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COLLABORATION AT THE BOUNDARY OF UNCERTAINTY

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PAPER ABSTRACT: The boundary of uncertainty is at the edge of what a learner can do without help. At this boundary, a learner can only succeed by collaborating with someone who has a broader knowledge, experience, or skill set. When someone supports an uncertain learner, the moment is termed a touchpoint. Touchpoints are important; relieving a learner's struggle too soon does not produce learning results and relieving them too late causes frustration that is counterproductive to learning. This paper discusses the uncertainty boundary in terms of collaborative design projects in which mentors use student-created artifacts to purposely pull a learner to a series of "need to know" places. These places indicate the boundary of the learner's independent ability. Successfully completing these projects requires the learner to connect with peers, mentors outside the specific course, and outside the academic environment, each with specific knowledge, experience, tools, and skillsets. We further discuss the advantages of extending this "need to know" impetus across course boundaries in a collaborative teaching environment and the struggles of implementing a more complex collaborative design project.

Keywords: touchpoints, uncertainty, motivation, need to know, collaborative design project

1. INTRODUCTION

The skills, tools, and knowledge required to educate industrial design students are expanding and changing (Wormald & Rodber, 2008). Design research methods, new materials and processes, rapid prototyping technologies, digital creation and presentation skills, user experience and interface, design thinking, and innovation are all aspects of a designer's education that are becoming more important. Incorporating these new and changing competencies while still retaining important core design skills in curriculum is important to the education and training of a professional industrial designer.
Teaching a broader base of knowledge, skills, and tools and promoting student learning with limited resources—faculty, facilities, finances, and credit hours—is a complicated task. Such a task requires new, efficient, and useful ways to approach educating designers within these academic constraints. Frank Lloyd Wright said, "The human race built most nobly when limitations were greatest" (Jones, 2017). In other words, sometimes constraints lead to more elegant solutions. We must learn how to engage and motivate students to help them take ownership of their own education.

2. PROJECT-BASED LEARNING

Project-based learning is receiving a lot of attention in the academic media. These learn-by-doing methodologies are becoming popular in both K–12 and university environments. This approach is based on the desire to move away from a traditional lecture-based pedagogy toward an experiential, student-involved pedagogy. Using this project-based model, students work together to learn, and activities are structured to emphasize collaborative, active, student-based discovery. Faculty serve as mentors by

providing projects, observing learning, answering questions, giving students opportunities, listening, and watching more than lecturing (Leiboff, 2010).

Most design education has focused on project-based instruction for over a century (Droste, 1990). Project-based instruction was adapted from the early training of artisans, in which education was to support and build real-world skills (Boyer & Mitgang, 1996). Today, most models in design education trace their roots to the approaches developed in the Bauhaus school under the direction of Walter Gropius and Johannes Itten, who taught design by actually having students work on designs (Boyer & Mitgang, 1996). The Industrial Design program at our university has been employing this project-based method of teaching for more than 40 years with good success. Project-based learning requires more involvement from the students and a different kind of involvement from professors than traditional education.

Project-based learning requires students to be less independent and much more collaborative than those who learn via traditional lecture-based classes. Students' work is made public to allow peers, professors, and outside experts to see and discuss it, permitting all to participate in the learning process. Students learn to accept feedback as a powerful tool to define and refine their ideas. These project-based learning environments are highly collaborative and less formal than traditional learning environments helping students feel more comfortable with sharing their ideas.

As professors focus on guiding student thinking, discovery, and application rather than on simply disseminating information, their role changes. Professors provide projects that will teach what the desired learning outcome is for the course. This means that professors need to have more contact hours with the students as they work to mentor them in their thinking and learning.

How can we leverage project-based learning by doing it more effectively? In this paper, we focus on experimental approaches being used by industrial design instructors at our university that build on project-based pedagogy. These approaches help students stay motivated, collaborate better, and mentor each other.

3. MOTIVATION

Experts have suggested that people learn more effectively and are more creative when they are intrinsically motivated. Though extrinsic rewards such as grades can increase productivity when tasks are routine, the quality of higher level learning is influenced most by intrinsic factors. When people find tasks rewarding, interesting, and challenging, they are more likely to experience lasting and deeper learning (Coon & Mitterer, 2010).

Malone and Lepper (1987, pp. 223–253) defined an intrinsically motivating activity as follows: "people engage in it for its own sake, rather than in order to receive some external reward or avoid some external punishment. We use the words fun, interesting, captivating, enjoyable, and intrinsically motivating all more or less interchangeably to describe such activities." Malone and Lepper identified five factors that increase intrinsic motivation:

- Challenge: People are more motivated when (a) they pursue goals that have personal meaning or relate to their self-esteem, (b) they can obtain performance feedback, and (c) they can attain the goal but not necessarily in a clear, certain, or easy way.
- Curiosity: People pay attention to something in their physical environment, or they want to learn more about something related to an activity.
- Control: People want control over themselves and their environments and want to determine

what they pursue.

- Cooperation and competition (i.e., collaboration): People gain satisfaction from helping others and also in cases in which they are able to compare their own performance favorably to that of others.
- Recognition: People enjoy having their accomplishments recognized by others.

Using these motivators can help teachers develop a pedagogy that challenges, pushes students to collaborate, and provides enough autonomy to engage students efficiently and effectively in the learning process.

4. COLLABORATION AT THE BOUNDARY OF UNCERTAINTY

When students are motivated to expend effort to explore difficult problems or make sense of challenging ideas, they engage in a struggle that goes beyond passive learning; they build useful, lasting understanding, skill and confidence (Hiebert & Grouws, 2007). The point at which this struggle becomes acute is the boundary of uncertainty.

The boundary of uncertainty is at the edge of what a learner can do without help. At this boundary, a learner can succeed only with guidance from a mentor or in collaboration with more capable peers (i.e., with the help of someone who has a broader knowledge and skill set; Vygotsky, 1987).

Each member of a collaborative group has a different level of ability and therefore a different boundary of uncertainty within the context of a project. This contrast among group members allows peers to help those who have skills and knowledge that are different from their own, thus providing the support necessary to work together toward the same goal. Vygotsky (1987) viewed interacting with peers as an effective way of developing and extending learning.

Summers (2012), former president of Harvard University, said, “Collaboration is a much greater part of what workers do, what businesses do and what governments do. Yet the great preponderance of work a student does is done alone at every level in the educational system. Indeed, excessive collaboration with others goes by the name of cheating.”

Collaboration is a way to leverage others to help provide the broader education students need. To make learning experiences more comprehensive or impactful, professors can focus on collaboration, whether among students, courses or disciplines. As projects become more complex, students need a broader base of knowledge and skills to draw from, and collaboration is a way to fill these gaps.

Mentors, either professors, peers, or outsiders must work closely enough with learners to be available when they reach the boundary of uncertainty to provide a “boost” that enables (or supports) further learning. This boost is called a touchpoint.

5. TOUCHPOINTS

Touchpoints are moments of mentored connection when a learner needs and obtains support. This collaborative support expands the learner’s boundary of uncertainty. Subsequent touchpoints come at the new edge of the learning frontier. Giving learners the most rigorous tasks they can do, along with a minimal amount of instruction, leads to the greatest learning gains. Touchpoints are most effective when the mentored support is matched to the needs of the learner, putting them in a position to achieve success in an activity that they would not have been able to do alone. This also gives students

more control over their learning.
To facilitate active learning for students, professors need to know whom and how peers can help during a project as they share knowledge and skills through collaborative interaction (Dixon-Krauss, 1996). Some tasks will be beyond the peers' ability to provide help, so professors may step in to provide a touchpoint. Some tasks may even be beyond a professor's knowledge and skill set; in these cases, professors must provide a mentor who can provide the needed help. Vygotsky (1987) held that when a student is experiencing the boundary of uncertainty for a particular task, providing the appropriate assistance would give the student enough support to achieve the task.
This "boost" is a key feature of effective teaching. Mentors should be careful not to alleviate the struggle or take control but to help support the learner in their struggle. This support can include giving general encouragement, modelling a skill, providing hints or cues (Copple & Bredekamp, 2009), or, when needed, offering specific instructions or direct demonstrations (Wood et al., 1976).
Professors' guidelines for touchpoints include assessing learners' current knowledge and experience so as to develop projects that will push them to the boundary of uncertainty, making connections to what students already understand to motivate them and create momentum, providing opportunities for feedback from peers and others, making work public, and using a variety of prompts to assist students (Silver, 2011).
Wood et al. (1976) identified several methods for giving effective support, which include gaining and maintaining learners' interest in the task, making the task challenging but achievable, emphasizing aspects that will help with the solution, balancing between accomplishment and frustration, allowing failure (with time and opportunity for recovery), and demonstrating what success may look like.

6. APPLICATION

In this paper, we discuss the boundary of uncertainty in terms of design projects in which mentors use student-created artifacts to lead learners to a series of "need to know" places requiring collaboration touchpoints with peers, mentors, or outside support. These places indicate the edge of the learners' independent ability. The successful completion of these artifacts requires learners to connect with several collaborators, courses, and disciplines, each with specific knowledge, experience, tools, or skillsets. These collaborative elements combine to provide the support learners need to complete the artifacts in an efficient and uninterrupted path. The paper also discusses the advantages of extending this "need to know" impetus across course boundaries in a collaborative teaching environment and the struggles of implementing a more complex collaborative design project.

7. PROJECT DESCRIPTIONS

In addition to teaching the skills, practices, and knowledge of a particular course, a secondary but impactful objective is to develop the student's mindset. This mindset recognizes the power of curiosity, challenge, and motivation and develops confidence in the ability to do things beyond their comfort level. A conscious effort has been made to try to infuse classes with multiple need-to-know moments to push the students to the struggle at the boundary of uncertainty, requiring connection with peers, mentors, and outside support. In other words, how to engage and motivate students to help them take ownership of their own education.
Below are examples of three sophomore course projects highlighting different collaborative connections

where students are purposefully pushed to need-to-know moments at the boundary of uncertainty.

7.1 BAR STOOL PROJECT

A project in the sophomore design studio course is to design a bar stool. The assignment requires the legs of the stool to be made from 3/8-inch steel rod and the seat is made from the student's choice of material and process. The students follow a typical design project process with research, sketches, and models to define their initial concepts and move to a final design (see fig. 1). The boundary of uncertainty comes with multiple assignment requirements bringing the students to need-to-know moments; 1) The students are divided into small teams, three or four per group. This is the student's first opportunity to collaborate with peers in a design project and learn the complexities of group dynamics. 2) The students must bend, cut, and fabricate the steel legs which means learning to weld, a skill most students have no experience with. 3) The students need to pick a material and associated process for the seat and experiment with construction. 4) the students are to fabricate 15 of their final designs which require them to create standardizing parts, fixtures, and tooling. 5) the students are required to find a venue, advertise, and sell their finished stools to the public.

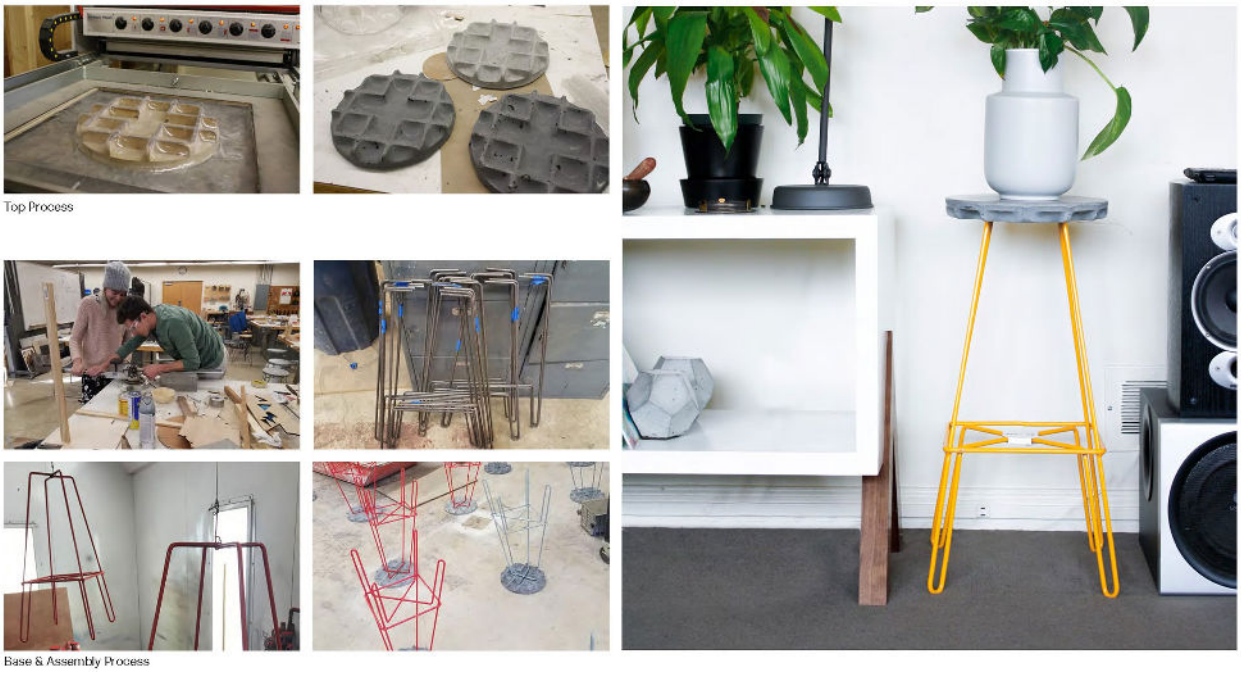

Figure 1. Bar Stool Project

7.2 LIGHTER PROJECT

A project in the sophomore introductory computer aided design (CAD) course is to design a lighter. The assignment requires designing a product that has symmetrical right and left injection molded plastic parts. The purpose of this assignment is to give the students a basic understanding of how a product would be designed for manufacturing. There are specific CAD tools and modeling methods that are taught as part of the class, but secondary to the larger learning experience is the push the students to a

need-to-know moments at the boundary of uncertainty. Touchpoints are 1) the students need to research the basic principles of injection molding part design, 2) the students need to collaborate to understand the component relationships, 3) The students need to connect with mentors to help with an introduction to CNC milling and rapid prototyping (see fig. 2).

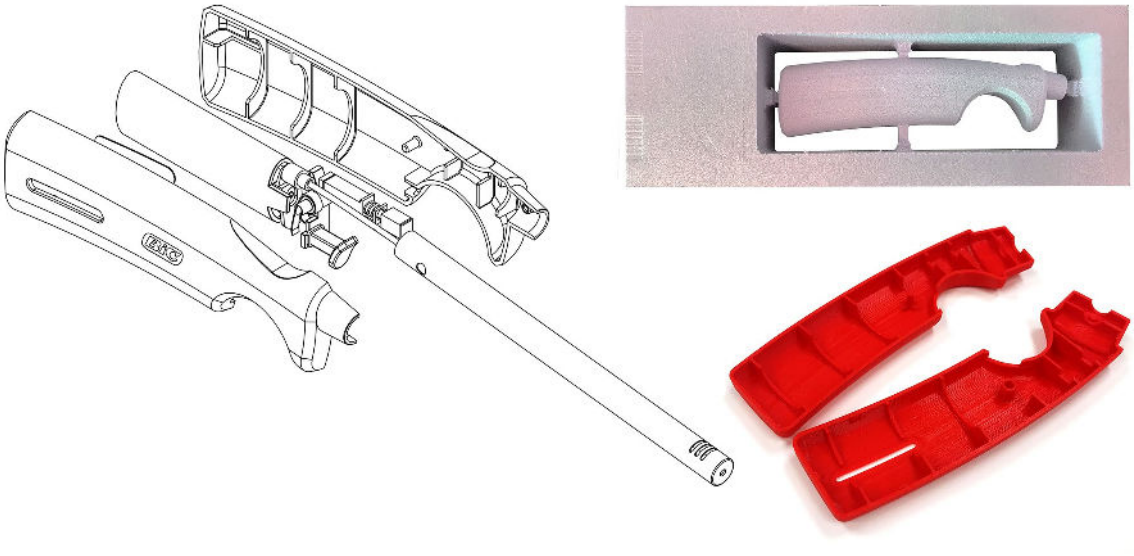

Figure 2 Lighter Project

7.3 PING PONG PADDLE PROJECT

A project in the sophomore design studio course is to design a ping pong paddle to meet the needs of a physical disability or impairment. This project highlights collaboration with outside resources, specifically understanding and testing a design with end users. The project begins with students spending class periods learning the rules of ping pong and playing the game. Ping pong tables were set up in the classroom giving these students an opportunity to play during the 3 hour studio class. After playing the sport and learning the rules of ping pong each student was given the assignment to pick a physical disability or impairment and to design a ping pong paddle to meet the needs of someone with that disability. A physical disability is defined as a limitation on a person's physical functioning, mobility, dexterity, or stamina. Students research to learn as much about their disability as possible and create a ping pong paddle that would meet the disability user's needs. The boundary of uncertainty need-to-know moment comes as the students were required to find, connect, and collaborate with someone who has the disability or could simulate accurately the disability in testing their proposed ping pong paddle designs (see fig. 3). The students then revise their concepts to meet the needs of the end user from the input they received from the testing.

Figure 3 Ping Pong Paddle

8. DISCUSSION

One goal of these assignments was to provide an extended exercise for students to practice coming to need-to-know moments. The product in each case is secondary to the learning that takes place throughout the process. As we reflected on the points of the projects at which we found students in the boundary of uncertainty, we were reminded that this boundary is different for each individual. Therefore, it is important to have an established relationship with each student to determine specific and somewhat customized support to meet their needs. Our role as professors/mentors is, in part, to assess the students' place in relationship to the edge of their ability and to provide an appropriate level of assistance in the form of touchpoint interventions. These interventions should not replace struggles conducive to building long-lasting skill and understanding; in fact, it is when these struggles become most acute that professors know students have reached the boundary of uncertainty.

Despite the individual nature of the boundary of uncertainty, there are times when, as a group, most students' needs coincide. These moments can be prompted when mentors provide an explicit "need to know." For example, taking apart products, researching processes, and testing products with end users. Then, when we directed students to apply their new information to a specific object, we provided them a "need to know." They now had concrete motivation to explore and apply their new knowledge. We observed that this "need to know" acted as a driving object, guiding them to discover on their own the possible interpretations, applications, and expressions in connection with the assigned product. The project application provided students with the challenge to move forward from what was accomplishable alone into the area of what they could not do alone (i.e., the boundary of uncertainty).

9. PROCESS

Incorporating need to know moments in project-based learning as an instructional approach involves students working on an extended project to explore. When designing a boundary of uncertainty learning assignment, follow these steps:

1. Start with an overview: Provide a brief introduction to the project, highlighting its purpose and significance. Explain that the assignment is designed to engage students in hands-on, collaborative learning that goes beyond traditional classroom activities.
2. Describe what a successful project will look like: Help the students begin with the end in mind. Don't show examples of good work as it prematurely sets directions in the students' minds, especially those who are prone to a closure mindset.
3. Explain the projects underlying requirements: Outline the specific requirements and guidelines for the project. This may include constraints, such as time limits or available resources, as well as any essential deliverables that need to be met. Emphasize the importance of creativity, critical thinking, and research in fulfilling project requirements.
4. Discuss collaboration and roles: Explain how students will collaborate with their peers, other mentors, and outside resources throughout the project. Describe any assigned roles or responsibilities within the team and emphasize the importance of effective communication, cooperation, and division of tasks.
5. Plan resources and support: Prepare for need-to-know moments with relevant resources, reference materials, or tools that students may need to utilize at their need-to-know moments, again allowing for a struggle during the project. Also, mention the availability of support from various mentors or teachers.
6. Address timeline and milestones: Provide a timeline or schedule that outlines key milestones or deadlines throughout the project. This helps students manage their time effectively and stay on track.
7. Include enthusiasm and motivation: Express enthusiasm for the project and the potential learning outcomes. Encourage students to embrace the opportunity for independent exploration, creativity, and personal growth that these projects offer.

Boundary of uncertainty learning assignments aim to foster student engagement, collaboration, and deeper understanding of the subject matter. By explaining the underlying project requirements clearly and providing the necessary touchpoints at the need-to-know moments, you can help students embark on a meaningful learning journey.

10. CONCLUSION

The power of this method of teaching, pushing students to the boundary of uncertainty, is represented in a story of a design student participating in a capstone course with a team of engineers. At a point in the project, the team needed to have a frame welded. When the team lead asked who could do the job, no one volunteered. The designer finally said, "I will do it." The team members asked if the designer knew how to weld, and the designer responded, "no I don't, but I will learn." This attitude becomes the mindset of those who have been to the boundary of uncertainty multiple times in their learning career. They gain great confidence in the ability to find a mentor and to collaborate to accomplish any task at hand.

Using these few methodologies—motivation, collaboration, the boundary of uncertainty, and peer and

mentored touchpoints—to push our students' skills, tools, and knowledge has proven interesting. The dynamic, project-based collaboration experiments discussed are on going iterations with modifications each year, but it seems to be working well enough that we will continue to refine and expand the projects until we find consistent results. We are also looking for other opportunities to challenge our students, to push them to the boundary of uncertainty and build peer and mentored support to help them learn more effectively. The broader application of these principles is that we can teach new and changing competencies along with core design skills within our limited resources. In fact, the constraints are helping us develop new and useful ideas for the education of our industrial design students.

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