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BOARD # 412: NSF RIEF: Enhancing design thinking transfer among undergraduate bioengineering students: A Dynamic Role Identity Approach

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RIEF: Enhancing design thinking transfer among undergraduate bioengineering students: A Dynamic Role Identity Approach

Introduction

A central goal in engineering education is developing students' design thinking for creative real-world problem-solving [1,2]. Design thinking provides engineers with a comprehensive set of principles for approaching diverse and emergent authentic challenges through deep needs assessment, contextualized problem definition, creative idea generation, and constructive iterative phases of implementing, testing, and improving a solution [3]. It is expected that engineering students will transfer the principles of design thinking they learn in their courses to new situations and problems [4]. Yet, decades of research have demonstrated that promoting transfer is very challenging [4–7]. We repeatedly encounter students who manifest fixated thinking (e.g., failing to go beyond an initial solution suggested by an advisor as an example) and who do not apply previously learned design thinking strategies required for identifying and evaluating different solutions to fit design criteria and end users' needs. This paper describes a theoretically-informed intervention in a Biodesign course that aimed to promote students' transfer of design thinking from the course to their capstone project in the following semester.

Design thinking: Design thinking (DT) reflects a professional orientation and skills considered central to the preparation of engineers for solving complex engineering problems of the 21st century [8]. Learning standards in undergraduate engineering education call for training students in **applying engineering design** to engineering problems that include "one or more of the following characteristics: involving wide-ranging or conflicting technical issues, having no obvious solution, addressing problems not encompassed by current standards and codes, involving diverse groups of stakeholders, including many component parts or sub-problems, involving multiple disciplines, or having significant consequences in a range of contexts." [9]. The process, as taught at Temple University, contained an iterative 5-step process: Empathize, Needs Assessment, Ideation, Prototype, and Test [10]. It is a teachable competence that is viewed highly valuable and is increasingly considered key for employee recruitment in both industry and academia. Thus, students' failure to transfer design thinking orientation and skills across tasks, courses, and domains is worrisome and constitutes a major challenge for engineering education [4].

Transfer of Strategies: Transfer refers to the process through which students use prior learning to solve problems in a new situation [7,11,12]. Arguably, transfer of learning to new situations constitutes a core goal of education. Yet decades of research have demonstrated that transfer of problem-solving strategies rarely happens spontaneously, and is hard to teach [4,13]. In the current project, we propose to address the transfer challenge by focusing on students' role identity and motivation: the complex processes that underlie students' decision to transfer and enact certain actions learned in a previous role (e.g., Biodesign student) in a new role (e.g., capstone student).

The Motivation to Transfer: The literature on student motivation includes numerous theories and multiple concepts that differ in their emphasis on and interplay of different personal characteristics (e.g., grit, growth mindset, task value, self-efficacy, stereotype threat) and contextual characteristics (e.g., reward systems, task characteristics, teacher-student relationship) [14]. Calls for integrating theoretical perspectives have led to recent frameworks that incorporate concepts from various theories into comprehensive models that explain the diversity of student-motivated action. In the current project, we adopt an integrative motivational model that corresponds with current views of transfer as embedded in social-cultural settings that frame students' identities: The Dynamic Systems Model of Role Identity (DSMRI) [15].

The basic premise of the DSMRI is that motivated action is based on the person's construction of their role identity—who they believe they are in a particular role and situation. This role identity includes the student's beliefs about their context, their goals in the role, their self-perceptions of ability, values, and social identities in the role, and their perceived action possibilities for enacting their role [15]. It is the difference between role identities in different situations that can explain why actions learned in one situation do not transfer to another situation. We use the DSMRI

to conceptualize how learned DT strategies from a person's prior role identity can be applied by this person in new situations [15]. To promote such role identity formation, we used the Reflective Design Practice (RDP) to introduce personal reflections as an integral part of learning DT in one situation and encourage DT transfer [4]. **We hypothesized that engaging students who learn DT within one role identity (Biodesign student) in imagining using those DT strategies in other role identities (future Capstone student, future Engineer, another concurrent life role)** would promote DT transfer into those other role identities when students occupy them.

Methods

This study reports on the first phase of the study conducted within the Biodesign course. The next phase will investigate transfer in the senior capstone course. We purposefully selected six undergraduate, senior-level bioengineering students (out of 16 consenting students) from the Fall 2024 Biodesign course. (Temple University's IRB exempt proposal 30861) This course consists of required weekly lectures and laboratory sessions and is a pre-requisite to the senior capstone course. This class reinforces learning about the DT process through three design modules, each requiring a complete cycle through the design process, including prototyping and testing. Course students were divided into teams of 2-3 for the laboratory sessions. The Biodesign course covered the theory of DT through class lectures about the DT elements and then applications of DT in the weekly laboratory section. This material was reinforced with weekly RDP reflective journals of students' self-description of their use of DT strategies. [4]. At each module's end, students also created a DSMRI-informed summary reflection involving imagining DT use in future roles. Journals, both weekly and end of module, were required from all students. Severely late journal submissions were not accepted by the course professor, nor reviewed by the research team. Finally, the selected students were interviewed at the end of the semester about their DT experiences in the class and expectations for their future use of DT. These interviewees were compensated for their time as this was the only element of data collection that was not a required part of the course. These students were selected to capture diverse intersections of characteristics, including gender, and skill competencies based on student self-assessment, and on the course TA's evaluation of temperament and learning behaviors. Table 1 describes these characteristics. We followed the DSMRI Analysis Guide [16] to conduct a combined deductive-inductive analysis of course observations, students' reflections, and interviews to identify emerging themes about students' engagement in the DT process and indications for future transfer into future courses and experiences using a DSMRI qualitative evaluation.

Table 1: Breakdown of students in the study with demographics and skill competencies

Student #	Team #	Gender Presenting	Course ability (Lab)	Course ability (lecture)	Other
1	8	male	Medium	Medium	3-person team
8	5	female	Weak	Weak	1st gen college
9	8	male	Medium weak	Weak	3-person team
12	3	female	Medium strong	Strong	Disability accommodation
15	9	female	Strong	Strong	3-person team
16	1	female	Medium	Medium strong	

Results and Discussion

The analysis of the six students' data pointed to five main themes: (1) Students' Biodesign role identity reflected beliefs, goals, self-perceptions, and actions that lacked agency and ownership over their designs and the design process; (2) Students manifested partial, simplistic, or erroneous understanding of DT; (3) Students considered DT transfer to senior capstone only minimally; (4) When considered, students' imagined DT transfer to the capstone was direct/concrete rather than conceptual; and (5) students did not value the reflection activities.

(1) Students' Biodesign role identity reflected beliefs, goals, self-perceptions, and actions that lacked agency and ownership over their designs and the design process. Instead, students' goals focused on good grades, validation

from the instructor and TA, and completing the assignment correctly. For example, student 15 reflected: *"We were able to speak with [the lab instructor] and ensure that his comments were being applied in the right way and that our corrections were beneficial"* (Weekly Reflection 9). Similarly, student 9 considered the instructor's instructions for the assignments as the ultimate criteria for success: "*I believe our design is well done and should be sufficient for the assembly estimate assignment"* (Weekly Reflection 9). This student later noted "*Our code is very well done and completes all the requirements for the final presentation and project"* (Weekly Reflection 14). This type of role identity construction also manifested in student 16's interview when they described frustration with needing help quickly when encountering problems: "*...Once we encounter problem[s], we're very much like help immediately"* (Interview).

In addition, the data indicated that students rarely considered role identities other than 'Biodesign student'. Even when considering applying experiences to the future, students focused on the Biodesign student in the future, as in next week or in the next module. For example, when prompted to consider what they learned for their future, student 12 reflected: *"I think I would go back to the computer we used this week because we were able to get more work done and not get distracted by other groups around us"* (Weekly Reflection 5).

(2) Students manifested partial, simplistic, or erroneous understanding of DT. The analysis provided substantial evidence that students seemed to have learned DT as concrete steps that aim at the 'one' best solution of the project, or as a set of steps to apply only when encountering problems and ill-defined tasks. At times, students indicated misinterpretation of DT terms. For example, some students interpreted DT as concrete steps to be learned distinctly in a lecture and then directly applied in the lab. Student 12 commented about the lack of correspondence between lecture and lab: *"maybe also a lack of communication of where we're at in lab and where we're at in lecture that sometimes make things too repetitive, or we're <u>not going over the right information for lab in lecture first</u>"* (Interview, emphasis added). This and other students' comments about wanting explicit links between each lecture and the subsequent laboratory session imply a misunderstanding of the concept of the DT process and its translation to practice, focusing on concrete, perhaps technical, instructions that aim at the goal of their designs to be "correct." Correspondingly, student 8 interpreted DT as a set of steps that guide to the single best solution: "*I believe the workspace allowed us to get input and advice from the instructors on <u>the best route</u>"* (Weekly Reflection 11, emphasis added). This seemed also to be student 16's interpretation: *"Know if you're making the right choice or not... I didn't feel like I knew enough about it to like <u>pick</u> <u>the right one</u>"* (Interview, emphasis added). Other indications of misunderstandings included referring to DT terms loosely, such as student 16 who referred in different places in her reflections to troubleshooting errors in simulations and to physical prototyping as "ideation."

(3) Students considered DT transfer only minimally. Across all six students and their various data throughout the semester, only one student provided an ***unprompted*** comment about transferring DT beyond the Biodesign course to the capstone course. Student 15 was the only one who seemed to have developed a conception of DT as a general approach to design. They noted in their weekly reflection: *"I will use this strategy in this semester's and next semester's SD [senior design capstone] projects in order to effectively walk through the build process without running into major issues after too much is completed"* (Weekly Reflection 3). When prompted by their end-of-module DSMRI reflection, this student also expressed self-perceptions as someone who uses DT, who values it, and who developed beliefs about its utility to pursue projects: *"As someone who uses design thinking, I have learned that I appreciate the design process and the progressive steps that go along with it. It gives me a method in which I can break down the work into more manageable and understandable parts"* (Module 1 Summary Reflection).

(4) When considered, students' imagined DT transfer to the Capstone was direct/concrete rather than conceptual. Other than student 15, two other students noted DT transfer when prompted in the interviews. Student 12 expressed both annoyance with the DT process and generalizing DT beyond the Biodesign task: *"Like going through the design iteration and running into those issues while it was really annoying, it was really helpful at the same time,*

because then we're also like in the end producing a design that like is the best like to fit the needs" (Interview). Also, student 1, when prompted, commented in the interview on direct DT transfer to the Capstone project: *"So I was just watching the senior designs go over their final project for senior [capstone] design 2 [final presentations]. I like the way this [Biodesign] class is set up like it basically really does emulate what you're doing in senior design, too. And it really does help you translate that to kind of success for senior design 2. I like that aspect of it"* (Interview). This comment reflects a 'low road transfer' [7] with the student being able to transfer similar content from the Biodesign course to their future senior capstone project. Student 12 made identical comments about enjoying the similarities between Biodesign and senior capstone classes, but could not project the use of the DT process in other aspects of her life or for future engineering careers when prompted. Another student felt very comfortable commenting about the use of the DT process outside of the current class in her involvement with Engineers without Borders student organization or working with her father in the garden. However, student 16 felt that the design criteria inherent in engineering design were not 'fun' or 'creative': *"It's kind of fun because you don't need to abide by all the ASTM standard[s] and stuff. If it's your own little garden bed you can kind of just like have fun with it."*(Interview) Later in the interview, this student presented an ontological belief that having fewer resources forces more creative solutions and that having more resources negated the need to use the DT process: *"If you're for like a big firm, you have like all these resources and stuff, and you could probably find like in your documents like, oh, this is how they did before and then you just do like a pretty similar thing. Like. If you're building like a well, we don't have latrines. But if you're building like a bathroom plumbing system like you have, all these examples of people have done it before, and you can kind of just do the same thing like push it along. But for like this [Engineering without Borders] project, it's not something that like has really been super done before. So we kind of talked to like, really think about it, and really understand, like what every component of the system does and how it's going to like, think about all the ways it's gonna interact with like the people and the land like, how it's gonna ultimately solve their problem of like not having like adequate sanitation. So I think that's kind of the fun part is like really engaging with something and really like getting to know, like the people that it's affecting, and the like having worked these new constraints that like force you to get a little more creative with the solution"* (Interview).

(5) Students did not value the reflection activities. The RDP was implemented as an implicit introspection tool to help students improve future work products or practices and encourage DT transfer [4]. Our data shows that students only completed the bare minimum required by the assignment, or did not engage with the reflection activities. Student 16's weekly reflections for weeks 5 and 6 had many spelling and grammatical errors. Further, student 16 turned in blank reflections for weeks 8, 11, and 12. Several students, including student 8, turned in partially complete reflections. Additionally, student 1 turned in all his weekly reflections and module summaries on the last day of the semester. Therefore, negating any benefits the reflections may have provided throughout the semester. Thus, it was apparent that the reflections were generally considered an "afterthought" and not regarded as an integral part of the DT process.

Conclusion and Future work: DSMRI states that a person's role identity includes their beliefs, goals, and actions that they take with regards to their current role. The findings suggest that the students' beliefs about what was important in the Biodesign course, such assignment completion and getting 'the right answer,' was not conducive to learning and then transferring DT. Their comments about needing validation of their work by the instructor suggest that, while some students acknowledged the benefit of a DT process, their formation of Biodesign role identities focused on satisfying the instructor's requirements rather than assuming ownership over their work and internalizing the DT approach. Moreover, students' understanding of DT was partial and sometimes erroneous. Thus, it is unsurprising that they did not readily imagine the DT process in their future careers. In the few instances that they did, when prompted, the DT transfer was to the capstone course based on exact task matching (and not to the task of engineering). This transfer was concrete rather than conceptual, which would limit their ability to broaden the scope of their design thinking in other situations.

The next phase of our study involves following these six students during their senior capstone course in Spring 2025 to investigate the transfer of DT from the Biodesign class to those future projects. This will be conducted through end-of-term interviews and a review of their senior capstone final reports. Currently, our findings call for a redesign of the intervention, as our data suggests that DT transfer is not going to be pervasive. We have shared our findings with the Biodesign instructors and considered with them the implications for the pedagogy of teaching DT. In addition, we will revise the RDP and end-of-module DSMRI prompts, reflection questions, and presentation of the need for reflection in DT to better impart the importance of reflections for DT learning and the promotion of DT transfer.

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