020, the International Association of Universities (IAU) interviewed 424 institutions in 109 countries and found that two thirds of the institutions transitioned to virtual instruction due to COVID-19 (Marinori et al., 2020). This forced migration to virtual environments has put a spotlight on self-regulated learning (SRL), as the extrinsic accountability that is traditionally created through face-to-face interactions between instructors and students, was significantly reduced. Self-regulated learning has been widely studied in the behavioral sciences (Zimmerman, 1986; Panadero, 2017; Boekaerts et al., 2000; Pintrich, 2004). To foster self-regulated learning among students, building educational scaffolding is critical. As we will show, scaffolding in education relates to concrete and thoughtful teaching techniques that enable the students to become more autonomous.

The following article is a descriptive, qualitative case study of Johns Hopkin's well-known undergraduate design program in biomedical engineering (BME). We employ a Design-based Research approach by using intervention-oriented strategies for conducting research in learning more pertinent to classroom practices (Reimann, 2011). We first identify scaffolding practices in literature related to self-regulated learning. Then, we describe the interventions undertaken in the Johns Hopkins BME design course during Fall 2021 and Spring 2022 under a Design-based Research strategy. We then analyze these interventions through student interviews intended to ascertain student perception of scaffolding techniques. Lastly, we match these interventions to the practices in educational literature and reflect on their uses.

2. THEORETICAL FRAMEWORK

2.1 Design pedagogy in biomedical engineering

Engaging with open-ended problems has been a major component of building interdisciplinary competencies (Lattuca et al, 2017) and expertise in future engineers. Design pedagogy has been key to achieving learning

outcomes such as the ability to address a real-world problem, to design a technology-based product or service, and to communicate effectively (ABET, 2022).

2.2 Self-regulated design learning (SRDL) and the design studio

In his book "Self-Regulated Design Learning," Matthew Powers writes that Self-Regulated Design Learning (SRDL) is a "theory and methodology that synthesizes two important concepts: (1) design learning; and (2) self-regulated learning (SRL), into a two-part structure that includes a theoretical foundation to help explain how students learn (and don't learn) in design studios" (Powers 2017, p. xxi). Design studios and Project-based Learning (PBL) strategies put the student at the center of their learning experience, which is focused on *learning* by *doing* (Schön, 1987). Powers defines self-regulated learning as "the belief that meaningful learning comes from an individual learner actively participating in his or her own learning" (Powers, 2017, p. xxiii). With the exception of Powers, scant literature exists that explores SRL for design.

2.3 What is scaffolding and why would it help SRL?

Wood et al. coined the term "scaffolding" in the context of human learning and tutoring, in which a more experienced individual enables a novice or a child to complete a task or acquire a skill "which would be beyond his assisted efforts" (Wood et al., 1976, p. 90). Since its introduction into instructional pedagogy, scaffolding has been applied to myriad contexts, including online and computer-based learning environments. According to Azevedo, scaffolds are "tools, strategies, and guides" used by instructors to develop student understandings "beyond their immediate grasp" (Azevedo, 2005). We define scaffolding **as a teaching method in which an instructor provides support during the design process that facilitates skill development, autonomy, and increased understanding of the complexity of the problem.**

Scaffolding is particularly helpful when students are faced with ill-structured problems; it not only facilitates skill development, but it also allows the learner to "internalize their approach to then apply to other tasks that are similar in nature" (Yelland, 2007). Scaffolding can increase self-regulated design learning and drive typical design team engineering programs toward greater SRL in ways that have not been previously explored on a large scale.

2.4 Forms of scaffolding to be used in design learning

Scaffolding can take the form of "pre-stocked questions, static questions, dynamic support" (Azevedo, 2005), "suggestions, guides, diagrams, explanations" (Niu et al., 2019), as well as coaching through prompts, templates, tools, strategies, expert advice, and other resources (Gallardo et al., 2012).

3. METHODS

3.1 Research strategy

To provide an understanding of how scaffolding works in Self-Regulated Design Learning (SRDL) we utilized a Design Based Research (DBR) approach. This is a strategy conducted in the field, through interventions in the realm of educational strategies, curricular tasks, and other types of elements (Reimann, 2011). It is important to note that Design Based Research is not a sequence of predefined steps, but rather a collection of research and design actions aimed at studying and enhancing learning spaces in their original natural contexts (Barab, 2014).

Based on our theoretical research on scaffolding and SRDL, we matched literature with actual practices undertaken in the course. As a result, we conducted a descriptive, qualitative case study intended to understand different forms of education design interventions in the literature, and then, to align this literature with the structure of the Design Team course. The intended outcome of this case study is to identify forms of scaffolding that already exist within the curriculum to then iterate on them. Interviews with students were conducted to understand the perception of scaffolding techniques.

3.1 Research context

The Biomedical Engineering (BME) Design Teams program at The Johns Hopkins University has been around for 15 years and looks to teach undergraduate biomedical engineers how to work in teams to design, prototype, and test technical solutions to real-world problems. Students—including sophomores, juniors, and seniors—from the anonymized program apply to participate in the Design Teams program. Students can also voluntarily apply to be a Design Teams Leader. As of 2022, 160 students are divided into 18 teams of 5 - 8 individuals (5 students begin in Fall and then 3 freshmen students are onboarded in Spring), with an anonymized Leader guiding each team. Each team is connected to a clinical sponsor with a specific real-world clinical issue across medical areas (Miranda et al., 2022). Students are likely to be unfamiliar with the clinical specificities concerning their project. As a result, students engage in checkpoints with their clinical sponsor, whose expertise in the specific clinical area can aid students' projects development (Manbachi et al., 2020). At large, the course suite provides the scaffolding of interdisciplinary assistance, structure, and competencies for students aimed at preparing them to develop solutions to open-ended, real-world problems. Looked through the lens of literature, we will further analyze some of the most clear and transferable scaffolding practices to promote self-regulated design learning.

4. RESULTS AND DISCUSSION

Utilizing Gallardo's scaffolding framework, Design Teams has implemented four types of scaffolding: "macro-scaffolding," "micro-scaffolding," "social-guidance scaffolding," and "systems-guidance scaffolding" (Gallardo, 2012). "Macro-scaffolding," which supports an entire activity workflow, consists of the four-phase structure of the Design Teams program itself, including the roadmap that is clearly laid out on the class syllabus—"problem-framing," "solution conceptualization," "prototyping," "validating and verifying." "Micro-scaffolding," or support of a specific task, has been implemented through topic-based classes, worksheets, and tools. For example, lecture-based classes on the craft of graphic design, storytelling or building an effective team are oriented toward learning goals, skills, and knowledge. "Social-guidance scaffolding," or support provided by individuals, is mostly present in the form of desk and group critiques. "Systems-guidance scaffolding," support provided by technological systems, takes the form of asynchronous, pre-recorded, digital lectures and pre-packaged online courses.

4. CONCLUSION

This Design Based Research case study looks to be a contribution to the understanding of using scaffolding strategies with the intention of achieving self-regulated design learning in biomedical engineering undergraduate PBL/studio-based courses. Setting self-regulated design learning as a conscious purpose for BME education can be helpful to move away from the issues brought up by folk-design-pedagogy, and toward a more intentional educational experience for our undergraduate PBL courses. Future work entails the implementation of possible learning analytic tools that could support the tracking and self-management tools like time-on-task management monitoring (Hilliger et al., 2021; Miranda et al., 2020) and the triangulation of this case study with datapoints such as teaching surveys and other forms of qualitative assessment.

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