Architectural Engineering Starts with Design from Day 1

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Abstract

This paper describes the implementation of an event for first year students of a new engineering program to build teamwork skills and introduce the iterative design process. The university of the author group has recently implemented a new Architectural Engineering (AE) program, which is believed to be the first program of its kind in Canada to integrate core engineering education with open ended design studio courses throughout the program's entirety. An event called AE Design Days was held during the first two days of classes for the incoming AE students. Much like the program itself, the event sought to combine engineering and architectural pedagogy in a synergistic fashion. In groups of four, students were tasked with designing, building, and testing a furniture piece. The projects were evaluated by core course instructors and teaching assistants against the following criteria: identifying and proposing a solution for a problem specific to the given site, choosing an appropriate match between design, material, and construction technique, and efficiently resisting service loads. The final task of the event was a simultaneous slideshow presentation and load test where students explained their group's design rationale, tested their designs with estimated service loads, and subsequently continued load testing to failure. Both a 'people's choice' winner and overall winner were identified, with no grade being assigned to the students. According to the student survey conducted after the event, 90% of the participants felt that AE Design Days was a positive experience and wish to have a similar event in future academic terms. The paper will discuss details of the AE Design Days event and its effects on the students through the analysis of the survey questions.

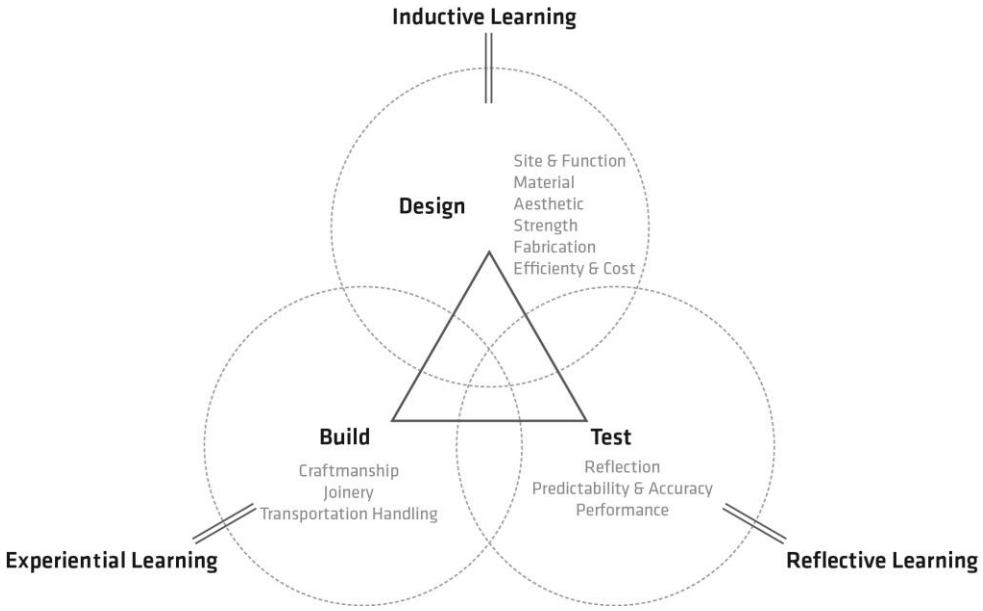
1.0 Introduction

The event had the following learning objectives:

1. providing an opportunity to build working relationships with classmates, faculty, and staff,
2. introducing the students to core course content in a practical situation before any of the theory is introduced in class,
3. allowing the students to gain experience working with their hands,
4. allowing the instructors to gauge the skill sets of incoming students and get a feel for how each cohort of students is different over the years (note: instructors can use this experience to calibrate course material, taking into account what skills each cohort has already built before entry), and
5. introducing the students to the iterative design process and breeding a culture of open-ended problem solving confidence.

The event is unique because it combines the architecture studio model, common to most architectural schools, with the engineering tradition of physical testing. The two-day event was divided into three activities: design, build, and test; which employ the following pedagogical techniques: inductive, experiential, and reflective learning respectively (Figure 1). These activities each achieve one or more of the learning objectives: The design activity serves Learning Objectives 2 and 4 by splitting students' time between two sets of design sketching and

feedback sessions. The build activity facilitates Learning Objective 3. The test activity serves Learning Objectives 4 and 5 through its presentation, load testing, and instructor feedback components. All activities engage Learning Objective 1 because this is a group work project, and requires efficient teamwork in order to complete in the modest two-day timeframe.



[Figure 1] Three Core Principles of the AE Days Event

2.0 Background

Architectural engineering encompasses a wide variety of disciplines from the building industry. Exact combination of these disciplines differs between programs; however, there is a general consensus that such a program should have at least two if not more of such disciplines [1]. The "design days" model has been successfully introduced as a multifaceted design activity in other engineering programs, which interconnect various course content [2, 3, 4 & 5]. Given the success of such events, it was presumed that such an activity would be suitable for introducing students to the multidisciplinary field of architectural engineering.

The design aspect of the AE Days project was conceived as a project-based inductive learning experience. According to Prince and Felder, Inductive learning is conclusively better than traditional deductive pedagogy [6]. Project-based inductive learning is typical to most engineering capstone course projects [6], where course knowledge and theories are meant to be discovered by the students through a realistic design problem, rather than delivered to them at the onset of the assignment. In our particular case, we are attempting a self-driven inductive learning exercise before the students have received any formal post-secondary level instruction. It is therefore important that a sufficient support structure is maintained at all times.

In the case of the AE design days activity, this support was given in the form of constructive feedback meetings known as critique sessions; which are borrowed from architecture pedagogy. A critique session is one where students bring their proposed design solution, and are provided guidance on whether or not their design effectively addresses the original problem statement.

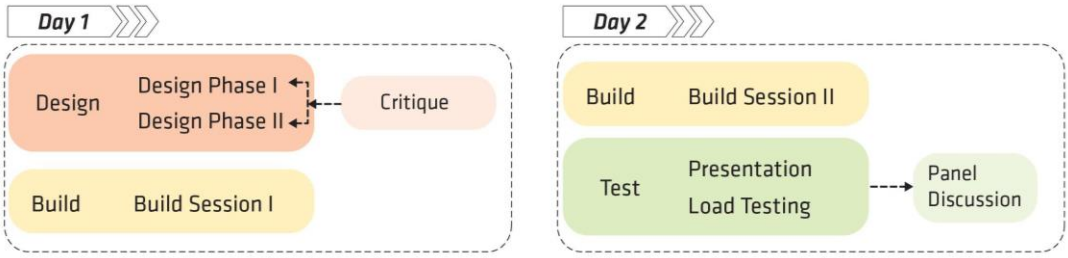
The purpose of such sessions is to develop student critical thinking skills [7]. In essence, the critique is a constructive discourse conducted in small groups of students and instructors. Although many of the instructors in the engineering field are not directly familiar with critique session, a study by Current and Kowalske shows that significant training may not be required to conduct a constructive discourse with students [8].

The build aspect was intended primarily to be an experiential learning exercise. In a study of a similar event by Philips et al., it was shown that student participation in experiential learning activities had a noticeable impact on their grades [9]. Allowing students to create their own designs aids them in grasping intended concepts [10]. Furthermore, according to a study by D'Mello and Graesser, learning environments that productively confuse learners elicit critical thought and deep inquiry necessary to deep learning. Allowing students to tackle problems first, while providing instructor support on the sidelines, prevents the activity from sliding into a negative cycle of frustration and confusion [11].

The purpose of the testing activity within the overall project was to facilitate reflective learning. Schön, in his studies of professional design practitioners, emphasized the importance of knowledge gained through reflection on a professional's own practical experiences. Schön argues that a practitioner whose knowledge is only based in rational and cognitive exercises will be less effective than a reflective practitioner [12]. The difference between the way in which junior engineering students and senior engineering students approach design projects is the number of issues considered; however, it is difficult to understand the breadth of issues to be considered without first commencing a design [13]. In this way, the AE Design Days event serves the unique purpose of providing a baseline experience for students to reflect back on as they acquire new knowledge in their subsequent academic study.

3.0 Process

The AE Design Days event was focused on a single project, which tasked students in groups of four to design, build, and load test a piece of furniture for a specific site in the Engineering 7 (E7) building. The activity was organized according to the diagram in Figure 2.



[Figure 2] Event Timeline

3.1 Design Activity Details

After the ice breaking activity, the students began the first phase of design where groups were assigned to one of the predetermined spots. They were equipped with tape measures and graph paper, and given free access to their assigned site. The deliverable of the activity was a set of

sketches that communicate the design of the furniture piece they have conceived of together. The first phase of design ends with each group of students participating in a design critique session with an instructor. This initial feedback session is focused on high level elements of the group's proposed design, the instructor points out feasibility issues and proposes alterations. The purpose of the first design phase is twofold, the first is to facilitate team building and the second is to introduce them to the iterative design process through experiential learning.

The second part of the activity was to revise their group's design based on the feedback from their instructor, as well as integrate fabrication constraints into their design. The students were allowed to use Hydro-Stone plaster and cardboard in any combination of their choosing, so long as they are within a set budget of $200. These materials were chosen because they represent the two major categories of construction materials: cast elements, and slender mechanically joined elements. Students were asked to deliver dimensioned sketches of the components of their furniture laid out on the sheet sizes available. If the student group's design required plaster, they were asked to design and provide similar sketches for their mold and estimate the quantity of plaster they would require. At the end of the activity, there was another feedback session where an instructor pointed out flaws in the mold design or joint design, and provided solutions and suggestions for improvement. The purpose of this activity is to get the students thinking about the relationship between a design on paper and the restriction of what is possible to build in the field. Furthermore, this planning activity was meant to enhance the students' reflective learning experience after they run into trouble when they built their piece in the next activity.

[Figure 3] Design Critique Session (Left); Idea Sketch Exercise (Right)

3.2 Build Activity Details

The build activity was scheduled in two sessions: the first taking up the remainder of the first day, and the second during the morning of the second day. Students were instructed to finish their molds by the first day so that plaster could be poured immediately the following day. Students were not allowed to work on their projects outside of assigned hours for two reasons: the first was because we were not able to provide adequate supervision, and the second was to promote good time management skills. Hydro-Stone plaster was chosen specifically for its ability to reach 30 MPa strength after one hour, making the logistics of the event more manageable. While the students were building their furniture pieces, the instructors provided roaming assistance with the many problems that the students inevitably faced while trying to construct their furniture piece. Some examples of problems that the student groups faced were:

discrepancies in member size because tolerances were not accounted for, not accounting for the hydrostatic pressure exerted by liquid plaster on the mold, and the importance of water-tight detailing in preventing blow-out of the molds. The amount of time allotted and instructor support was calibrated such that each group could experience problems, and have enough time and support to revise and adapt their designs in order to have a functional design for the test. In this way, the build activity was a major opportunity for experiential learning. At the end of the second build session, the groups were asked to create a slideshow presentation explaining how their design satisfied the three project objectives.

[Figure 4] Aerial View of Build Activity (Left), Mold Making Process (Right)

3.3 Test Activity Details

The groups were divided into two panels where they would present and test their furniture designs in front of a panel of instructors. They were given 5 minutes to explain: what problem they identified in their given site and how they addressed it, why their chosen combination of the two materials was the most appropriate for their design, what the service load they designed for was, and what was the total cost of their design. After the group presentation, they were asked to load their design up to the service load with sandbags, and then load it to failure (Figure 5). Students were given feedback on how to improve both their design and their presentation.

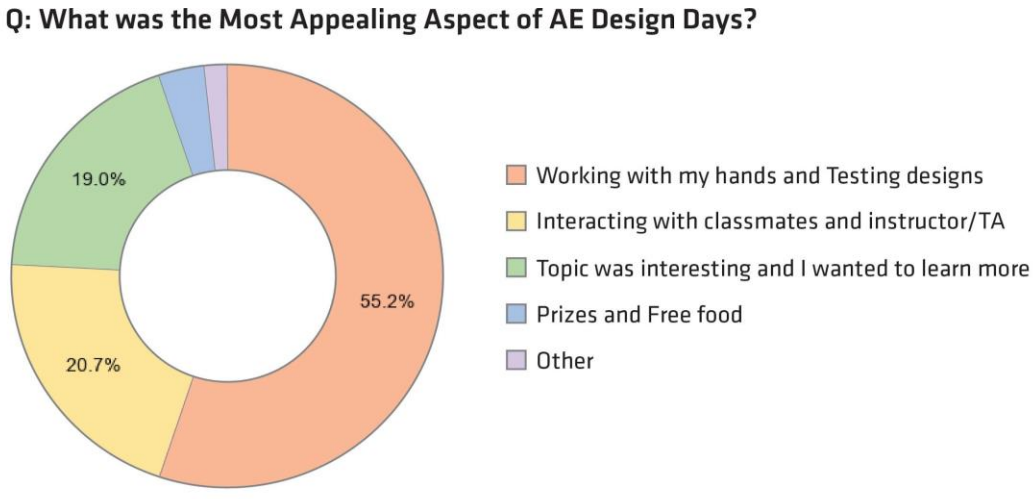
Projects were scored by each reviewer based on: the value of their proposed design to their site, how convincing their material choice was, how realistic their predicted service load was, and how economical their design was in comparison to the load they needed to resist. At the end of the activity, there was a prize given for the top scoring project, as well as a people's choice. The choice to make the students test their projects with sandbags directly was to facilitate experiential learning, in hopes that the students will develop an intuitive sense of what is a kilonewton.

In addition to the instructors directly participating in the event, many course instructors dropped in on the final presentations allowing them to gauge the skills of the student cohort before the first lecture. The reflections on the entire project given through the final feedback session with the review panel provided insights directly applicable to their upcoming studio design course.

[Figure 5] Load Testing and Presentation (Left); Performance Evaluation (Right)

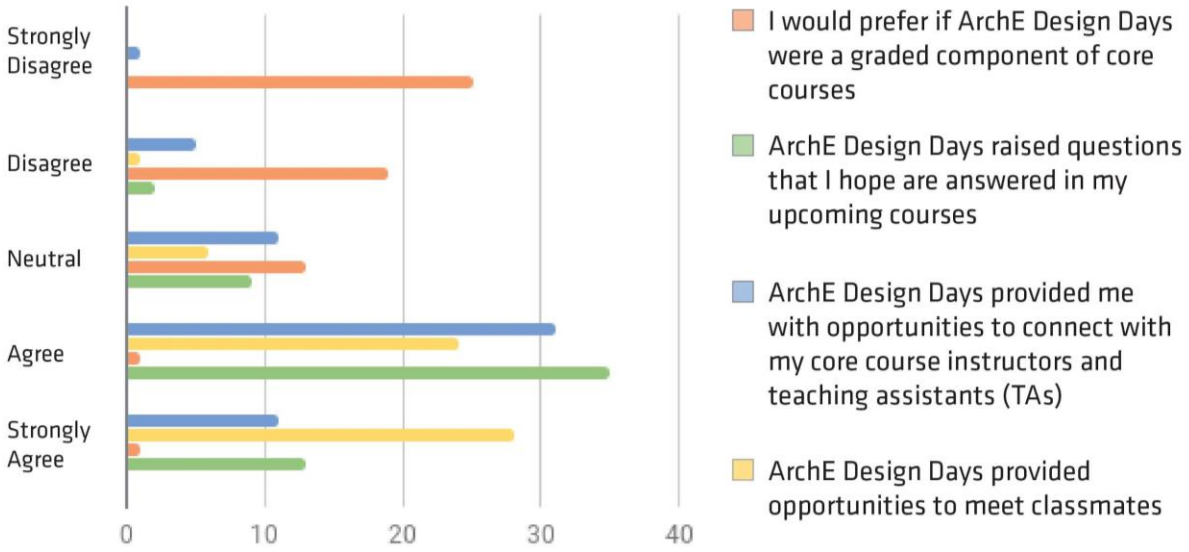
4.0 Results

The effectiveness of AE Days was measured using an optional student survey, distributed immediately following the event, as well as from observations made throughout the event. The optional student survey, which 59 of 90 students completed, was targeted at gauging what the students gained, including: insights for their core courses, relationships with their instructors, and understanding the nature of architectural design, to determine the value of the format used for AE Days.The students were asked which component of AE Days appealed most to them. The results (see Figure 6) showed that the majority of students (32) founds working with their hands and testing designs was most appealing. Twelve students found interacting with classmates and instructors/teaching assistants (TAs) most appealing, eleven indicated that the appeal came from the interesting topic and desire to learn more, and the prizes and free food were the most appealing factor to one student. Figure 6 summarizes the responses to this question.



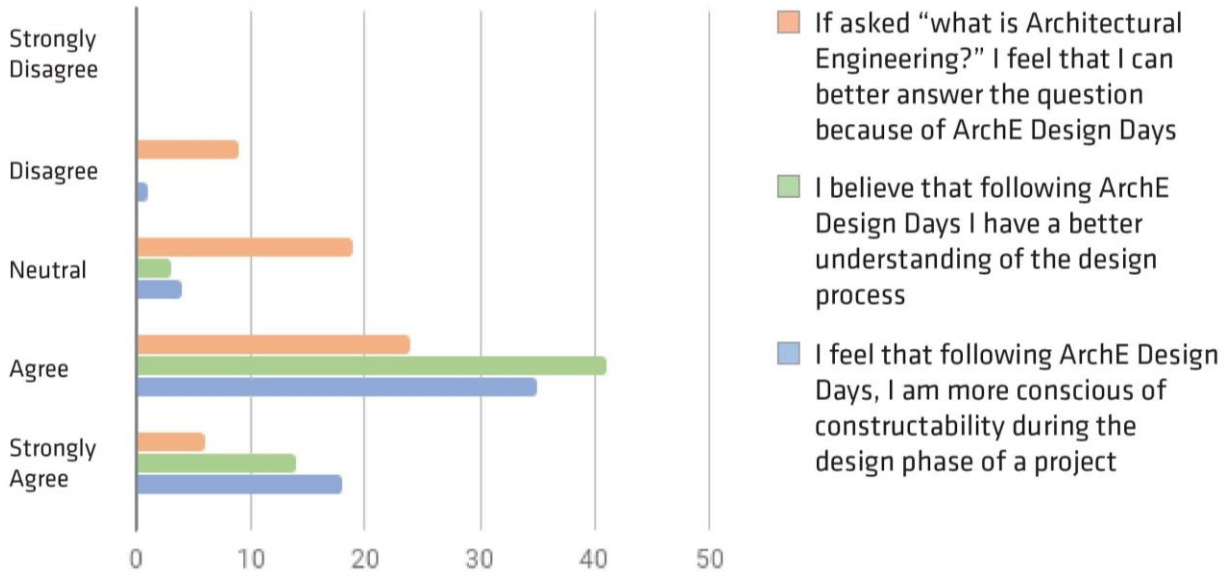
[Figure 6] Student responses when prompted with the statement "The most appealing aspect of ArchE Design Days was…".

Figure 7 summarizes the results of the survey questions regarding the student thoughts toward their core courses and classmates, with the survey questions in the legend.



[Figure 7] Student level of agreement with the statements indicated in the legend on the right.

Figure 8 summarizes the responses to the survey questions relating to architectural engineering design, shown in the legend.



[Figure 8] Students' level of agreement with the statements indicated in the legend on the right.

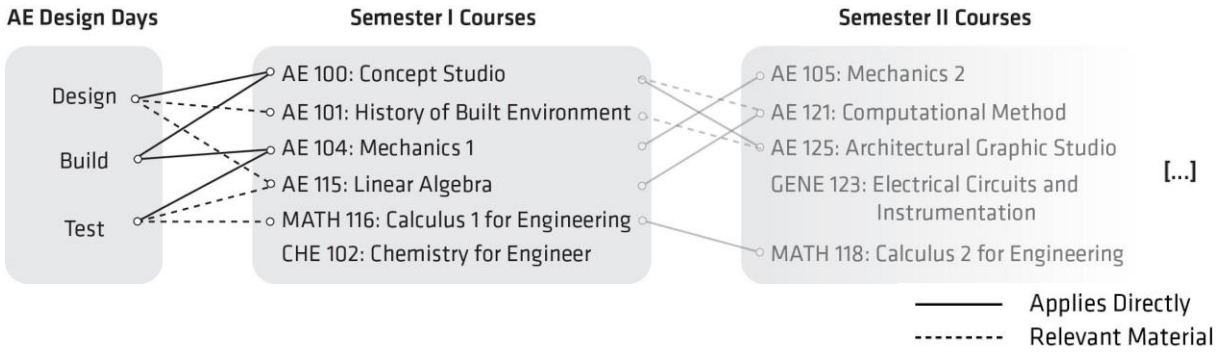
When asked how AE Design Days could be improved, multiple students wrote that they would have benefited from more collaboration between groups. Other students mentioned that they

would have preferred a less open-ended problem and for example design solutions to be provided. When given the opportunity to provide comments on why they enjoyed AE Design Days, several students reiterated their enjoyment with working with their hands and meeting and interacting with their new classmates. It is also notable that 85% of students indicated that they would like to participate in an event like AE Design Days in the future.

5.0 Discussion and Conclusion

The implementation of inductive, experiential, and reflective learning pedagogies can be evaluated by reviewing the responses to the optional survey, particularly the question regarding the students' ability to answer the question "what is Architectural Engineering?". 52% of the survey participants indicated that they either agreed or strongly agreed that they could better answer this question following AE Design Days. Also, the majority of the survey participants indicated that working with their hands and testing their design was the most appealing aspect of AE Design Days. Student enjoyment with a given task generally translates to the student retaining more information, as they will tend to give it more of their attention and effort. AE Design Days can be deemed valuable when it is evident that the indirect lessons taught are applicable to courses that follow the event. Figure 9 demonstrates how the activities from AE Days are utilized to enhance the student learning experience in their first-year courses, with direct and indirect connections made with solid and dashed lines, respectively.

Several new architectural engineering concepts were introduced to the students during the AE Design Days event. The concepts were taught directly, with topics such as the parti diagram and load paths introduced in a lecture format, as well as indirectly, with the students experiencing the design process first-hand. The students learned from trial-and-error, with instructors and TAs occasionally providing insight and nudging them in a certain direction during the critique sessions. The majority of students indicated that they had questions after the event and hoped that they would be answered in their upcoming courses. The practice of only giving students practical examples, rather than a formal traditional lectures, encourages them to think and reason about new concepts. When the students are subsequently introduced formally to new concepts in a lecture format (e.g. structure load paths taught in the mechanics course), they can recall experiences from AE Days and potentially grasp the concept faster.



[Figure 9] Relationship between AE Days Activities and Future Courses

Since the event took place at the beginning of the inaugural year of the AE program, historical student performance data was not available to examine and compare to the performance of

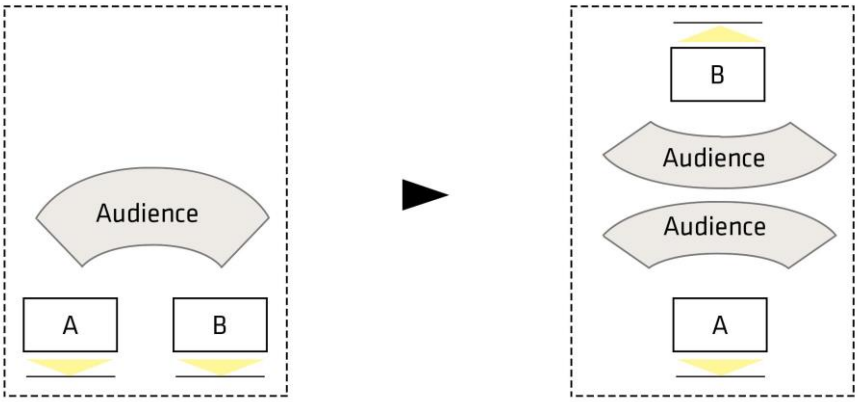
students that participated in AE Days. However, the fact that the event occurred at the start of the first semester of a new academic program provided several insights to the course instructors. Course instructors were present during most of the event and the final judging, therefore they were able to observe the skill level and state-of-knowledge of most students. Instructors noticed that in certain areas, the students were more advanced than expected. This allowed them to make minor adjustments to their course content and delivery. For example, the quality of the presentation component of the final judging, both the presentation itself and the oral presentation skills of the students, surpassed expectations. The vast majority of groups prepared an exceptional presentation using computer software, which indicated that there would not need to be as great of an emphasis on oral presentation fundamentals covered in the architecture studio course. In the future, this phenomenon should be formalized and perhaps a survey targeted towards the instructors and TAs attending the event should be developed to record their insights following the event, regarding the students' abilities and existing knowledge.

AE Days was an ice-breaking event, which acted as a device to foster a collaborative class dynamic. One-fifth of the students that completed the optional survey indicated that the most appealing aspect of the event was interacting with classmates and instructors/TAs, with additional relevant positive comments made later in the survey. However, since collaboration played a significant role in the event, it would be beneficial to explore this topic more in depth in a future student survey. For example, students can be asked if conflict arose in their group and if they were able to effectively resolve it. AE Days provided a unique environment for the students to meet their colleagues and instructors. One observation, which indicated the value of the collaborative nature of AE Days, was that when the skill or motivation level varied throughout a group and an individual student ended up (as a result) leading the other three, the less motivated students gained insight from the strongest performing student and were also subsequently motivated to contribute to the group effort. There were clearly groups with individuals that excelled with the assigned problem. For example, some students explored the use of computer software to model their piece and some students prepared an orthographic projection drawing – a concept the students will be exposed to in their future academic studies.

Overall, the combination of the open-ended nature of the problem, which included new concepts and an opportunity to build and test, and the timing of the event, made AE Design Days a resounding success. The student satisfaction, evident in the survey, indicates that a similar event would be beneficial in future years. While the survey provided some insight on the effectiveness of AE Design Days, if the event is held again in the future, further opportunities should be explored to compare valuable metrics such as course marks. Also, the delivery of the student survey can be improved to increase the response rate. Instead of asking the students to complete the survey after the event has finished and in the classroom afterwards, it is recommended that an incentive is provided to the groups that complete the survey, prior to the scoring and awards component (i.e. increase a group score if all members complete the survey).

In the future, several changes would be made to improve the event. The material cost of Hydro-Stone will be lowered, as well as adding the ability to purchase partial bags. The feedback from instructors and students was that the costing of the material was in favor of cardboard use, where the two materials were meant to be on equal footing. The organization of the final review also needs improvement. The groups were set too close to one another, which caused the two panels

to have to speak over one another (Figure 10). Breaking the class into more panels could be advantageous, because it was observed that the students who were further away from the panel had trouble hearing, and thus had greater difficulty paying attention to the proceedings.



[Figure 10] Final review room arrangement used for the event (left), and proposed room arrangement for future events (right).

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