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Multidisciplinary Patient-Centered Capstone Senior Design Projects

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Dr. Kleinke has over 25 years of industry experience in the design and development of electro-mechanical systems. As a tenure-track faculty member of the UDM mechanical engineering department, he has adopted a program of instruction which UDM has branded "Faces on Design". The guiding principle is that student project work is more meaningful and fulfilling when students have the opportunity to see and experience the faces of real live clients. In the series of design courses he teaches, students design mechanical devices for use by disabled clients. The students are required to interview the client and design a device that will address one of the client's unmet needs. The series concludes with students presenting prototypes of designs. The reactions of the client, as seen in their faces, is the ultimate grade. In addition to academic work, Dr Kleinke is a registered professional engineer and conducts seminars on innovation which are tailored to the needs of automotive engineers. Dr Kleinke's recent publication, "Capstones Lessons to Prepare Students for the Changing World of Corporate Innovation", was awarded fist place as "best paper" at a 2011 regional conference of the American Society for Engineering Education.

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Abstract

Capstone design projects are the culmination of the student learning process at the undergraduate level and provide an opportunity for students to work on real-world, open-ended problems. Following the engineering design process, students discover needs, propose solutions, build prototypes and test the implemented design. There are many models that exist in the exact implementation of this student experience, which satisfies many of the outcomes required by the Accreditation Board for Engineering and Technology (ABET), ranging from need-based design to basic research.[1] A common model for biomedical engineering (BME) students is to interact with clinicians such as nurses, doctors and residents, through interviews and in some cases, immersion experiences.[2] In other cases, faculty may communicate with the clinicians or industrial sponsors and provide the students with a set of problems.[3]

This paper introduces a new model for empathy-driven design experiences that have been implemented through a collaboration between three departments, spread across two universities. The research questions leading to the development of an alternative educational model were threefold:

1. Does a multidisciplinary approach to capstone design enhance student understanding of the importance of collaboration in the design process?
2. Does the use of actual clients with physical disabilities improve student recognition of social responsibility?
3. Does a multidisciplinary, multiple university educational model lead to improved technologies compared to a single discipline approach?

Over the past two years, BME students at Lawrence Technological University (LTU) have been working on multidisciplinary teams with mechanical engineering (ME) and nursing students from University of Detroit, Mercy (UDM). At the heart of this collaborative effort are Veterans ('clients') with physical disabilities from a local Veteran Administration (VA) hospital who volunteer to interact with the multidisciplinary student teams. This patient-centered model is a transformative experience for the students and there are many aspects of customer-interaction, needs finding and brainstorming that are not possible with the aforementioned models. Students not only learn how to interact with people living with various types and degrees of disabilities but in many cases build long lasting relationships with the clients. The experience also fosters the social responsibility aspect of the engineering and healthcare professions since in most cases, the teams have to understand and incorporate the socioeconomic conditions and cultural pretexts specific to the client.

The opportunity to have a direct impact on the quality of a client's life is a driving force for student design. However, successful implementation of such a model requires significant planning and close interaction between instructors, hospital partners, and university departments. Communication between student teams is of paramount importance and is often found to be the

primary cause in cases of strained team dynamics. Furthermore, methods of periodic team health assessment are necessary to prevent floundering and ensure participation from all team members. The instructors coordinate course timelines and some course assignments as well as cross-campus lectures. Some of the designed products have resulted in intellectual property for the students and have also garnered praise in the local and national media.[4-6] Methods for further improvement to this multidisciplinary empathy-driven design approach include pre and post surveys that assess student confidence and attitudes to solving problems. Prototypes can also improve from an emphasis on industrial design perspectives.

Perspectives

The unique multidisciplinary educational model was initiated in 2009 in part based on literature suggesting cross discipline collaboration in higher education improves a variety of student, faculty, and client outcomes.[7-10]. The goal of designing, building and delivering innovative assistive technologies requires the collaboration of several disciplines. Multidisciplinary education and work requires greater effort, but can produce substantial results. The increased effort is due in part to different perspectives on a situation, different ideas of how to solve problems, different professional language and communication styles, different schedules, and a variety of personalities. Nonetheless, multidisciplinary work is greatly needed in the increasingly global society. Therefore, learning how to collaborate across disciplines should be taught in educational institutions.

Student and Faculty Needs

Faculty and students have a need to innovate and design using contemporary ideas and technology. Many faculty members teach a variety of different classes and need some common teaching tools that will enable them to inspire innovation in many different classes. Students need to see how classroom topics can be applied and create value through the design of an innovative product or service. Both faculty and students need topics in the classroom that are relevant and applicable in the modern world. Students seldom learn structured techniques (beyond brainstorming) that can aid in the concept generation technique.

Patient Centered Projects

There are a few other universities which offer assistive technology courses or as an option for design or capstone projects. DeRemer has summarized some of the courses and projects while developing a similar collaborative course at University of Toledo.[19] Many of these courses focus on design process, interdisciplinary studies or service learning opportunities. Furthermore, there have been other similar collaborations for capstone senior. A brief description of other capstone design projects focusing on assistive technologies is presented here. Up until 2009, University of Massachusetts Lowell offered a two course series through SLICE (Service-Learning Integrated throughout the College of Engineering) focusing on assistive technology. The collaboration between the CoE and community partners allowed students to specifically work with student with assistive technology needs. Other capstone design course pairs students with health care professionals to build custom assistive, recreational, or therapeutic devices for people with disabilities in the local community. These include Duke University (Assistive Technology

Design Projects), University of Rhode Island (Biomedical Engineering Capstone Design I & II) and University of Washington DO-IT (Disabilities, Opportunities, Internetworking, and Technology) programs among others.[20]

The projects described here differ in two main respects:

- First, the LTU/UDM collaboration pair students directly with clients. While many of the patients have physical disabilities due to spinal cord injuries, the circumstances, which include the nature of disability, socioeconomic background and level of assistive care of each client, are very different. The students are not given any ideas available projects. Instead, they meet and interact with the client to determine possible avenues for projects based on client's needs. This clean sheet approach is unique and requires keen observation from students. These steps are referred to *opportunity recognition* and *customer interaction* in the entrepreneurial minded learning process and are important component of customer-centered design that rarely a part of the undergraduate engineering experience.[21]

- Second, most of the other capstone experiences are only offered to students in one major (e.g. University of Rhode Island BME 484/485, Duke University BME 460, and Loyola Marymount University MECH 401/402). Other universities have developed centers specifically focusing on disability (e.g. Center for Assistive, Rehabilitation and Robotics Technologies (CARRT) at University of South Florida, SLICE at UMass Lowell and DO-IT at University of Washington). These centers and programs focus on degree programs and certificates in disability studies and as such are not targeted toward engineering design. The collaboration between two universities (LTU and UDM) and three different colleges (Biomedical, Mechanical and Nursing) combines the diverse backgrounds and capabilities of students. Multidisciplinary team of this kind are the norm in industry and require project management skills such as effective communication, decision making, resource gathering and scheduling of various tasks. Therefore, the students not only must demonstrate a prototype designed for specific customer need(s) but also the execution process followed by the teams. This requires the students to recognize their roles for contributions in the team.

The following sections give a brief perspective of three programs that are involved in this collaboration:

Mechanical Engineering

The technical tasks required of the mechanical engineering students are no different than any traditional capstone course. However, using a client centered model, the engineers have learned the value of empathy and customer discovery by observing how nurses and biomedical students interact with clients. The engineers come to value universal design practices as they work with clients that have limited physical abilities. The student teams, and particularly the team leaders, learn to grapple with the division of duties and system interface management, which is complicated by multi-university reporting, multiple physical locations, and varied core competencies.

Nursing

Nursing students were added to the collaborative educational model to provide medical and healthcare expertise. Student nurses, working under the guidance of nursing faculty, are primarily responsible for providing information about the physical disabilities, client limitations, complications and health risks related to the physical disability and the medical safety of the device. Additionally, student nurses have experience and expertise in talking with clients and are useful in assessing client needs and initiating relationships between the client and other members of the collaboration.

Biomedical Engineering

Biomedical engineering (BME) education prepares students to work at the intersection of science, medicine and mathematics to solve biological and medical problems. While all of BME revolves around improving health and lifestyles of patients in one way or another, certain key areas of BME, such as clinical and rehabilitation engineers, directly interact with the users of technology (clinicians and patients) on a regular basis.

In particular, clinical engineers support and advance patient care by applying engineering and managerial skills to healthcare technology. Clinical engineers can be based in hospitals, where responsibilities can include managing the hospital's medical equipment systems, ensuring that all medical equipment is safe and effective, and working with physicians to adapt instrumentation to meet the specific physician and hospital needs. In industry, clinical engineers can work in medical product development, from product design to sales and support. They play a critical role in ensuring that new products meet the demands of medical practice.

Rehabilitation engineering is the application of science and technology to improve the quality of life for people with disabilities. This includes the design of augmentative and alternative communication systems, increasing computer accessibility for people with disabilities and developing new materials and designs for assistive devices.

In both of these areas, patient interaction can yield important information that directly impacts the design and capabilities of medical products. Therefore it is important for BME students to engage with the users to understand the problems, develop need statements and find appropriate solutions. There is no substitute for the information that can be gathered through this contact.

Project Execution

Patient Selection process

Selecting potential clients to work with the student teams is the first and essential step in the process. Establishing a contact at a health care facility or agency familiar with the multidisciplinary collaborative program can provide access to people with physical disabilities.[11-13] The contact person should be familiar with the goals of the program and the faculty involved. Getting approval from agency administrators will also ensure appropriate privacy and legal standards have been maintained. Other strategies to finding willing clients includes contacting associations or organizations focusing on a particular disability such as a Spinal Cord Injury Association or the Wheelchair Association of America and asking for willing volunteers. The initial contact with the patient client is made by the nursing faculty. The faculty finds an appropriate time and location for the students to meet with the client.

Teams Selection

The participation requirement varies by discipline. To date, mechanical engineering students have been required to take the course, while nursing and BME students self-select to join the course. Teams are created to assure a blend of multidisciplinary talent on each team. Fortunately, there has been enthusiastic self-selection such that it has been possible to create teams that include at least one representative of each discipline and each university on every team. The instructors have used a software tool called CATME (https://www.catme.org/login/index) to develop team rosters based on selection criteria such as proximity to campus, leadership tendencies, skill sets, and practical experiences.

Kickoff Meeting

At the start of the fall semester, the ME and nursing faculty from UDM present the scope of the project to the BME students at LTU. The students hear about the project history and the collaboration between the two universities and the difference made by the student designed projects in the lives of the clients. Usually most of the BME students interested in the project sign up immediately. For the past two years, six BME students have signed up for the projects. BME faculty from LTU also presents in front of the ME students. Once the students involved in the projects are finalized, the faculty assign a client to each team. During the first year of the current collaboration, each client was assigned three BME students and each team had one or more nursing students. During the second year three teams were created with two BME students. The number of ME students varied from three to five. With the teams and clients assigned, all the students and faculty meet together and discuss the project expectations and timeline.

Meeting with the Client

The students arrange the first meeting with the client and are required to have the nursing student and faculty present at the initial meeting. It is not uncommon to meet at the client's home but the client makes the decision on the meeting time and place. Sometimes it is not feasible for all team members to be present at the initial meeting due to space limitations or conflicting class schedules. However, at least one BME and ME engineer is required to attend along with the nursing student and faculty. Depending on the client's comfort level, the students can coordinate future meetings without the need for the faculty to be present. Indeed, in many cases the students and clients have built strong bonds of friendship over the course of the project.

Timeline / Milestones

The full course covers two 16 week semesters. UDM follows the design procedures as prescribed by "The Mechanical Design Process" by David G. Ullman.[15] Biomedical engineering students follow the "Biodesign: The Process of Innovating Medical Technologies" by Paul Yock et. al.[16] LTU requires 3 and 2 credits, while UDM requires 2 and 3 credits (respectively).

Table 1: Approximate milestones and project timeline

TABLE 1: COURSE MILESTONES	
Pre-Semester	Nursing students self-select and register for directed study
Week 1	Introduce all students to the program plan. BME students self-select
Week 2	Form teams via CATME tool, conduct all-hands kick-off meeting
Week 4	Introduction to clients, students plan project
Week 6	Complete project plan
Week 12	Complete product definition
Week 16:	Complete conceptual design and achieve client buy-in
End semester 1, Begin Semester 2	
Week 20:	Complete mock-ups, prototypes, and computer models
Week 24:	Complete initial build, begin testing.
Week 28:	Refine design, react to testing data, build final product.
Week 32:	Final presentation and delivery of working prototype to client.

Student Mentoring and Advising

Faculty with expertise in a particular discipline are responsible for mentoring and advising the students in their own discipline. Team communication, individual responsibilities to the project, and completion of required assignments are common areas where students often need advising from faculty. Faculty also frequently offer mentoring to the entire team based on their particular area of expertise. For example, a recent assistive device involved the creation of a prototype for warming the skin. The engineering students were seeking advice from the nursing faculty about the differences between core body temperature and systemic skin temperature. The faculty also make sure to have at least two joint meetings every semester.

Facilities and Funding

The teams have access to equipment for fabrication, machining and testing of designed devices at both campuses. The close proximity of the two campuses makes it easier for students to commute. Currently, Kern Family Foundation grant is covering the cost of materials and parts for the projects. Each team is allocated roughly $1,000 for their projects although they are encouraged to consider cost efficiency and affordability of their products.

Project Evaluations and Assessment Tools

All students are primarily assessed by the reaction of the client at the end of the two semester course when they deliver the device to the client. If the client is happy, satisfied with the device, pleased with the interactions with the student and the device is delivered on time, then the student team is considered successful in the course.

Beyond the basic requirement of customer satisfaction, certain other assignments are also required. The BME students must also present twice during the Fall semester, once regarding the chosen need statement after meeting with the client (Week 9) and then again at the end of the semester when the design has been finalized (Week 16). In addition, they are required to submit a project report that includes a synopsis of the ideation process as well as plan for implementation in the following semester (Week 17). During Spring semester, the students meet with primary advisor every week and also provide short biweekly updates in class. The students create a poster for a poster session where members of the industrial advisory board and faculty evaluate the project progress and outcomes (Week 30). The end of the semester requirements are similar to Fall semester where students present (Week 32) and create a final project report (Week 33). Rubrics for each of the assignments have been developed. Each project is assessed by all BME faculty and the advisors from ME and Nursing. (See appendix for rubrics used in BME at LTU for 1) needs finding 2) design concepts 3) final presentation during the first semester 4) poster session and 5) final presentation during the second semester)

The faculty have started to implement pre and post surveys to assess student expectations and highlight major hurdles in project execution. Currently, client satisfaction is qualitative and mostly done verbally. However, the faculty are also creating surveys for clients to get concrete data about patient expectations and satisfaction with project outcomes. Previous surveys of students who have worked on developing assistive devices for people with disabilities have shown that these projects increased students' empathy toward persons with disabilities and caused them to have a desire to help others with their engineering knowledge.[22]

The faculty are also deeply interested in evaluating the effects of social interaction between students and patients and the positive effects of student projects on patients' health. Previous research in the literature has identified that a wide range of indicators of social isolation pose health risks. These include living alone, having a small social network, infrequent participation in social activities, and feelings of loneliness.[17] A majority of the clients come from low income backgrounds and either live alone or with caretakers who may also be dealing with health issues. Under these circumstances, the long lasting friendship between many of the students and clients is as important, if not more, than the actual devices created by the student teams.

Table 2: The number of students from each of the programs as well as the teams and the devices that were produced. In 2014, UDM also collaborated with Ohio Northern University for the client projects. In 2010 – 2013, Baylor and Villanova Universities also participated with UDM.

Year	ME	Nursing	BME	Teams	Devices	Satisfied Clients
2015	11	4	6	3	-	-
2014	7	12	6	5	4	4
2013	12	8	0	3	3	3
2012	10	5	0	3	3	3
2011	13	5	0	2	2	2
2010	15	6	0	2	2	2
2009	12	0	0	1	1	1

To date 80 ME, 12 BME and 30 Nursing students have been part of these collaborative projects (See Table 2). The student teams have created 15 prototypes which have helped 15 clients. The number of students per team has changed based on the client's disability and the scope of the project. During 2014, the three BME students were assigned to each of the two clients. However, in 2015, each team was assigned two BME students because a number of students found it difficult to effectively communicate with the larger team.

Student Feedback

The results of the pre-survey from the current cohort indicate that none of the ME students have worked with patients before these projects. Two BME had experience with patient contact through internships while all nursing students had this experience due to Nursing program requirements. The students appreciated the ability to work directly with the patient and using their engineering skills to impact client's quality of life. The responses correspond to similar studies which have found that critical or immersive experiences involving real clients are important in allowing the students to experience human-centered design.[23-24]

Patient Contact: Why did you choose a project with an actual patient/client?	
Emergent Categories	Example Student Responses
Engineering Impact Improving quality of life for others	*Interacting with a client is an enriching and beneficial experience. Working with and actual patients reveals the real impact of engineering fields…This truly motivates me and strengthens my position as to why I chose this field.* BME student
	It provides you with different experiences than what you are used to. It also teaches you life lessons since you think from a different perspective. ME student
	I love having contact with patients and teaching them about disease / illness and providing my knowledge to help better their lives and situation… Nursing student

The students also recognized that the ability to work on collaborative projects brings a new perspective to the client needs and one that is more aligned with real world situations. All students ranked their ability to be work on collaborative projects to be high or very high on a Likert scale (Average = 3.73, 1 – lowest, 5 – Highest).

Multidisciplinary Teams: Describe your feelings about working with students from other programs on this project?	
Emergent Categories	Example Student Responses
Collaboration important in Real world Better outcomes	*Working with students from other programs does help give the sense that real world projects needs a variety of disciplines to produce a completed product* BME student
	I am looking forward to learning from other students in different fields and I hope we can collaborate with each other by sharing and accepting our ideas. ME student
	It has allowed me to meet new people as well as learn more about other majors and how all of our knowledge can be used to create something special. Nursing student

The students were confident about their ability to producing a device for the client but some anticipated hurdles due to communication between the teams due to presence at two campuses and personality traits.

Challenges: What are some of the personal hurdles that you anticipate during this project?	
Emergent Categories	Example Student Responses
Conflict Resolution	*Each one of us have our own way to thinking and we see things from different perspectives so there might be disagreement among us.* BME student
Communication	*Communication and the tendency to flounder when working on this project. Also coming to agreement with different decision that must be made…* ME student
Scheduling	*Being able to effectively collaborate. Find times to meet with all programs.* Nursing student

Client Feedback

To date every client has verbalized satisfaction with participation in the project. Clients have been pleased to be engaging with college students. Several have requested to participate in subsequent years. Clients have verbalized satisfaction with the functionality of the device, the ability to help others with similar disabilities, the improvement in daily life and the customization of the device. Many have voiced pleasure that the students created the device to match the color scheme requested by the client. For example, one client loved the color purple, another wanted his device Army green with a yellow stripe on it and a former Marine wanted his device red and gold to match Marine colors. Student attention to such minute details has led to significant client satisfaction.

Example Projects

Innovative assistive technologies can be anything to improve the life of the physically disabled person. Students must create a unique solution not already commercially available. A secondary goal is to create an entrepreneurial mindset and a business to produce additional devices which may assist others with similar disabilities. Examples of created projects include:

- A triceps strengthener to help a wheelchair bound man to transfer in and out of his wheelchair.
- A hip and knee exerciser for a man with worsening muscular sclerosis.
- A baby carrier that could attach to an electric wheelchair and allowed a paraplegic mother to taker her child out for a stroll.
- A crib that opens sideways to accommodate a mother in a wheelchair who was unable to get her chair next to the crib when the rail was in the down position.
- A laundry extractor for a woman with spina bifida who was unable to get her clothes out of the washing machine.
- A spoon-type device to hold liquids for a burn victim with severe elbow contractures who wanted to feed himself liquids.

- A camera stabilizer bar for a man with spinocerebellar ataxia.
- A detachable motor for use with non-electric wheelchairs.
- A grasping device for a man with right-sided hemiplegia following a gunshot wound who wanted to be able to hold papers in his disabled hand.

Figure 1: The collaborative project resulted in the development of two rehabilitation devices that allowed the clients to exercise upper body or hand muscles. Student teams must address client's feedback which is why the device was painted green with a yellow stripe.

Entrepreneurship

The students worked interactively with students from the College of Health Professions to learn the fundamentals of basic human functions, which in turn helped them design a product. The intention of the commercialization plan is to unleash the potential of undergraduate energy at UDM and then, if successful, to have a broad impact across the country. In one case, the client had been involved in a tragic fire four decades before the students met him.[18] His injuries severely limited the dexterity of his arms and hands. Consequently, the client had not been able to independently use utensils to eat soups or cereal from a bowl for decades. The students designed a special eating utensil that made it possible for him to eat soup independently without any expensive equipment. In this case, the students learned to not take everyday abilities, like eating, for granted. They also understood that there are many more people that could benefit from their work. Consequently, following completion of the course, the students applied for a provisional United States patent. The inventors include engineers and nurses. They entered the Accelerate Michigan Innovation Competition, applied for an E-Team grant, and continue to develop the product.

Recommendation for Implementation

There are several models to accomplish our multidisciplinary, multi-university collaboration which include industrial sponsored projects, competition teams and involvement of management student to develop business models for a project.[25] In the collaborative space of the assistive technology projects described there, there are three possible models for execution of the projects for the engineering students. BME and ME students can:

1) work independently addressing different needs of the same client.
2) work in a competition type mode where each team addresses the same need but finds a unique solution.
3) work collaboratively where both teams address the same need of the client and divide the tasks according to expertise and necessity.

In all these cases, the nursing students act as liaisons and provide clinical / patient care advice to students and patients alike. Each model has its advantages. Model 1 would results in more student projects and assistive devices. However, this model is not collaborative and does not utilize the expertise and background of students. Model 2 can run as a friendly competition with the potential to have higher quality outcomes.

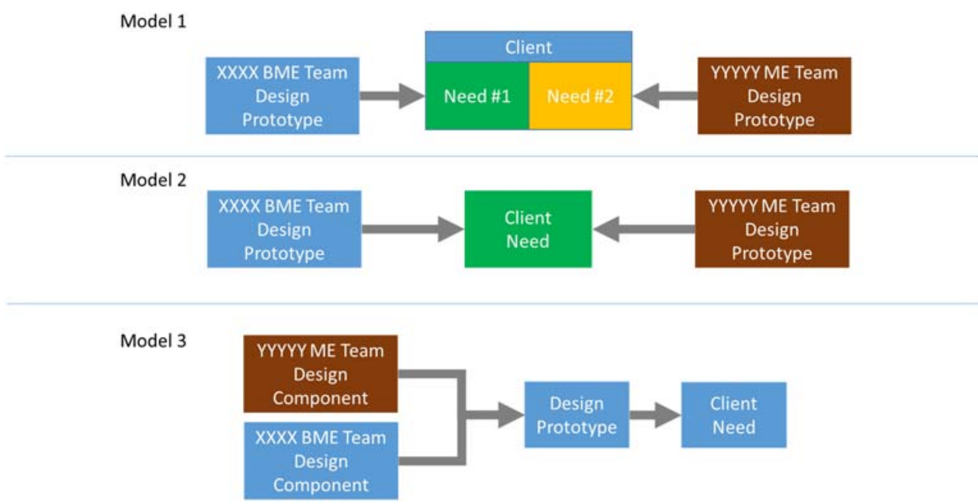

Figure 2: Three models for collaboration between LTU and UDM Teams.

Model 3 is the most effective use of the multidisciplinary team. However, collaborative model requires good communication between the students as well as regular meetings with client, mentors and advisors. To date, all but one project completed were done using the collaborative model (Model 3). The mentors in particular have to ensure that all members of the team are contributing and also every team member is able to provide input at various decision-points of the projects. A schematic depicting our proposed strategies are shown in Figure 2. Expanding collaboration to include business, marketing, and artistic design are future goals for the program. Expansion of the entrepreneurial aspects of the multidisciplinary educational capstone model is another goal for the program.

The professors from both colleges work well together in educating the students. The professors involved in the course have learned much from the process and continue to improve the course. Challenges such as scheduling conflicts, communication barriers, personality issues, and processing issues remain. Resolutions to some of these problems require flexibility and creativity. For example, because nursing students often have scheduled clinical time during engineering classroom time, they are unable to attend the theory portion of the course. One solution to this scheduling conflict is the increased use of technologies such as Skype, Blackboard discussion boards, on campus meetings during evening and weekend hours, Facebook, and Twitter.

Communication between engineering and nursing students requires explanation from both teams regarding the meaning of discipline-specific jargon. Initially, communication is slower because of the need for term explanation but with continued encouragement, all disciplines gain a new understanding of terminology. Another barrier is the lack of time to move the designed products to the marketplace. Students are encouraged to distribute, market, and pitch their designs to potential buyers or even develop a company to manufacture the innovations. Students are taught entrepreneurial skills, but because the course is only two semesters in length, they must take the initiative to commercialize their products following graduation. However, with continued determination and purpose, the outcomes of multidisciplinary collaborative education are proving to be vastly rewarding for both faculty and students. It is our goal to continue to educate students using more multidisciplinary collaboration and, more importantly, to use those collaborative efforts for innovation to improve the lives of people in need.[14]

The expected course outcomes are to develop the ability to carry out the design process starting with a recognized need, through problem definition and specification culminating with a complete design package including assembly drawings and part prints using a collaborative multidisciplinary approach. Engineering students focus on technical details, specifications, marketability and usefulness of the product. Nursing students evaluate the potential client's physical, emotional and mental health needs throughout the design and implementation process.

Conclusion

The success and longevity of a client-centered, multidisciplinary, multi-university approach to senior capstone design can and should be replicated throughout universities of higher education. Improved student outcomes, client satisfaction and enhanced social responsibility have been some significant findings resulting from this unique educational model. More research will help validate and refine the effectiveness of the program but to date, anecdotal findings confirm the importance and value of using client-centered, multidisciplinary approaches to higher education.

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Appendix

Rubric used by LTU for Needs Finding Presentation is shown below:

	Did not Address	Unsatisfactory	Average	Excellent	Points
Title and Introduction	Presentation Title | Student name | Affiliation Mission Statement | Strategic Focus				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	
Need Statement #1	Background | Client/Patient/Clinician Interview|Observation Problem Identification | Treatment options | Market Analysis Stakeholder Analysis | Structured Need statement				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	
Need Statement #2	Background | Client/Patient/Clinician Interview|Observation Problem Identification | Treatment options | Market Analysis Stakeholder Analysis | Structured Need statement				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	
Need Statement #3	Background | Client/Patient/Clinician Interview|Observation Problem Identification | Treatment options | Market Analysis Stakeholder Analysis | Structured Need statement				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	
Needs Filtering	Needs Ranking | Criteria Used				
	Points Range: 0 - 1	Points Range: 2 - 3	Points Range: 4	Points Range: 5	
Questions and Answers	Willingness to Answer | Quality of Response | Needs Ranking				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	
Presentation Delivery	Enthusisam | Pacing | Eye Contact | Engaging Clarity | Delivery | Timing				
	Points Range: 0 - 3	Points Range: 4 - 7	Points Range: 7 - 8	Points Range: 8 - 10	
Presentation Slides	10 Slides | Graphics | Quotes | Quality Minimal Text | Font Size | References				
	Points Range: 0 - 3	Points Range: 4 - 7	Points Range: 7 - 8	Points Range: 8 - 10	

Rubric used by LTU for Design Concept Presentation is shown below:

	Did not Address	Unsatisfactory	Average	Excellent	Points
Title and Introduction	Presentation Title | Student names | Affiliation Group Mission Statement | Strategic Focus				
	Points Range: 0 - 1	Points Range: 2	Points Range: 3 - 4	Points Range: 5	
Background Information	Client/Patient/Clinician Interview|Observation Problem Identification | Current Treatment options Market Analysis | Stakeholder Analysis				
	Points Range: 0 - 5	Points Range: 6 - 10	Points Range: 11 - 15	Points Range: 16 -20	
Need Statement	Structured Need statement | Balanced | Solution Free				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	
Design Concepts	At least Three Concepts | Design parameters | Approach Use of engineering disciplines | Estimated deliverables Project schedule | Expected outcomes				
	Points Range: 0 - 6	Points Range: 7 - 12	Points Range: 13 - 20	Points Range: 21 - 25	
Concept Ranking	Concept Ranking | Criteria Used				
	Points Range: 0 - 3	Points Range: 4 -6	Points Range: 7-8	Points Range: 9 - 10	
Questions and Answers	Willingness to Answer | Quality of Response Clear & Concise				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	
Presentation Delivery	Enthusisam | Pacing | Eye Contact | Engaging Clarity | Delivery | Timing | Contribution from all members				
	Points Range: 0 - 3	Points Range: 4 - 7	Points Range: 7 - 8	Points Range: 8 - 10	
Presentation Slides	10 Slides | Graphics | Quotes | Quality Minimal Text | Font Size | References				
	Points Range: 0 - 3	Points Range: 4 - 7	Points Range: 7 - 8	Points Range: 8 - 10	

Rubric used by LTU for Final Presentations during first semester is shown below:

	Did not Address	Unsatisfactory	Average	Excellent	Points
Title and Introduction	Presentation Title | Student names | Affiliation | Advisors and Affiliates				
	Points Range: 0 - 1	Points Range: 1 - 2	Points Range: 2 - 4	Points Range: 4 - 5	
Background Information	Client/Patient/Clinician Interview and Observation | Problem Identification | Current Treatment options| Market Analysis				
	Points Range: 0 - 5	Points Range: 6 - 10	Points Range: 11 - 15	Points Range: 16 -20	
Need Statement	Structured Need statement | Balanced | Solution Free				
	Points Range: 0 - 1	Points Range: 1 - 2	Points Range: 2 - 4	Points Range: 4 - 5	
Design Concepts	Short Justification on how it Address the Need | Chosen Design Concept | Design Highlights | Design parameters | Novelty | Estimated deliverable				
	Points Range: 0 - 5	Points Range: 5-9	Points Range: 9-12	Points Range: 12 - 15	
Methods	Projected Simulations, Tests and Experiment to be done | Equipment to be used | Design Validation				
	Points Range: 0 - 2	Points Range: 2 - 4	Points Range: 4-7	Points Range: 7 - 10	
Budget	Table | Justification | Funding Source				
	Points Range: 0 - 1	Points Range: 1 - 2	Points Range: 2 - 4	Points Range: 4 - 5	
Timeline	Milestones | Deadlines				
	Points Range: 0 - 1	Points Range: 1 - 2	Points Range: 2 - 4	Points Range: 4 - 5	
Team Structure	Team Contribution | Task Assignment | Communication |				
	Points Range: 0 - 1	Points Range: 1 - 2	Points Range: 2 - 4	Points Range: 4 - 5	
Questions and Answers	Quality of Response | Clear & Concise				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	
Presentation Delivery	Enthusisam | Pacing | Eye Contact | Engaging Clarity | Delivery | Timing | Contribution from all members				
	Points Range: 0 - 3	Points Range: 4 - 7	Points Range: 7 - 8	Points Range: 8 - 10	
Presentation Slides	Graphics | Quality | Minimal Text | Font Size | References				
	Points Range: 0 - 3	Points Range: 4 - 7	Points Range: 7 - 8	Points Range: 8 - 10	

Rubric used by LTU for Final Presentations during second semester:

	Did not Address	Unsatisfactory	Average	Excellent	Points
Project Overview	Title | Team Members | Project Introduction | Project Goal				
	Points Range: 0 - 1	Points Range: 2 - 3	Points Range: 4	Points Range: 5	
Background Information	Background | Problem Identification | Need Statement | Brief Market Analysis | Design Information				
	Points Range: 0 - 2	Points Range: 3- 5	Points Range: 6 - 8	Points Range: 9 -10	
Methods	Equipment used | Description of Experiments | Testing | Data Processing | Controls Used				
	Points Range: 0 - 4	Points Range: 5 - 8	Points Range: 9 - 12	Points Range: 13 - 15	
Results and Discussion	Includes Results | Explain the Results and Figures | Significance | Sensible Conclusions | Timeline of Project Execution | Deviations from Original Design				
	Points Range: 0 - 7	Points Range: 8 - 13	Points Range: 14 - 20	Points Range: 21 - 25	
Questions and Answers	Quality of Response | Clarity | Concise				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	
Presentation Delivery	Enthusisam | Pacing | Eye Contact | Engaging Clarity | Delivery | Timing | Contribution from all members				
	Points Range: 0 - 4	Points Range: 5 - 8	Points Range: 9 - 12	Points Range: 13 - 15	
Presentation Slides	Graphics | Quality | Minimal Text | Font Size | References				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	
Team Structure	Team Contribution | Task Assignment | Communication | Workload Division				
	Points Range: 0 - 3	Points Range: 4 - 6	Points Range: 7 - 8	Points Range: 9 - 10	

Rubric used by LTU for Poster Sessions during second semester:

	Did not Address	Unsatisfactory	Average	Excellent	Points
Abstract and Project Goal	Points Range: 0 - 4	Points Range: 5 - 9	Points Range: 10- 14	Points Range: 15 - 20	
	Explain: Introductions | Project Goal | Relevance and Motivation | Summary of findings				
Methods	Points Range: 0 - 4	Points Range: 5- 8	Points Range: 9 - 12	Points Range: 13 -15	
	How Data was obtained | Equipment and Instuments Used | Type of Analysis Used | Controls Used				
Results	Points Range: 0 - 4	Points Range: 5- 8	Points Range: 9 - 12	Points Range: 13 -15	
	Includes Some Results | Explain the Results and Figures | Significance | Sensible Conclusions				
Poster Structure	Points Range: 0 - 4	Points Range: 5 - 9	Points Range: 10- 14	Points Range: 15 - 20	
	Quality of Figures | Readability | Layout | Included Sections | Conclusions | Future Directions				
Poster Presentation	Points Range: 0 - 8	Points Range: 9 - 15	Points Range: 16- 24	Points Range: 25 - 30	
	Clarity | Delivery | Confidence | Member Contributions | Enthusiasm | Engaging | Eye Contact				
				TOTAL	