Leveraging a Pre-collegiate Innovation Competition to Integrate Entrepreneurial Concepts in Capstone Design Projects

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Engineering Capstone Design programs can serve as highly effective venues for integration of entrepreneurship-related concepts. Toward this end, the University of Idaho has successfully piloted an integration between a statewide pre-collegiate invention competition with the undergraduate engineering capstone design program to enhance innovation and development of students' entrepreneurial mind set. In 2021, a trial run of this collaboration was piloted, with undergraduate students mentoring young inventors via Zoom. One of the invention ideas (from a 7th grade participant) was converted to a capstone project, resulting in a functional prototype and formal Invention Disclosure. Follow-up surveys indicated positive impacts from the mentoring process, while the capstone project enabled students to position themselves as a startup venture. This unique process enables all participants to engage their entrepreneurial spirit, regardless of their socioeconomic backgrounds.

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Introduction

Engineering Capstone Design programs can serve as highly effective venues for integration of entrepreneurship-related learning outcomes[1-6]. Especially since the capstone experience is often the first opportunity for students to take ownership of their design projects. Since it is recognized that entrepreneurship skills will be highly valuable for engineering leaders of the future[1-4,7], many programs have formally integrated entrepreneurship concepts into their capstone curriculums[1-6].

Through the Interdisciplinary Capstone Design program at the U of I, student teams from multiple engineering disciplines execute product development projects over a two-semester course sequence. Most projects are financed by industrial partners or internal university faculty, with the goal for student teams to design, build, and validate a functional prototype of their design. While these projects provide highly effective educational experiences, the opportunity for students to develop their "entrepreneurial mind set"[2] on sponsor-driven projects is relatively limited.

Simultaneously, the statewide Invent Idaho[8] program is offered to grade 1-12 children throughout the state of Idaho. The program is an extracurricular student competition for pre-collegiate students to create novel inventions and pitch their ideas via poster and prototype presentations. Participating students (~2000 each year) initially compete within their local school networks, with stronger ideas progressively advancing to regional and statewide competitions throughout the school year. Top competitors (20-25 annually) are invited to participate in the National Invention Convention each spring. Unfortunately, there are limited resources and opportunities for students to continue developing their novel ideas beyond this point, and the young inventors typically lack the engineering expertise to advance the idea on their own.

The objective of this manuscript is to outline an initiative to establish a sustainable synergy with the statewide Invent Idaho competition to create a pipeline of innovative capstone projects and provide mutually beneficial educational experiences. The program is successfully piloted, including completion of a collaborative capstone design project with a pre-collegiate inventor.

Methodology

The following sections describe the vision for integrating two existing programs involving both precollegiate Invent Idaho participants and undergraduate (UG) engineering students. The protocol described below was piloted in 2021 and is envisioned to continue annually.

Invent Idaho Mentoring

Engagement between Invent Idaho and the U of I begins following the regional Invent Idaho competitions in January (Fig. 1). Through the judging process facilitated by Invent Idaho, participants with strong, high potential

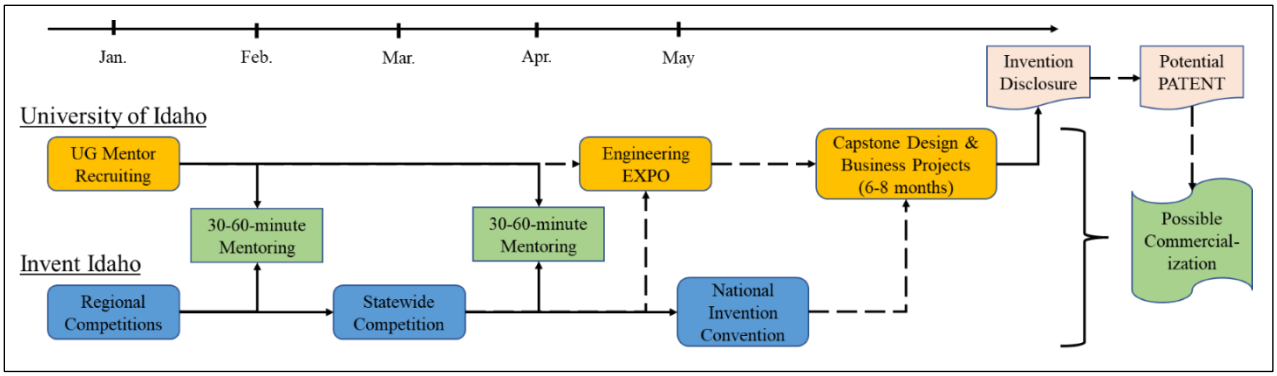

Figure 1. Illustration of program integration. U of I undergraduate students mentor grade 1-12 Invent Idaho participants during the Spring semester, creating a pipeline for capstone project inventions and potential commercialization of new products.

ideas are invited to continue onto the statewide competition in March. Continuing participants with mechanical or electromechanical invention ideas are selected and sent a formal invitation (from the Director of Invent Idaho) for optional mentoring with U of I mentors. In parallel, volunteer UG students in the junior level design class in mechanical engineering are recruited to serve as mentors for the Invent Idaho participants. The volunteer mentors are provided with basic training on coaching techniques, protocols for capstone design projects, and commercialization strategies. The primary purpose of the mentorship is to provide encouragement to the young inventors, provide feedback on likely feasibility of the invention ideas, facilitate brainstorming to enhance their inventions, and assist the inventors with articulating the value proposition for their invention idea.

For all participants, a U of I instructor facilitates a mentoring session via Zoom between each young inventor and an UG mentor. During this session, the inventor presents the motivation for their idea, discusses the progress they have made so far, and asks for advice. At the same time, mentors ask open-ended questions to help the inventor discover potential ideas to improve upon the current state and enhance their product pitch. If appropriate, UG mentors are allowed to assist with simple 3D printing or laser cutting to help with basic prototyping. Following the statewide Invent Idaho competition in March, some participants advancing to the National Invention Convention are invited to present their invention ideas at the Annual Engineering Design EXPO on the U of I campus, showcasing their projects adjacent to current capstone design presentations.

Transition to Capstone Design

After the Invent Idaho cycle has concluded, a team of 8 interdisciplinary capstone instructors review each invention idea and selects candidates for conversion to capstone design projects. Team formation for capstone projects involves three fundamental phases: a) introduction of project options to students, b) students "bidding" for their project preferences, and c) faculty assignment of the project teams using student preferences. The projects are formally "pitched" to the students via a Project Fair format[9]. Following introduction, each student identifies their project preferences, which informs assignment of project teams by the capstone faculty. Simultaneously, student teams in the Entrepreneurship course within the U of I's College of Business are assigned following a similar format. These teams will advance the product pitch, compete in regional pitch competitions, and draft a preliminary business plan for the potential new product. Throughout the entire capstone project, the original inventor adopts the role of "client" for the project, participating in formal design reviews and presentations along the way.

Results

In 2021, a trial run of this collaboration was piloted, with remarkable success. Several Invent Idaho participants were matched with UG design students for mentoring over Zoom. Subsequently, one of the Invent Idaho participants (7th grade) presented their invention (a novel tree planting device) at the Annual Engineering Design EXPO on the U of I campus. This idea was then converted to a UG capstone design project beginning June 2021.

Undergraduate mentoring of participants

Following the Invent Idaho regional competitions in January 2021, several participants were selected and invited to be paired with an UG mentor through coordination with the Invent Idaho Director. Selection of ideas was focused on inventions that were perceived to be more electromechanical in nature and would likely be a good fit with the skill sets of the UG mentors. Of the 13 invited participants, 10 pre-collegiate inventors within grades 5-8 accepted the opportunity. Seven out of the 10 pre-collegiate participants were female.

At the same time, volunteer UG mentors were recruited in the junior-level design class, with a total of 13 students (~20% of the class) agreeing to participate in mentoring. The Invent Idaho participants and the UG mentors were paired based on coordinated time availability, while additional effort was made to match female participants with female UG mentors. Through coordination and email communication with parents, a total of 10 mentoring sessions ranging 30-60 minutes long were conducted via Zoom between the Invent Idaho participants and the UG students. Discussion topics included design ideas, product messaging and pitch, and potential applications for the invention. In one case, an UG mentor did follow up work to model and 3D-print a prototype component to assist an inventor with visualization of their idea. Through follow up surveys, participants on both sides expressed positive feedback from the experience.

Pilot Capstone Project

At the conclusion of the Invent Idaho competitions, one idea was selected for transition to a Capstone Design project. The idea was a novel tree planting device for high volume planting of trees for reforestation purposes. Selection was based on the perceived high potential of the novel idea and the expected scope that would fit well within a single capstone sequence. An interdisciplinary team with mechanical engineering and materials science students was assigned to the project, while the young inventor was positioned as the "client" for the project. At the onset of the project, the capstone design team was charged to envision themselves as a start-up company developing a new product for the market. The team was given a budget of $500.

While the capstone team was given autonomy to define their own direction, the young inventor was a periodic participant in the project. In particular, the inventor attended key milestone events including the kickoff meeting, formal design reviews, and presentations, providing input and perspective from their own learning experiences. The project concluded in December 2021 with a fully functional prototype and a formal Invention Disclosure submitted to the Office of Technology Transfer (OTT), and it has already gained interest from the USDA Forest Service as a future tool for reforestation.

Discussion

The Invent Idaho program is an open competition that limits participant investment to less than $25, ensuring that any young inventors may participate regardless of economic or social status. Plus, the potential for young inventor ideas to become capstone projects and eventual commercial products creates an opportunity that is not readily available to kids today (to the authors' knowledge). Furthermore, UG mentors participate voluntarily, and all capstone teams are selected based on student preferences. As a result, the entire process empowers young inventors and students to control the outcomes through their own entrepreneurial spirit.

Mentoring Relationship

Based on limited feedback from follow-up surveys, the mentoring phase of the process appears to be mutually beneficial for both the pre-collegiate inventors and the UG mentors. On the pre-collegiate side, young students receive engineering-based coaching and assistance with realization of their ideas, which was previously not available to them. Invent Idaho participants consistently indicated that they benefitted from the mentoring, learning more about how to develop and pitch ideas and the overall product development process. Participants also indicated an increase in confidence and belief that they can make a difference through developing new solutions. They also consistently stated that they valued the experience and had an increased interest in STEM and entrepreneurship as a result of the mentoring.

Similarly, UG mentors indicated a clear benefit from the mentoring experience, also citing an increase in confidence in their own ideas and skills. They also indicated that the process would have a long-term positive impact on their leadership skill development. In particular, they were able to practice active listening skills and apply their own skills and knowledge to help others grow and succeed. Through integrating these programs, new opportunities have been created for students to engage in experiential learning at multiple levels while aiding the transition from an academic exercise to a real-world entrepreneurial experience.

Capstone Project Opportunities

At the conclusion of the Invent Idaho competitions, most pre-collegiate participants do not have the resources or expertise to continue with product development. Therefore, the potential for the invention idea to be converted to a capstone project offers a unique opportunity. For the young inventors, adoption by the university provides the impetus to keep going and enables the inventor to collaborate with engineering students that have stronger design skills sets. Through this effort, it is expected that the invention idea may climb several stages on the technical readiness level spectrum. In addition to the innovation benefits, the inventor is also enabled to shadow a capstone design team, witnessing the engineering process while having direct input into the product development.

For the UG students, the team is enabled to position themselves as a startup venture and define their own path.

Using the available resources at the university, the team is free to develop a minimum viable product to enable more systematic evaluation of the idea, while being empowered to enhance their entrepreneurial mind set. In fact, it is conceivable that an UG student could both serve as a Invent Idaho mentor as a junior, then proceed on the same project as a senior in capstone design.

In addition, conversion to a capstone design project further enables integration with entrepreneurship students from the College of business, simultaneously. These students can apply their skills in parallel to conduct more directed customer research, develop a foundational business plan, and potentially compete in pitch competition to raise additional seed funding.

Final Ownership and Commercialization

At the conclusion of each capstone project, an Invention Disclosure is submitted to the OTT for evaluation of patentability. At this point, the U of I assumes ownership of the intellectual property created by the UG capstone students and reserves the right to patent the design. If a patent application is pursued, it is important to coordinate closely with the OTT to successfully manage the timing between any disclosure of the invention idea throughout the process and the actual patent application.

The mechanism for commercializing the design is through a licensing agreement with an industry business partner. With licensing fees closely tied to sales, royalties from the university are dispersed to each inventor based on the relative contributions identified on the original Invention Disclosure. Through this process, it is possible for a pre-collegiate child to: 1) conceive an idea for an invention, 2) compete in Invent Idaho, 3) participate as a "client" on a capstone project, 4) be named on a patent, and 5) generate tangible revenue via royalties. All of this is possible without any financial risk to the original inventor, making programmatic success possible for any child, regardless of socioeconomic status.

Conclusions

The University of Idaho has successfully piloted an integration between a statewide pre-collegiate invention competition with the undergraduate engineering capstone design program. Some key reflections from the experience include:

- Undergraduate mentoring of pre-collegiate participants was mutually beneficial for both the Invent Idaho participants and the undergraduate student mentors.
- Transitioning an invention idea from the Invent Idaho program is viable, offering unique skill development for pre-collegiate, UG engineering, and UG business/entrepreneurship students.
- When pursuing a patent for commercialization, the timing of public disclosure must be very closely managed through each phase of the process.

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