Building Better Together: Engineering Design with Occupational Therapists and End Users

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Abstract - This paper presents Building Better Together (BBT), an interdisciplinary project-based teaching and learning experience that facilitated a collaboration between the engineering and occupational therapy programs within Queen’s, a Canadian University. We share the inter-professional and discipline-specific learning objectives, resources utilized, weekly course format, and outcomes of this experience. This project integrated different frameworks to develop competencies for students from both programs which included: an engineering design process, a clinical process framework used by occupational therapists, and an inter-professional framework. Feedback from students who participated in BBT is provided.

Keywords: Interdisciplinary, education, design, assistive devices, occupational therapy, engineering

1. INTRODUCTION

Engineers and occupational therapists have roles in designing, building, and providing access to technology for members of society. In particular, biomechanical engineering and occupational therapy students are taught methods and analytical techniques to provide assistive devices for people with disabilities. However, people with disabilities report challenges in accessing functional, affordable and appropriate assistive devices when they need it [1]. Studies have also found that 18-53% of assistive devices prescribed to older adults is not used, and this rate increases over time [2]. One of the biggest issues contributing to use is the fit between the person, the environment, and their equipment. These findings reflect the critical importance of understanding the complex interplay between personal factors and the technology. Ultimately there is a need for engineers, who specialize in design, and therapists, who focus on disability, to learn and work together to build competencies to address these issues.

1.1. Interdisciplinary Teaching and Learning Opportunities

In engineering education, interdisciplinary learning opportunities are reported to “appreciate the skills and competencies” that other disciplines can contribute to solving a problem [3]. Student satisfaction in these cross-discipline learning experience is high [4]. Implementation strategies of cross-discipline learning opportunities include the structure of the interactions, how the workload is divided, attributes of discipline specific contributions within the collaboration, and the implications within the professional field [5].

1.2. Project-Based Learning Opportunities

Project-based learning is a model of teaching that is student-centered. Project-based learning opportunities in engineering education provide a problem that would most likely be addressed in the professional world and students are asked to engage in solving this problem within a supportive environment [7]. To come up with a solution a team must work together, identify, organize, and apply the team’s perspectives, knowledge and skills effectively. Students are asked to work in groups to solve a complex problem. The problems are usually open-ended, complement curriculum learning objectives and are interdisciplinary in nature [6]. Project-based learning helps students develop skills and knowledge and allows them to apply these strategies appropriately. Projects are time limited, follow a particular theme, and elicit specific skills to be applied to help solve the problem.

1.2. Academic Resources and Administrative Support

University engineering programs have a long history in creating assistive devices [8]. For instance, in Ghannam’s investigation of the role of engineering programs to address community-based problems, students are exposed to enriched learning experiences that he argues, can build a student’s character [9]. However, the teaching methodology and time invested in non-traditional training may not be supported by the administration. Lewis and Matsuoka further supports academia’s role in meeting community-based problems [10]. She claims that universities are a vital, untapped resource that can meet the gap in technology, as well as being platforms to enable showcasing of innovation that can turn into marketable products. However, there is evidence that a gap exists between the engineer, clinician, and end-user [11]. More opportunities to aptly prepare future engineers and clinicians are needed to
tackle this problem. Support for more interdisciplinary, and project-based teaching and learning opportunities within universities are essential to prepare students to effectively address the real problems of today.

2. BUILDING BETTER TOGETHER (BBT) PROJECT FORMAT

Building Better Together (BBT), an interdisciplinary, project-based learning opportunity was designed to provide students in the occupational therapy and engineering classes: OT827 Enabling Occupation in Older Adults and MECH 393 Biomedical Product Design, an opportunity to learn how to design and build technology together to meet the needs of the aging population. This initiative integrated practice frameworks and models that are discipline-specific as well as facilitating interdisciplinary practice. In particular, the engineers utilized a Define, Measure, Analyze, Improve and Control (DMAIC) approach while occupational therapy students applied the Canadian Practice Process Framework (CPPF) [12] to engage with older adults. The Canadian Interprofessional Health Collaborative framework was adapted and applied to this project to assist in targeting skills essential to interdisciplinary practice [13].

2.1. Project-Based Learning Experience

BBT provided students a complex real-life problem that would benefit from perspectives, knowledge, and skills from different disciplines. The project merged the lived experience with clinical knowledge of disability and expertise in design. The overall outcome provided a model to engage in designing a novel assistive device with an older adult that would enable them to perform an activity that they reported as being challenging.

Over 130 students from both OT and Engineering were allocated to 24 design teams. Design teams were made up of at least three occupational therapy students and 2-3 engineering students. Each design team was partnered with an older adult. The older adults who participated in this project were living in the Kingston community with varying abilities and impairments including stroke, Parkinson’s disease, osteoarthritis, low vision, and dementia. Students met with the older adults three times over six weeks. Assistive devices requested by the older adults that offered potential for design included: a pill management system, an ileostomy bag guiding system, a finger splint, a one handed Ziploc bag opener/closer, a memory aid system, a wheelchair charging system, and a transfer bench.

The project took place over 6-weeks. Design teams formally met every week for 2 hours for a shared tutorial. For each of the six two hour sessions, students had access to a professor from the engineering department, two engineering teaching assistants, two occupational therapy instructors and one occupational therapy teaching assistant. Design teams were also expected to meet outside of classroom hours to complete the project objectives. Engineering students had access to a prototyping space and a budget for materials.

Occupational Therapy and Engineering are both professional degrees and this required significant reworking of the previous courses. The course developer was a doctoral engineering student, who is a practicing clinical occupational therapist, and her interdisciplinary focus allowed her to oversee both the engineering and the occupational therapy curriculum. Many of the course assessments were discipline specific, with a shared poster presentation output at the end as well as peer evaluations. The teaching resources provided by a grant from the Centre for Teaching and Learning at Queen’s University allowed the instructors to effectively balance all aspects of the assessments to ensure that professional requirements were met effectively.

2.2. Discipline-Specific and Shared Learning Opportunities

**Engineering Design**

Within the engineering course, students were asked to gather, organize, and engage with their older adult collaborators using the Six-Sigma strategy of define, measure, analyze, improve, and control (DMAIC) [14]. This model has been applied and taught to engineering students in other courses to promote innovation in design.

**Canadian Practice Process Framework (CPPF)**

For occupational therapy students, they were asked to engage with the Canadian Practice Process Framework (CPPF). This practice framework was created by Polatajk, Craik, Davis, and Townsend which considers the different elements to working with a client. The practice framework highlights where the client and therapist interact as well as the role of both the client and other factors such as context, a frame of reference, factor in this process [12]. The occupational therapy students in this course have already been introduced to this framework and have applied it in previous courses. For this project, they were given this opportunity to apply it to collaborate effectively with engineering students and an older adult to build an assistive device.

**Canadian Interprofessional Health Collaborative (CIHC)**

In BBT the Canadian Interprofessional Health Collaborative (CIHC) framework was applied within an
academic environment. The CIHC framework was developed to inform education and practice across health professions based on a standard approach to competencies [13]. OT and engineering students had the opportunity to use an interdisciplinary approach to product design to address the needs of older adults. The CIHC framework was used to guide shared curriculum for this project to facilitate the development of transferable skills, such as teamwork, conflict resolution, and communication. Specific skills were the focus of individual tutorials; in the initial orientation, design teams were asked to establish a team contract and discuss roles and responsibilities, for example. Most of the inter-professional skills were facilitated during natural teaching moments, where design teams had to learn to effectively work together and problem-solve.

2.3 Leveraging Educational Resources

2.3.1 Purpose of project and learning objectives

The aim of Building Better Together (BBT) was to capitalize on the space, teaching and learning resources within Queen’s University and these respective programs to develop the skills of OTs and engineers in designing and building technology for the aging population. Lectures along with tutorials highlighted the particular context, roles, team demands, communication needs (written and verbal), and leadership skills to be applied and assessed over the duration of the project.

The project objectives were:

1. To enable students to work collaboratively in interdisciplinary teams to meet the needs of end-user needs
2. To gain a full appreciation of team dynamics among engineers, clinicians, and end-users during design development, and building assistive devices
3. To understand the personal, social, and ethical implications of designing and building assistive technology

Each course was chosen because it provided foundational knowledge and complementary timelines where project objectives could be met.

2.3.2 Engineering Course and Resources

MECH 393: Biomedical Product Development:

MECH 393: Biomedical Product Development is a 3rd-year undergraduate level engineering course that focuses on providing knowledge on the design, manufacturing and product management of various devices. Students are taught engineering concepts and skills that follow DMAIC. The approach includes a method to engage with various stakeholders (quality functional deployment- QFD), a strategy for matching the wants and needs of the client (KANO), and an analysis to evaluate the quality of a product (Failure mode and effects analysis – FMEA). They are also introduced to liability considerations, and manufacturing concerns. Using these techniques, they can fully prototype an end product.

Space

The Faculty of Engineering and Applied Science houses small group rooms enabling each of the 24 teams independent access during the tutorial slots while instructors and TAs walked around visiting each. Prototyping space and equipment were provided by the engineering department and utilized by the engineering students.

2.3.3. Occupational Therapy Course and Resources

OT 827: Enabling Older Adults:

OT 827: Enabling Older Adults is a 2nd-year occupational therapy graduate level course that provided students with the foundational knowledge necessary to identify factors influencing performance and participation of older adults. Evaluation and intervention approach at the level of impairment, activity limitation, and participation were explored by considering the diverse roles of occupational therapy practitioners in collaboration with families and inter-professional service providers across a range of service provisions. Students at this level had previous opportunities to work with people directly to help them meet their daily occupational challenges, however, students did not have experience in design.

2.3.4. Community Need

The older adults were recruited from a community contact that has had past working relationships with the School of Rehabilitation Therapy at Queen’s University.

2.3.5 Shared Teaching

Additional course content was provided to occupational therapy students on design, liability, and clinical reasoning as it pertains to designing an assistive device. The teaching resource was provided by the engineering instructor.

3. KNOWLEDGE AND SKILLS DEVELOPMENT: COMPETENCIES & GRADUATE ATTRIBUTES

Building Better Together (BBT) targeted specific competencies to develop and assess in students.

3.1 Engineering Graduate Attributes

Engineering students were assessed on the following:
• Knowledge
• Problem Analysis
• Investigation
• Design
• Use of Engineering tools
• Individual and team work
• Team skills
• Communication skills
• Professionalism

Through BBT, students applied their knowledge base in engineering fundamentals to design and prototype of an assistive device. Engineering students had to consider a feasible design that would enable performance according to the identified challenges that the older adult reported. They also had to integrate the knowledge and perspective of the occupational therapy students in understanding function. Engineering students had to identify, formulate, analyze, and solve technical problems that came up with their design. The design process required acquiring appropriate feedback by team members and iterative design. Since technical knowledge may be hard to understand, engineering students had to translate engineering knowledge so the design team could act on the information from their various perspectives. Engineering students were also expected to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to design a prototype of the assistive device. Each team had to create and present reports that had evaluations of their designs and included specifications and justifications.

3.2 Occupational Therapy Competencies

Occupational therapy students were assessed on their ability to:

• Assume Professional Responsibilities
• Think Critically
• Demonstrate Practice Knowledge
• Utilize an OT Process to Enable Occupation
• Communicate and Collaborate
• Engage in Professional development
• Manage Own Practice and Advocate within a System

Each assignment engaged occupational therapy students to present and critically reflect on the process they were participating in within their design teams. For example, occupational therapy students’ first assignment entailed preparing themselves on how to engage with their design teams in establishing realistic goals within the context in which they were working. Students had to reflect on the constraints of the project as well as the limitations of their skills to determine an appropriate action plan to help address identified goals.

4. INTERDISCIPLINARY, PROJECT-BASED LEARNING OUTCOMES

4.1. What were the benefits of participating in an interdisciplinary learning experience?

The benefits of interdisciplinary learning according to the literature, highlight that diverse skills, communication, and interpersonal skills can be effectively developed in problem enriched learning opportunities.

Choi et al [15] summarizes interdisciplinary practice as: working between several disciplines, involves at least two disciplines, working on the same project, shared goals, common roles, and participants surrender some aspects of their disciplinary role but still maintains a discipline specific base.

The project required different perspectives and skills from each discipline be utilized. For example, occupational therapy students initiated the relationship with the older adult and facilitated gathering information of their needs. The engineering students further connected this information to what may be possible in a design. It also included discussion on the feasibility of design, materials, and safety concerns. Over the course of the project, formal and informal interactions, discipline-specific knowledge and perspectives were shared significantly improving the design outcomes as the students worked through several iterations with each other and the end user.

The problems presented by the older adults were complex, and each team had their unique solutions. Teamwork outcomes were evaluated through group assignments and presentations.

4.2. What were the benefits of utilizing project-based learning?

4.2.1 Complexity

There were many aspects of this project that could not be predicted or controlled; such as the needs of the older adults, how well the problem could be solved, and the skills and knowledge available in each team. This provided an opportunity to reflect on what was needed, and how the project could be completed with what was available. Discipline specific skills were expected to be utilized at different stages. How well developed these skills became and how they were used, varied among design teams.
4.2.2. Authenticity and its contribution
Collaborating with an older adult from the community made the problem real and meaningful. The older adult reported challenges that limited their daily tasks, and they communicated the need for support. The personalization of the problem provided significance to the work to be done, which in its nature added a dynamic that is not typical of case studies. The problem required a real solution. This team dynamic elicited different motivating and accountability factors for each of the design teams.

4.2.3. Context
The project took place within an academic setting that did not have an infrastructure to provide ongoing service or manufacturing of an assistive device. The occupational therapy and engineering students had to understand, communicate the limitations of the project to older adult collaborators and work within these constraints. The design teams were still expected to provide and work with their older adults through the process of identifying the problem, designing an assistive device to address the problem, prototyping that device and presenting it back to the older adult for feedback.

5. PROJECT RESOURCES AND SUPPORTS

5.1. Project Delivery
BBT took place over 6-weeks. Discipline specific course content was provided in lecture style format during the week. Tutorials were shared and occurred once a week for 2 hours. Attendance at tutorial sessions was mandatory. Tutorial sessions included time set aside to work with their design teams.

Assignments and grading were discipline specific. Feedback on assignments was given before the following tutorial. Some of the tutorials had a particular learning objective (i.e. team contracts, interviewing the older adult, quality deployment, etc.) that needed to be accomplished by the end of the tutorial.

Students were expected to meet with their design teams outside of classroom time to prepare for tutorial sessions and complete assignments. Design teams had an opportunity to meet with their older adult collaborator three times over the course of the project.

6. ASSESSMENTS and EVALUATIONS

Assessments were created and graded within each program that reflected learning objectives and competencies required for each discipline.

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<thead>
<tr>
<th>Week</th>
<th>Assessments and Evaluations</th>
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<tbody>
<tr>
<td>1</td>
<td>Team Contract (OT/ENG)</td>
</tr>
<tr>
<td>2</td>
<td>Quality Functional Deployment (ENG) Assessment – Goal Setting (OT)</td>
</tr>
<tr>
<td>3</td>
<td>First Design Iteration (ENG) Intervention Plan (OT)</td>
</tr>
<tr>
<td>5</td>
<td>Second Design Iteration (ENG) Analysis and Recommendations (OT)</td>
</tr>
<tr>
<td>6</td>
<td>Presentation (OT/ENG) Final Reports (OT/ENG)</td>
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Table 1. Summary of Assessment and Evaluations: (OT-Occupational Therapy students, ENG- Engineering Students)

As seen in Table 1. Assessments were mostly discipline specific but each informed the other’s assessment. For instance, the assessment and goal setting required by OT students helped inform the quality functional deployment that the engineering students were required to complete. The design iterations were a team exercise but the engineering students were responsible for conveying this information back to the end users and the instructors. The intervention plan required by occupational therapy students was a summary of the design process as well as the roles of the team players. Iterations of the design were reported to instructors and end-users by the engineering students, and the occupational therapy students’ responsibilities were to convey information of the design, functional use and usability to the older adult. The final project which was a formal presentation was a joint effort that merged the roles and responsibilities to present the design of the assistive device, rational of design features, safety, functionality and usability.

7. STUDENT FEEDBACK

7.1. Peer Reviews
Students had an opportunity to reflect on their experience during the project as well as comment on the productivity and performance of their peers. Overall, students reported positive experiences where they learned about the contributions of another discipline as well as developing critical skills for their practice.

7.1.1. Increase understanding of other disciplines
Students were asked what they learned and they answered with the following comments:

“Increased understanding of the potential for engineering and OT to collaborate to create an assistive that improves upon what is already out
there on the market, and how that collaborative process may play out in real life."

"the way that professionals of different fields break down goals is very different."  

"I think this course is a great opportunity for Interprofessional collaboration skill development... it was great to have an actual end-user as a member of the collaborative team."

Students reported that the course provided a great opportunity to learn about another discipline as well how to work well with them to address a novel and complex problem.

7.1.2. Development of professional practice skills

Students reported practice skills that were developed in this project. These included team work and how to be an effective team member. They also got experience working directly with a person who is meant to benefit from their knowledge and skills. This experience provided substance and meaning to the skills that they were developing and applying.

"I learned how to work collaboratively with people in a different faculty, as well as how to work with and deal with a client with specific needs. I learned how to talk to clients on a more personal level, and not just on the technical aspects."

"I realized that working within a team with good dynamics helps everyone develop their ideas better, and create an end design that is better than anything a single individual could develop. It was great to build relationships with OTs and to get their perspective on things. I also realized the importance of the team-leader role."

"I loved seeing how we were able to consistently problem-solve. Some of the ideas we discovered as a team we would not have found by ourselves."

"It was awesome seeing how happy our client was with our prototype."

7.2. Survey

Two surveys were sent to students after the course was completed. The first survey was an adapted version of the Readiness of Health Care Students for Interprofessional Learning (RIPLS). The RIPLS is a questionnaire designed to assess students’ readiness to learn collaboratively with other health care students [16]. The RIPLS was modified to consider the non-health care context/discipline.

The second survey examined student’s experience working across disciplines and the influence this had on their overall learning. The survey included both closed- and open-ended questions and provide an opportunity for recommendations for ongoing development.

7.3.1 Results

Over 38% of students who participated in BBT completed the survey. Engineering students who were surveyed reported that they did not have inter-professional experience before this project. However, the occupational therapy students reported that they had previously worked with end users. Both occupational therapy and engineering students agreed or strongly agreed that inter-professional teams are more effective to solve complex problems and meet client needs.

Engineering and occupational therapy students strongly agreed that they benefited from this inter-professional learning opportunity by enhancing their skills in communication, teamwork, understanding professional responsibility and solving technical and clinical problems.

Students reported that the project was interesting. The majority of the students reported that the project provided sufficient technical and clinical learning experience. Students reported that they felt like they belonged, the teachers were approachable, and the project gave them new insights to design. Students also reported that by participating in BBT they gained a better understanding of their role in an inter-professional team. Students felt comfortable to learn, communicate, share opinions and responsibility.

7.3. Applications for further skills development

7.3.1. Business Pitch (OT)

Students were not necessarily told or suggested to extend their projects to other aspects of their schooling. However, many students took the learning opportunity gained and applied developed other skills. Three teams went on to create business pitches for the products that were designed in BBT. They were evaluated on their understanding of the how the product would meet a broader population and other stakeholder needs.

7.3.2. Quality Assurance (Engineering)

Some students went on to develop further their skills in evaluating the quality of the products that were designed. As independently guided projects, students investigating the quality of the design of the project, and
the materials chosen to determine whether it would be a safe, functional, and usable project. They worked very closely with the older adult to ensure the end product met the needs of that end user.

8. LESSONS LEARNED

8.1. Administrative Support
Mechanical and Materials Engineering and the School of Rehabilitation Therapy were supportive of this collaboration. They provided support and authority to collaborate between these two schools. Both the heads of the departments authorized the project and engaged the instructors to meet the learning objectives of the courses, and to develop the competencies required in students within the respective programs.

8.2. Funding from the Centre for Teaching and Learning
Funding was provided by the Centre for Teaching and Learning to support the development of the project. A course developer was hired that crossed disciplines. This was helpful because the knowledge and skills facilitated were truly interdisciplinary.

8.3. Shared Curriculum
8.3.1. Orientation: Older adults and Students
Students were not properly orientated to the project due to timing of classes. They were orientated separately and did not have time to establish team norms before being asked to deliver on a project assignment.

8.3.2. Interprofessional Practice
Within BBT, students were introduced to the framework and asked to reflect on their inter-professional practice skills. Interprofessional resources available within the university will be utilized more to help enhance the development of inter-professional practice skills within future BBT projects. Students will be formally introduced to concepts like conflict resolution, effective communication, and team work skills that will be applied throughout their practice.

8.3.3. Shared teaching and the flipped classroom
Due to time constraints students were not able to benefit from a shared curriculum. There were many topics identified from each discipline that would have been able to benefit from sharing the content. OT students in particular would have benefited from the design curriculum that engineering students were taught so they too could engage in the design process in more in depth. Future BBT projects will provide shared content in the form of short videos that both disciplines would have access to over the course of the project.

8.4. Shared Resources
8.4.1. Space and Equipment
It was reported that only the engineering students accessed space and equipment for prototyping. OT students would have benefitted and gained more knowledge of the design process if they were allowed along with engineering students to access prototyping equipment. A deeper understanding on how a device is made may encourage more relevant or critical questions that could enhance a design. Makerspace access is being sought for future offerings of this course.

9. CONCLUSION
Students from engineering and occupational therapy developed discipline and inter-professional practice skills by participating in an interdisciplinary project-based learning opportunity. They were introduced to other models of teaching and learning. Shared content, space, and time provide ample opportunity to understand the needs and demands of their skills and knowledge to solve a real world problem. Students reported enhancing their communication, teamwork, and conflict resolution skills, as well as gaining confidence in addressing clinical and technical problems. With the support of the Faculty of Engineering and Applied Science and the School of Rehabilitation Therapy, students in these programs were provided a complex, and enriched learning experience that delivered on learning objectives. More opportunities for interdisciplinary project-based learning is encouraged and is possible as evidenced provided by the Building Better Together Project (BBT).

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REFERENCES


education: Project-based learning (PBL) strategy.”


