Extracurricular Design-Based Learning: Preparing Students for Careers in Innovation*

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Government and industry depend on educational institutions to play a pivotal role in preparing the future workforce for careers in innovation. Yet students learn how to innovate through practice, and opportunities for practice are limited in higher education. This paper addresses this challenge by presenting a new student-led approach to innovation education called Extracurricular Design-Based Learning. This model allows students to practice innovating solutions to authentic, pro-social, and local challenges in an extracurricular setting. This paper provides an overview of the model and its implementation in Design for America at Northwestern University. Findings from surveys, daily diaries, interviews, and observations suggest that students build innovation self-efficacy through successful task completion, social persuasion, and vicarious learning in communities of practice with clients, peers, industry professionals, and faculty. Further, students report achievement in learning outcomes outlined by the Accreditation Board for Engineering and Technology.

Keywords: innovation; self-efficacy; extracurricular; design-based learning

1. Introduction

Innovation supports economic and social prosperity. Government and industry depend on their employees to innovate solutions to complex challenges [1, 2]. But employees will not attempt such work if they do not believe in their abilities or do not know how to innovate. People gain confidence in their abilities and learn to innovate through practice. Government and industry expect higher education to provide opportunities for practice to prepare students for careers in innovation [5]. To support these expectations, the Accreditation Board for Engineering and Technology (ABET) requires higher education to provide opportunities to practice innovation related tasks such as solving real problems, understanding societal issues, and working in multidisciplinary teams [3]. Yet, meeting ABET criteria creates significant challenges for content-rich engineering programs, requiring costly and time consuming alterations of existing curricula [4]. Consequently, opportunities for authentic practice are limited in higher education and students are not prepared to create innovative solutions to complex challenges upon graduation [5].

In response to government and industry expectations, we sought to develop a new approach to innovation education that provides students with hands-on practice and meets ABET criteria without major alterations to existing curriculum. Such hands on practice should increase students' confidence in their ability to innovate. Extracurricular Design-Based Learning (EDBL) is student initiated and student directed learning that occurs independently of classroom expectations and responsibilities. Interdisciplinary teams of students identify authentic, pro social and local community challenges and apply the human-centered design and innovation process to develop and implement creative solutions. In this paper, we begin by describing the nature of innovation work and the role of confidence in learning innovation and related learning models. We describe EDBL's implementation in Design for America at Northwestern University and conclude with initial findings of the students' experiences.

2. Background

Innovation is defined as the intentional implementation of novel and useful processes, products, or procedures designed to benefit society applied to a new domain [1]. Examples range from technology for disaster relief to sustainable manufacturing processes. Despite anticipated benefits, innovation work can be unpredictable, controversial, and in competition with current courses of action. Innovators must develop, modify, and implement ideas

while navigating ambiguous problem contexts, overcoming setbacks, and persisting through uncertainty [6].

Historically, managerial researchers have focused on the domain expertise, creative and analytical thinking and interpersonal skills necessary to develop creative ideas for innovation work [7]. However, researchers increasingly emphasize self-efficacy, or belief in ability, as critical for innovation [8]. Self-efficacy positively influences innovation by strengthening creative performance, tendency to engage in expended effort, persistence through setbacks, and learning from failure [7, 9, 10]. Innovation self-efficacy refers to an individual's belief in his or her ability to accomplish tasks necessary to innovate. Task-specific self-efficacy is primarily developed through successful task completion or mastery experiences; however, individuals can build self-efficacy through vicarious learning and social persuasion. Individuals vicariously learn about their ability through observation of the behaviors of others who are similar or those with perceived prestige and competence. The observation becomes a guide for future action, promoting action over apprehension, and discouraging mimicking behaviors that receive negative results. Additionally, individuals build self-efficacy when persuaded by others of their ability to succeed at a given task and given supports to perform successfully [10].

Self-efficacy not only supports innovation; it supports academic motivation, retention, learning, and achievement [11]. Researchers suggest strategies for positively influencing self-efficacy in the classroom, such as fostering successful experiences for students, using peers as role models, presenting students with choices, communicating recent successes, and lowering anxiety around exams or presentations [12]. Such strategies assume an instructor-led learning environment and are included in project-based learning (PBL) and design-based learning (DBL) in the classroom. PBL is designed to prepare students for real-world work [13] and has shown considerable promise in enhancing and sustaining student motivation to learn as well as improving understanding and retention of subject matter content [14]. Related, DBL uses the process of design to engage students in authentic inquiry, initiate the learning process according to their own preferences, and construct cognitive concepts as a result of participating in design activities [15]. DBL supplies a process guideline for framing, researching, and testing solutions to novel problems.

To meet ABET criteria, educational institutions nationwide have added project and design-based learning to their formal engineering curricula. First year and capstone design classes situate learning in real-world project work and encourage application of classroom taught engineering concepts [16]. PBL and DBL are often paired with service learning (SL), or learning through community service, to expose students to contemporary issues and encourage civic responsibility [17]. These classes stand in contrast to classes which are lecture-based and content-centered rather than process-centered. Despite the success of PBL and DBL, the innovation work is often artificially constrained by academic schedules and instructor evaluations, with the former potentially limiting implementation of solutions, and the latter possibly extrinsically motivating students to generate conservative rather than risky and innovative solutions with the intention of preserving a grade. The result may be mastery experiences in project-based work rather than innovation work, inadequately preparing students for careers in innovation.

Increasingly, students themselves are demanding more real-world experience external to the classroom [18]. In response, educational institutions support situated learning through industry sponsored internships and extracurricular initiatives such as robotics competitions, solar car teams, and Engineers For a Sustainable World [16]. Situated learning allows students to apply course content to complex problems in uncertain organizational systems [19]. These initiatives are popular among students and initial assessment suggests that these initiatives positively impact skills and self-efficacy in tasks related to engineering design [20], applying technology to needs, and business venturing [21]. The authenticity of the work and ability to see how the work impacts society are critical to developing self-efficacy [2]. By expanding opportunities for practice beyond the traditional structural and temporal boundaries of higher education, students can further prepare for careers in innovation.

Extracurricular Design-Based Learning blends successful elements from project-based learning [14], design-based learning [15], service learning [17], and situated learning [19] to provide hands on practice in innovation. Students apply the human-centered design and innovation process to authentic, pro social, local community challenges. Such practice is designed to increase confidence and skills necessary for innovation work. Like PBL and DBL, EDBL leverages the student-centered elements of student interest and self-direction to motivate learning [22]. Like DBL, EDBL relies on a design process of discovery including observation, idea generation, prototyping, and testing. EDBL emphasizes insight driven through empathy with human users; however, it depends upon knowledge

being co-created by the students, peer mentors, professionals, and faculty in a non-evaluative environment over an extended timeframe. Like service learning, EDBL motivates awareness and interest in people with real needs and contemporary issues by focusing on innovating solutions to local community challenges. By working locally, students gain in-depth knowledge of complex societal challenges and regularly test prototypes in context, receiving authentic feedback from community partners. EDBL emphasizes innovative solution generation, testing, and implementation often deemed too challenging to achieve in the 10–16 week time frame of course instruction. Through testing and implementation, students engage in situated learning, applying course content to complex problems in uncertain organizational systems. Unlike traditional classroom learning, EDBL's community of practice expands beyond the physical boundaries of the undergraduate engineering community to include local experienced professionals and local clients, as shown in Fig. 1. The experience continues beyond the temporal boundaries of student life as they can remain participating in projects as alumni. Participation is voluntary and motivated by a passion to solve a particular societal challenge. Due to the extracurricular nature of EDBL, projects conclude when ideas are implemented, rather than when the academic term ends.

Extracurricular Design-Based Learning was examined in the context of Design for America (DFA) at Northwestern University (NU). DFA is a nationwide network of extracurricular and interdisciplinary student-led studios anchored in universities. DFA aims to foster students' beliefs in their ability to use the human centered design and innovation process to create social impact through the implementation of innovative solutions. DFA at NU sponsors three studios: School Year Studio, Summer Studio, and Leadership Studio. Normally, students research and develop solutions during the intensive six-week Summer Studio and implement the solutions during the School Year Studio. An individual student typically commits approximately

150 hours to the School Year Studio and 240 hours to the Summer Studio per year. With the exception of approximately 24 hours of professional coaching during Summer Studio, student leaders manage and direct their own studio work addressing client-described needs. Faculty, staff, and professional coaches are available for student-initiated consultation during Summer and School Year Studios. Student leaders teach the human-centered design and innovation process to newer students by facilitating the observation of users in context, ideating and prototyping solutions, and testing with real-world users. They work in teams to solve challenges such as healthcare, education, and the environment for local clients. Design challenges include reducing hospital-acquired infections and reducing water waste in institutional cafeterias. During the annual 4-day Leadership Studio, experienced student leaders train new student leaders in studio management and leadership.

3. Method

To understand the experience of EDBL as implemented in DFA, we used a non-experimental, single group research design. Following Dunlap's approach to examining changes in self-efficacy during project-based learning [23], we examined the process of change by collecting baseline data before the study began. We then took a time series approach to collecting data throughout the six week Summer Studio via daily questionnaires and observations to changes in the experience over time. This combination of data was used to answer the following question: Does EDBL influence students' beliefs in their ability to complete innovation related tasks and ABET outcomes and, if so, how?

3.1 Data sources

We focused our data collection on the 13 participants (five women) in the DFA Summer Studio 2010 at Northwestern University that included nine students majoring in science, technology, engineering, and math related disciplines and four majoring in
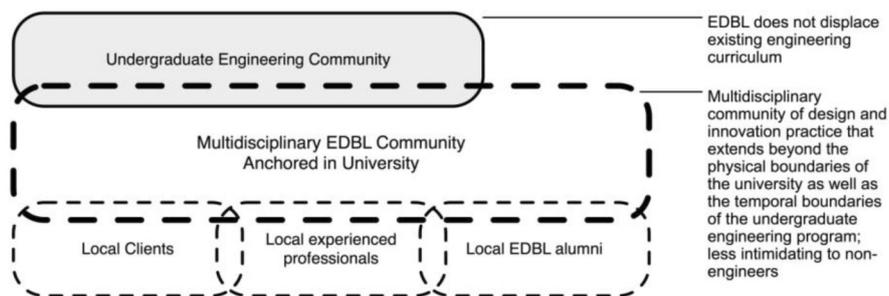

Fig. 1. EDBL's Community of Practice Anchored by University Sponsor.

the behavioral sciences. Grade level ranged from freshmen to senior. Data was collected from multiple sources to inform our inferences and to avoid the potential problem of construct validity within a single case [24]. The findings were supported by the convergence of multiple, independent sources. These sources can be divided into four categories: semi-structured interviews, daily questionnaires, pre-post surveys, and observations of day-to-day activities and client engagements.

Semi-structured interviews. Students participated in a one-on-one 45 minute interview at the end of the program and were asked about their initial perceptions of DFA; which experiences were most influential; beliefs about their ability to innovate; what benefit, if any, was realized after participation; how the experience affected future plans, if at all; and how DFA compared to their classroom experiences.

Daily questionnaires. To obtain daily reports of the student experience, we employed an Electronic Event Sampling Methodology [25] that involved electronically administrating a daily questionnaire through the entire course of the program. Each student was asked to reflect on his beliefs about his ability to innovate and on the related events that influenced these beliefs. Twelve of thirteen students completed daily diary reflections for the six-week period. Average response rate was 72%. Participants were compensated 50–75 dollars based on their frequency of completion. The questionnaire served as both a means for data collection as well as a daily reflection tool.

Pre and post surveys. Pre and post surveys captured self-reported data on innovation self-efficacy and satisfaction with and effort expended during Summer Studio. All students completed pre-post surveys, taking approximately 20 minutes to complete 112 discrete questions. On the pre-post surveys, we collected measures of innovation self-efficacy, altering Carberry and colleagues' measure of engineering design self-efficacy to emphasize innovation [26]. One example of an altered task was 'develop innovative design solutions' instead of 'develop design solutions.' Because innovation involves unique insight and implementation in a team and not just generation of the concept, tasks were added to the measure, such as these: take the perspective of the person(s) expressing the need, determine an implementation plan for the solution, use the design process to achieve a successful outcome, and work with a team to achieve a successful outcome. Additionally, surveys captured data on individual factors that could be expected to affect innovation self-efficacy and group interactions,

such as gender, age, race, program satisfaction, personality type, and team satisfaction. For these factors, we found no differences among individuals on responses.

Because the first and second authors were involved in developing the DFA initiative, the third author (who had no previous ties with DFA) administered all interviews and daily questionnaires. Data collection included 60 hours of observing the day-to-day activity of the students and coaches; 15 hours observing client engagements; and ten hours of interviews resulting in 150 pages of verbal transcriptions.

3.2 Data analysis

To understand if EDBL, as implemented in DFA, influenced students' beliefs in their ability to complete innovation related tasks, we conducted paired t-tests of the difference (D) between normalized pre and post measures of innovation self-efficacy. To understand how beliefs were fostered and whether ABET outcomes were achieved, we followed Miles and Huberman's [27] recommendations for qualitative data analysis. We reviewed all data and coded and clustered processes, events, and learning design elements in search of patterns and themes regarding participants' emergent beliefs in their ability to innovate and ABET outcomes. Our initial findings result from our iterative process of moving between inductive and deductive thinking, using the strength of the evidence to inform whether we should maintain, modify, or abandon our inferences.

4. Findings

Initial findings suggest that participation in EDBL, as implemented in DFA, strengthens self-efficacy in innovation related tasks. Pre and post surveys showed statistically significant gains in the following tasks: beliefs in their ability to identify a design need ($D = 12.3$, $p < 0.01$); research a design need ($D = 15.4$, $p < 0.01$); take the perspective of someone expressing the need ($D = 6.1$, $p < 0.10$); conduct design work ($D = 16.9$, $p < 0.01$); develop innovative design solutions ($D = 12.3$, $p < 0.01$); construct a prototype ($D = 6.9$, $p < 0.10$); evaluate and test a design ($D = 13.1$, $p < 0.10$); select the best possible design ($D = 19.2$, $p < 0.01$); use the design process to achieve a successful outcome ($D = 15.0$, $p < 0.01$); and work with a team to achieve a successful outcome ($D = 6.6$, $p < 0.05$). While beliefs in their ability to understand the systematic implications for the design solutions and determine an implementation plan increased over time, the results were not statistically significant.

4.1 Sources of self-efficacy

Initial findings suggest that students who participated in EDBL, as implemented in DFA, developed innovation self-efficacy through mastery experiences, vicarious learning, and social persuasion [10].

Mastery experiences. Students gained hands on experience completing innovation tasks. Successful completion fostered innovation self-efficacy. A student explains, '[Before my DFA experience] I had very little hands on experience in terms of drafting ideas and getting them out there and putting them into action . . . [now] I feel more confident.' His teammate describes how hands on experience influenced his confidence, ability, and perspective on innovation. '[DFA has changed] how I look at problems . . . you experience the act of creating a solution. Because of that, I now look at problems and want to create a solution for them because I know it's possible. Whereas before I was always like complaining about something and never really thinking, wait, there could be a solution. I guess it's automatic now.' This response suggests that mastery experiences supports beliefs in ability and motivates engagement in similar tasks in the future.

Through DFA, students engaged in a diverse set of tasks related to innovation. Via brief weekly coaching sessions, professional coaches and student leaders taught students how to identify a design need; research a need; ideate and prototype solutions; and evaluate and implement solutions. Students requested guidance when challenged to perform these tasks successfully. A student explains, 'I learned to grasp a problem . . . enough to create a solution. It was the first time I actually went about doing first hand research . . . I analyzed a full system without any . . . well, there was guidance, but it was all us. So that's why it was valuable.' By doing the work independently, he was able to attribute success to his own actions. Another student commented on how the extracurricular nature of DFA was intrinsically motivating. 'Learning how to do something when there's not a teacher breathing down your neck telling you to get this report in . . .there's no one breathing down your neck but it needs to get done so it's a personal investment in the success or lack of.' From these responses, we can infer the importance of students feeling independent yet supported and intrinsically motivated when engaged in extracurricular innovation work.

Vicarious learning. The data suggests that students developed innovation self-efficacy in communities of practice of peers and professional designers as they engaged in innovation related tasks. One important characteristic of a community of practice is the involvement in a process of collective learning [19]. Students observed and listened to their peers as they engaged in think-aloud protocols about their reasoning, framing, and problem-solving. A student noted, 'I think a lot of what I've learned through DFA is through other people . . . There are a lot of people who know stuff that is not being taught in classes, and it's almost more valuable than the stuff being taught in classes.' A student cited seeing the success of her peers in creating and implementing hand hygiene solutions during the School Year Studio as a reason for joining DFA Summer Studio. 'I see problems as being able to be solved . . . [They] inspired me because you do all your uncomfortable things here then you start to become more comfortable with your own skills, so I guess it inspires you just to go for things.' Consistent with prior research [10], the similarity of the observer and model influences the extent to which students develop self-efficacy through vicarious learning. While peer-to-peer learning was effective, students also developed confidence when observing design professionals engage in innovation related tasks such as understanding client constraints—an area in which the student leaders' experiences were limited. A student describes her response to an advising session with a professional designer. 'Yesterday, we talked with [George] who gave us insights into the design process. What was especially helpful were the ways he mapped out the components and the picture of the problem, as well as how everything was broken down.' This and similar engagements were driven by a specific request for advice from a student at a given phase in the project.

Students chose to use techniques that they felt were valuable and abandoned non-useful techniques. A student describes two demonstrations given by experienced professionals. 'We started brainstorming and were given two different approaches by two different design coaches. [Ben] tried to organize our brainstorm by doing two-by-two's . . . meanwhile, [Claire] had us make a list of potential audience targets, and then brainstorm ideas around them . . . we ended up going with [Claire's] approach because it let us lay down our ideas faster . . . I'm confident we will be able to deliver something tangible by the end of six weeks.' Exposure to different practices from working practitioners and development of one's own innovation practice appears to contribute to beliefs in ability. From these examples, we can infer that students gained confidence in their ability to innovate through vicarious learning from peers and professionals in their community of practice.

Social persuasion. Social persuasion occurred through regular feedback sessions. Such sessions regularly occurred because stakeholders were local

and students could regularly visit and share their recent work. The feedback not only provided useful information for revisions but also built confidence in the student's ability. A student reported, 'Based on the results we are seeing, it [our solution] really has had an impact . . . it was nice to get positive feedback. It certainly made me more confident . . . I think part of it is just knowing that I am capable of things such as this . . . it is really cool to see it come to fruition.' A student reiterated the importance of client feedback, '[Our client] really liked the game idea and gave us more confidence that we would be able to move forward with it.' Consistent with previous research, feedback allows people to attribute success to their action and motivate future action—increasingly the likelihood of successful performance [10].

Once the project was underway, the student leaders encouraged their teams to share their progress frequently with users, clients, design professionals, and other teams. Frequent feedback allowed students to either adjust their approach or adapt the goals of the project to achieve the desired outcomes [28]. The intent was to allow them to realign their expectations with those of the stakeholders, and preserve their interest and positive orientation towards the project. A student reported the importance of talking to users. 'Once the parents [of the users of the client system] heard about our project, they were incredibly excited and urged us to move forward. It is reciprocal.' A week later, the same student reported, 'We had a phone call with [Doug] . . . he heads up User Experience at [Fortune 500 company]. A pretty big guy. He was like, 'Guys, you're still doing this, right? It was a cool idea. I want to make sure that this is real.' Yeah, we still have believers. We can do this.' Students retained a realistic perspective about the feedback that they received during the process, however. A student reported, 'Although our client was excited about the idea of making the school into a game, our client is a school. Of course they are going to be excited about an educational game.'

Social persuasion was not limited to clients and professionals. Experienced students enforced guidelines for group work based on professional practice. They modified the guidelines and posted them on the wall. The guidelines helped to promote mutually supportive intra-team behaviors as well. A student reported, 'I love our brainstorming sessions where we build on each other's ideas. It validates your design skills to have teammates build on your ideas. My biggest hurdle in becoming a contributing factor for the team is getting over the fear of not having good contributions. They definitely help . . . [team members] would say, 'yeah, that is a great idea' and after that it continues to grow and you get more

confidence.' A student compared his DFA experience with his traditional classes and how the lack of positive persuasion from non-DFA students inhibits his creativity outside of DFA. He commented, '[In class] I was brainstorming with a group . . .you were always worried about what you were going to say. You say something and they're like, 'oh, that's stupid' or 'that's lame.' There is a lot of judgment in the system. It's like we're trying to get to a solution as quickly as possible . . . they just wanted to get it done already.' Extracurricular non-competitive learning appears to support a safe culture for students to share and develop ideas. Students reported being greatly affected by praise, encouragement, and feedback given to them by their teammates, professionals, and clients indicating an increase in student belief in their abilities to complete their projects suggesting an effect of social persuasion on innovation self-efficacy.

4.2 ABET outcomes

Initial evidence suggests that EDBL as implemented in DFA supports the following ABET outcomes: identify, formulate, and solve engineering problems; function on a multidisciplinary team; communicate effectively; and attain knowledge of contemporary issues.

Solving engineering problems. Students learned how to identify, formulate, and solve problems by engaging in user-centered research at the beginning of the design process, by gaining knowledge/confidence that finding a solution is possible, and by communicating to identify client needs. Comparing her PBL classroom experience to DFA, a student explained her active role in identifying, formulating, and solving the problem. '[The first year design class] handed us the problem on a platter and told us 'here is what the problem is and you have to figure it out.' In DFA, you have to find out what the problem is regardless of what the client says the problem is.'

Multidisciplinary teamwork. Students learned about themselves and how to function on a team by working with students from different majors and different approaches to work. A student reported, 'It's been incredible working with very different thinkers . . . I'm realizing more and more how much of a logical thinker I am and so to be confronted with people who are coming at it in a more visual or physical way . . . I think being aware of those different approaches and being really frustrated by what feels like unproductivity, but it's just a different timing, a different speed . . . to trust that it will get done in a very different way and, I think, in a rich and more well-rounded way.' Students learned not only about

different problem solving approaches but also about motivation. 'This summer's takeaway was that if you put the right people together, and you put them through the right process, you will have something interesting in the end. No problem can change that.'

Communicate effectively. By working with interdisciplinary teammates and clients, students learned to communicate effectively. To understand the problem and gain client support for solutions, students managed the client relationships, and learned to ask questions and present to clients. A student reported, 'You're put into a position where you have to deal with people. You don't deal with people in the classroom, you deal with books. You're actually interacting with the people. You're prodding them with questions.' Students frequently requested advice from professional coaches about understanding clients and how to communicate sensitive information.

Attain knowledge of contemporary issues. Students developed knowledge of contemporary issues by working closely with local community partners. When meeting with a tour guide at a home for mentally challenged adults, a student reported, 'Our tour guide told us an emotional story [about the residents] that brought her and us near to tears. That emotional response . . . is the light you see in both volunteers and worker's eyes, which is something we need to be able to capture somehow in the [solution].' In addition to knowledge of contemporary issues, students also develop empathy for those who experience the issues first hand.

5. Discussion

The National Academy of Engineering [29] and the National Science Board [5] have challenged engineering educators to transform engineering education to meet global demands for innovation. This study suggests that EDBL may help to meet those challenges by offering learning opportunities outside of the traditional classroom and designing learning experiences that foster both the skills and confidence necessary for innovation work while reducing the need to overload existing engineering curricula. As implemented in DFA, EDBL positively influenced students' beliefs in their ability to innovate and achieve ABET outcomes through hands on practice. Such confidence and skills influence the persistence, creativity, and self-directed learning necessary for innovation work.

EDBL's service-learning focus engages students in the investigation of authentic community needs and is an enhancement to, but not a replacement for,

classroom experiences [17]. EDBL captures the benefits of student-centered learning, such as increasing students' interest as well as their motivation to participate in self-directed learning, It encourages them to adapt to change, think critically, and work collaboratively since students select and scope their own problems [14, 15, 22]. EDBL also takes advantage of the benefits conferred by a community of practice, such as a sense of shared identity around the learning and joint enterprise, building relationships to assist in learning, and the development of a self-organizing capacity that sustains it in the absence of a formally-recognized instructor [19]. Finally, EDBL's attraction to a diverse set of majors allows engineers to gain a multi-lens perspective on complex problems. This experience revises the perspective that non-engineers have of the engineering sciences and the impact of the engineering sciences on complex societal problems such as improving health and the environment.

6. Conclusion

In response to a call for new models of innovation education from industry, government, and students, this paper presented Extracurricular Design-Based Learning. Initial evidence suggests that the model positively influences students' skills and beliefs in ability in innovation related tasks. Future work will consider how participation in a multi-year program influences innovation self-efficacy, performance in innovation careers, and how self-selection influences learning outcomes in an extracurricular setting. Self-selection allows for participants with similar motivations for socially oriented project-based work to influence each other through social persuasion. The EDBL experience rewards those who seek out this development experience through higher visibility within the university community, with faculty, and with experienced design professionals, as well as access to challenging and interesting projects for portfolio building—elements that may also support students' motivation to seek careers in innovation.

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