DESIGN DAYS BOOT CAMP: ENHANCING STUDENT MOTIVATION TO START THINKING IN ENGINEERING DESIGN TERMS IN THE FIRST YEAR

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Abstract – Engineering design is a core aspect of engineering education. Students might not appreciate the importance of engineering design early on, especially in the first term of their academic study. In this paper, we propose an approach for motivating students to think early about engineering design, namely at the start of their first academic term. The approach entails organizing an immersive design boot camp – “Design Days” – that replaces lectures for the first two days of the term. During the two days, students are divided into randomly assigned teams, and provided specifications to work on a design challenge. As part of the challenge, students are incentivized to fully understand the problem before attempting to solve it, instructed to follow a design process and apply iterative design, and asked to document their design and its rationale. The proposed method was successfully applied in Fall 2016. The approach will be applied again in Fall 2017 with minor modifications based on student feedback.

Keywords: Engineering Design, Enhancing Learning Experience, Collaborative Learning, Engineering Design Boot Camp, Hands-On Introduction to Iterative Design

1. INTRODUCTION

Engineering design is a core aspect of education provided to students in engineering. In the Systems Design Engineering (SYDE) program, students learn about design methodologies and design thinking, and then apply the learned concepts through projects inside and outside the classroom from their first year onwards. As observed in previously published research, teaching students about design can be quite a challenge [1, 2]. Students might not appreciate the importance of engineering design early on, especially in the first term of their academic study. In addition, as they develop knowledge in engineering science, they might not recognize the importance of fully understanding the problem before attempting to solve it, the significance of iterative design, the need to identify and follow a design process, and the importance of teamwork and communication. Engineering design instructors may choose to emphasize these concepts early on in student development to ensure that students follow adequate design techniques for the entirety of their undergraduate careers, and to make study and practice of engineering design a lifelong learning goal.

In previous years, to introduce students to design and prototyping, a small design activity of approximately 90 minutes in length was presented to students in their first day of class. While the students enjoyed the activity, the connection between the activity and the various aspects of design was not obvious, and it also did not allow for other instructors to participate nor to link to courses that students would be taking in their first year. Building on this experience and to further motivate students to think early about engineering design, a new approach was taken where students would be fully immersed in a design boot camp – “Design Days” – that replaced lectures for the first two days of the term.

The proposed method was applied in Fall 2016 to first-year Systems Design Engineering and Biomedical Engineering students. Students were assigned to work on the challenge for the full two days, and the results were evaluated by the facilitators during and at the end of the two days. After the activity, student feedback was collected, and the results of the feedback suggested improved enthusiasm for engineering design and verbalized appreciation of related concepts. In addition, course instructors of engineering design and engineering science courses noted increased engagement among students in comparison to previous terms when this method was not applied. The approach will be applied again in Fall 2017 with minor modifications based on student feedback.

The rest of this paper is organized as follows: in Section 2, we introduce our Design Days approach, explain different stages, provide a timeline for administration and integration into curriculum, describe the results of the pilot application in Fall 2016, and indicate what changes are planned for the next iteration in Fall 2017. Finally, in Section 3, we provide summary and conclusions.
2. DESIGN DAYS BOOT CAMP

Our motivation for introducing an approach such as Design Days into the curriculum was based on our previous experience with the short design activity and the work by Ambrose et al. on “How Learning Works” [3]. In their work, Ambrose and co-authors discuss the effects of environment, value, and efficacy on student motivation for learning. They indicate that for students to be motivated to learn, the following aspects are important:

- **Students’ environment is supportive:** Students see the learning environment as supportive of their learning. For instance, students see their instructors or teaching assistants as approachable, and they see their peers as available to support them during the learning process. If the environment is not supportive, students may feel hopeless, reject or evade instruction methods, or act in defiance of the instructions given to them.

- **Students see value in content:** Students see value and importance in the material being taught. For example, this value could pertain to attainment value, such as the satisfaction gained through mastery or accomplishment of a goal. If students do not see value in the material being taught, they may reject or evade instruction methods.

- **Student efficacy is high:** Students are confident about their abilities to achieve set learning goals. If students do not feel confident, they may feel hopeless or fragile, or they may reject instruction methods.

    Offering the design boot camp as the first experience for students would allow us to introduce students to design methodologies while also addressing all three dimensions of student motivation – environment, value, and efficacy, as early as possible.

    The inspiration for conducting a design boot camp came from hackathon-like events in which students participate to learn about new technologies. These events are fully immersive and outside distractions are limited, usually span more than one day, and students are asked to produce specific deliverables by the end.

    We decided to enhance the hackathon model with a more structured engineering design process, and asked students to do the following:

    - **Understand the problem before trying to solve it.** Before attempting to design a solution for a problem, we asked students to spend time better understanding the problem, and better identifying requirements and constraints for potential solutions. Furthermore, students were encouraged to consider multiple options before selecting the best prototype.

    - **Follow a design process and apply iterative design.** As students were designing a solution that fits identified requirements and constraints, we asked them to follow a design process where application of specific techniques or tools is not random, where adequate analysis is performed before specific design decisions are made, and where rationale for design decisions is documented. We also asked students to create solution prototypes iteratively, where the performance of a solution is improved on systematically and through iterations (e.g., low-fidelity, medium-fidelity, and high-fidelity prototypes).

    - **Ensure communication among team members.** While students are working on their design solutions in teams, we asked them to keep a logbook of design decisions made, design analysis performed, and rationale for prototype iteration. We also created situations where some team members were not available for periods of time, so that the logbook becomes means for them to keep track and become informed of progress on project deliverables.

      Based on the objectives above, we decided to create an engineering design challenge, and conduct this challenge as a boot camp.

      To ensure that the environment is supportive, we decided to have engineering design instructors and teaching assistants for the related first-year courses present to help students with their design and ensure safety of the activities performed. To ensure that students would see value in the activity, we communicated to them how the activity connects to engineering science courses in their first term (e.g., physics, mathematics).

      Moreover, we decided to gamify the challenge and have students compete as teams in three challenges related to different aspects of engineering design, such as accuracy and precision. To ensure high student efficacy, we chose a design challenge so that it does not require specific prior knowledge of engineering science, and so that new first-year students feel they are capable of solving it.

      As supporting activities, to reinforce safety practices and introduce students to working in an engineering machine shop, we included sessions on machine shop orientation and machining of a simple metal part.

      Given the anticipated number of students, complexity of the design challenge, and space and time required in the machine shop, we scheduled the activity over two days; hence, the name, Design Days.

      To minimize external distractions and ensure that the boot camp is an immersive experience, with support from our department and faculty, we postponed all classes for the duration of Design Days until the following week.
In the sections below, we explain different stages of Design Days planning, scheduling, and execution; this will be based on our pilot study conducted in Fall 2016. In an attempt to formalize Design Days, we have specified individual steps of the approach as a Unified Modeling Language (UML) Activity Diagram; see Fig. 1. As comments of the model, we have provided recommended timeline for the activity implementation.

2.1. Design Days Boot Camp: Planning Stage

During the planning stage, the main objectives were to:

1. Establish learning objectives and plan related activities: The learning objectives should be integrated within the objectives of the program of study, student level and prior knowledge (e.g., first term or later, prior courses taken), and identified areas for improvement (e.g., aligned with Canadian Engineering Accreditation Board (CEAB) attributes).

Given that this activity is crucial and precursor to many others, for the pilot implementation, we recommend that this activity be completed at least one full term ahead of the term selected for Design Days (e.g., it should be completed in the Winter term if Design Days will be held in the Fall term).

In our pilot study, we focused on the following learning objectives:

i. students demonstrating an understanding of their program of study and related courses, resources, faculty and teaching assistants, and traditions within the department or faculty;

ii. students showing a sense of community within their program, the department, and the faculty;

iii. students demonstrating an understanding of how design and technical courses are related as part of the program;

iv. students being able to explain the importance of safety during design activities and recognize important safety standards;

v. students using common machining tools in a machine shop setting; and

vi. students producing a design solution for a specified problem in a team-based setting by understanding the problem before trying to solve it, following a design process and applying iterative design, and ensuring communication among team members.

To support the above learning objectives, we included the following learning activities:

a) Design Days Challenge: The challenge was based on a similar activity administered by the IMechE in the United Kingdom [4]. The activity includes student building a device that launches a plastic golf ball or another projectile with a light-weight line attached to it over meaningful distances with both accuracy and precision. The challenge simulates practical situations, such as nautical settings, where lines are deployed from ship to ship or from ship to shore; or in river crossing, where lines are suspended across large rivers to start deploying bridges.

Successful launcher design would provide means for sufficient mechanical potential energy to be stored, controlled release of mechanical potential energy and conversion into adequate kinetic energy, and accurate and precise aiming of the projectile motion. The challenge was specifically chosen since it used concepts of mechanical potential energy and kinetic energy that are related to engineering science courses – physics specifically – that students take in their first year.

To complete their design, students were assigned to work in large teams of approximately 12 students per team. Challenges associated with the large team size were addressed by asking students to form smaller sub teams to tackle different aspects of the problem. Students from the two programs offered by Systems Design Engineering – Systems Design Engineering and Biomedical Engineering – were joined together, and each team included a balanced representation of both programs. The teams were entered into three challenges: the highest score challenge, focused on achieving precision and accuracy; the greatest distance, focused on achieving the highest distance; and the Team Spirit award, for effective teamwork and communication.

The challenge assigned was to create a launcher of plastic golf balls made from commonly available light materials, such as newspapers, large popsicle sticks, duct tape, elastic bands, and plastic water bottles. Students were provided with an initial set of supplies, and were then allowed to obtain supplies from around campus, or acquire more supplies within a limited budget.
**Fig. 1. Design Days Overview**

- **Two terms before the event**
  - Establish Learning Objectives and Plan Related Activities
  - Get Support from Faculty or Department and Other Instructors

- **One term before the event**
  - Adjust Course Schedules to Accommodate Design Days
  - Set Design Days Schedule and Allocate People and Resources
  - Announce the Event to Students and Collect Pre-Activity Feedback

- **During the term selected for the event**
  - Administer the Event and Collect Post-Activity Feedback
  - Analyze Post-Activity Feedback and Plan for Next Iteration
Target ranges were setup where students could test their design for precision and accuracy or for distance. Each range was staffed by a member of the teaching team to ensure safety. Before students could launch their projectile, they would have to demonstrate that a design iteration was performed and that the iteration was logical and adequately documented in the team’s logbook.

Finally, student results were evaluated based on specified judging criteria, and the winners selected based on the observed and verified results (e.g., largest distance observed and verified for the distance challenge).

This activity was introduced to address objectives (ii), (iii), and (vi).

b) **Student Machine Shop Safety Training:** During the mandated safety training, equipment available to students in the Engineering Student Machine Shop (ESMS) is discussed in detail, and students are made aware of hazards associated with each piece of equipment (e.g., use a push stick when using a bandsaw and feeding material past the blade). Before they can obtain their safety card that allows them access to ESMS, students are asked to complete WHMIS training online, and pass a short quiz that tests their knowledge of machine shop safety; these two activities were completed outside of Design Days.

All students attending Design Days in Fall 2016 were scheduled to attend safety orientation and training during assigned timeslots.

This activity was meant to address objective (iv).

c) **Keychain Activity:** This activity was designed before Design Days, and successfully administered more than once in the past. It includes students working on two pre-fabricated metal parts that are eventually attached together using fasteners to form a metallic keychain. As part of the activity, students learn how to drill holes using a drill press, clean holes using a deburring tool, use a vice to hold parts while they are being worked on, assemble the parts using fasteners, insert keyrings without damaging metal surface, and finally stamp the keychain with their initials.

This activity was meant to address objectives (ii) and (v).

d) **Integrated Program and Course Introductions:** During Design Days, we organized sessions meant to introduce students to their programs of study, which were conducted by Department Chair, Associate Chair Undergraduate, and Biomedical Engineering Program Academic Director. During these sessions, students were introduced to the curriculum, resources available, and traditions of the department (e.g., focus on engineering design throughout the program). Later, we held course introductions for all first-term courses, where instructors explained how their courses relate to design, and highlighted key learning objectives of each course.

This activity was meant to address objectives (i), (ii), and (iii).

e) **Problem Solving Challenges:** A number of short problem-solving challenges were used to maintain student engagement during breaks between activities, such as lunch break. The challenges were based on questions asked during technical interviews, such as questions that require algorithmic solutions and step-wise problem solving. Winners of each challenge were provided with small prizes, such as battery chargers, covers for mobile phones, and so on.

This activity was meant to address objective (iii).

2. **Obtain support from faculty or department and other instructors:** An approval and buy-in from other colleagues in the department or faculty is important for the event to proceed and succeed. After the learning objectives are established, a proposal should be submitted to the department or faculty for possible refinement and approval.

After the approval is obtained, instructors who may be affected by Design Days due to rescheduling or who may benefit from integration of course concepts into Design Days activities should be contacted.

In our pilot study, we obtained approval from our department, and then obtained support from other first-year course instructors. However, that process required several months, and the scheduling of the event could not start until all the approvals were obtained. Therefore, we recommend that department or faculty approvals and support from other instructors be obtained as soon as possible, and at least one full term ahead the term selected for Design Days.
2.2. Design Days Boot Camp: Scheduling Stage

During the scheduling stage, the main objectives were to:

3. Adjust Course Schedules to Accommodate Design Days: To ensure full immersion in Design Days activities, we decided to reschedule all lectures during the two days. This step requires support from department administration responsible for course scheduling, possible trading of lecture hours with other instructors, and repeatedly reminding students of potential changes in their weekly schedule.

In our pilot study, to minimize impact, we have localized schedule changes to the first week immediately after Design Days. Alternative approach would be to schedule make-up lectures throughout the term to make up for the lecture hours not held due to Design Days.

4. Set Design Days Schedule and Allocate People and Resources: To ensure that Design Days activities provide a supportive learning environment, we decided to include all course instructors and teaching assistants of design courses held in the first term. As roles are assigned, it may be necessary to include additional people to help administer the activities (e.g., other faculty members, graduate students, and technical staff).

Furthermore, it is necessary to plan where the event will be held, how the space will be utilized, what budget is available for supplies and food, and what are the requirements in terms of daily setups and teardowns.

In our pilot study, given the large number of students (over 150 students), the objectives of the design challenge, and space and time required in the machine shop, we needed support from other faculty members, graduate students, and technical staff. At the same time, we needed to get budget approval, allocate space, reserve student machine shop, and set space usage protocols, to ensure that everything is ready on time. People and resources needed to be allocated a few months before the event was to take place to ensure availability.

5. Announce the Event to Students and Collect Pre-Activity Feedback: Before the activity is to commence, students need to be aware of its goals, when it would be held, and its location. For students who are coming to the University for the first term, this is very important. This step requires support from department administration responsible for student enrolment and communication with students.

For our pilot study, we sent announcements to all incoming students a few months before the event, and reminded them at least once closer to the start date. In this first iteration, we did not ask students for pre-activity feedback.

As part of pre-activity feedback, students may be asked about their expectations of the program and courses, and prior experience with particular equipment or practice area (e.g., experience working in a machine shop). This feedback could then be used to fine-tune Design Days activities or provide additional student support.

2.3. Design Days Boot Camp: Execution Stage

During the execution stage, the main objectives were to:

6. Administer the Event and Collect Post-Activity Feedback: As part of the event administration, all participants should be provided with event overview document, hourly schedules that include locations, and name tags or badges.

For the pilot study, we used badges as status checks of student progress, where upon completion of each activity student would get a special sticker to attach to their badge. After all the activities were completed, students would be given certificates of completion while the winners of the three challenges were also provided t-shirts that were specially designed and printed for the event.

After the event, as part of our pilot study, we collected student feedback about their Design Days experience using Piazza discussion forums.

The overwhelming majority of students in both Systems Design Engineering and Biomedical Engineering indicated that they enjoyed the following aspects of the event:

- Meeting classmates from both cohorts immediately and setting expectations for the term – sample quote: “Design Days was an immensely enjoyable and valuable learning experience. We got an opportunity to meet our classmates on a more personal level, while understanding their thought process and learning style”;

- Having a chance to work in a team and learning about team dynamics – sample quote: “Design
Days were an excellent opportunity to engage in team-building exercises”;

- Having a chance to learn about machine shop safety and completing a short machining project – sample quote: “The training we did was very useful and educational since I had never been to machine shop before and drilled stuff”; and
- The design challenge was fun – sample quote: “Launching balls is a lot of fun, especially when you have a decent shot of breaking records”.

At the same time, students in both Systems Design Engineering and Biomedical Engineering indicated that they did not enjoy the following aspects of the event:

- The design challenge was not sufficiently complex to span two days and some students perceived it as too long – “I think that more should have been done besides just making the catapult as it dragged on a little bit”; and
- The event was scheduled from 8:30am until 9:00pm on Day 1 and from 8:30am until 7:00pm on Day 2, and students found that to be too long – sample quote: “It was too long; people started leaving and getting really tired by lunch on Friday”.

7. Analyze Post-Activity Feedback and Plan for Next Iteration: Before too much time passes after the event, collected feedback should be reviewed and analyzed. If the event is going to be held again, important feedback should be identified, and a select number of changes set to be implemented in the next iteration.

Based on our pilot study, in the second iteration of Design Days, we plan to introduce an additional design challenge for Day 2 of the event, and limit daily schedules to 8:30am-4:30pm timeslots to ensure that students are engaged and have energy to complete activities for the full two days.

3. SUMMARY AND CONCLUSIONS

Teaching engineering design and ensuring that students appreciate its importance can be a challenge. In this paper, which is presented as an experience report, an approach was introduced for motivating students to think in engineering design terms in their first academic term. The approach, titled Design Days, was applied through a pilot study in Fall 2016, and will be applied again in Fall 2017 with minor modifications.

The presented description of the approach includes the context for its application and a set of intended learning objectives. As part of the description, a set of guidelines for how to plan, schedule, and execute Design Days-like event is included. This description can be used as the basis to tailor Design Days to other engineering programs and other learning objectives.

Since the pilot study was held, other departments in the Faculty of Engineering, such as Electrical and Computer Engineering and Mechanical and Mechatronics Engineering, have developed and administered their own versions based on Design Days.

Only preliminary data about user experience based on a pilot study has been collected. Hence, the validity of the approach and its limitations cannot be adequately assessed until more data is collected.

In the future applications of Design Days, pre-activity and post-activity data will be collected to allow for further study. In addition, overall learning objectives will be further aligned with each activity to ensure that activity outcomes are measurable and can be improved over time.

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References


