Proto: Constructing a Solution-Oriented Design Network Amongst the UVa Health System and Engineering Undergraduates

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Abstract

In the Fall of 2020, the idea of Proto was conceived and we began developing it further as part of our Biomedical Engineering Capstone project. Our mission was to establish a functional and sustainable network that connected undergraduate engineers with design problems that healthcare professionals from the University of Virginia (UVA) present. In this paper we touch on our rationale behind Proto, our methodology, the key results, and we include a discussion about how those results compare to what we hypothesized prior. Our approach contained network building initiatives, project briefing, project outlines, and measurable, tangible results. The Proto team worked to construct and market the network by utilizing program flyers, student interest forms, existing identification databases, and word of mouth advertising. Projects suggested by healthcare professionals were vetted and refined with the Proto team to form a consolidated project brief that could attract potential engineers. Project outlines detailed step by step what student teams should focus their efforts on according to an associated specifically catered timeline. Checkpoints included Research, Discovery, and Design phases with tangible deliverables following each step. Projects overseen by Proto began in the Spring of 2021, therefore, they are ongoing and in the early stages of the project outline. The results of their projects are undetermined at this time. Project descriptions and the up-to-date progress reports are discussed in this paper. The goal of this paper is to document the methodology that we incorporated into Proto and report its successes and shortcomings, in hope that we can promote and facilitate the growth of Proto and other programs that resemble it.

Keywords: Network, Burnout, Design, Student Experience

Introduction

Healthcare professionals are facing a burnout epidemic with 44% of physicians reporting feelings of burnout[1]. Burnout is a state of emotional, physical, and mental exhaustion caused by excessive and prolonged stress. It occurs when a person feels overwhelmed, emotionally drained, and unable to meet constant demands. The ramifications of this stress is shown by a study from the American Foundation for Suicide Prevention where they claimed that on average, death by suicide is about 70% more likely among male physicians than among other professionals and 250–400% higher among female doctors[2]. There is a large lack of care for our healthcare professionals that has a detrimental impact on the personal health of our caretakers. This epidemic can be addressed, with 44% of doctors crediting their burnout to lack of resources, we sought to devise a plan to care for our caretakers[3]. By constructing a network to connect University of Virginia (UVA) undergraduate biomedical engineering students, with UVA physicians, we worked to take the problems physicians identified in their daily practice to create engineering design projects. The network, Proto, procured 3 engineering projects for 3 teams of biomedical engineering third-year students to research, design, and prototype solutions to assist the physicians we connected with. At the end of the pilot semester, students and physicians have shown interest in the continuation of their

current projects, as well as proposing the construction of three more project teams for the summer.

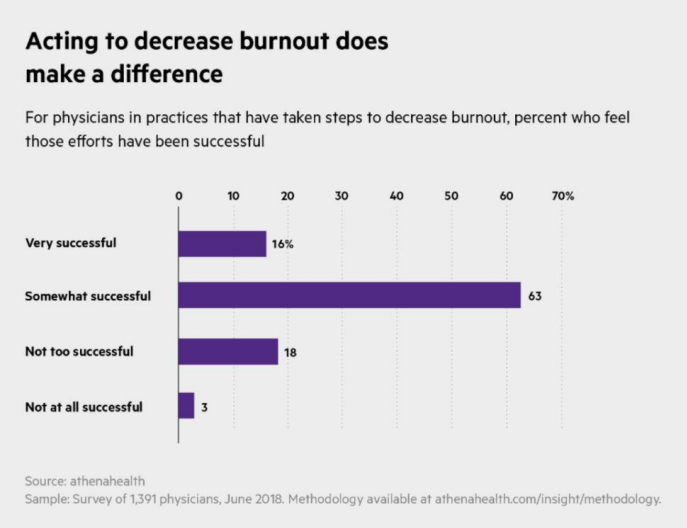

Fig. 1. Acting to decrease burnout does make a difference. Surveyed physicians report that efforts taken to decrease burnout report very highly that the efforts have some effect on their practice. This demonstrates the importance of efforts to care for doctors.

Immense workload of healthcare professionals

Healthcare professionals have long days of patient care that usually continues with on-call help after their work day "ends." Each day of work consists of seeing as many patients as possible, trying to provide the best care for each patient, interacting with work staff and administration, and logging hours of documentation, all on top of their lives outside of work. Geoffrey J. Riley provides an explanation of work stress in Karasek's model of "demand-control-imbalance" for job strain where high work demand with little to no control over changing the situation/outcome leads to high work stress[4]. This is very common with health care professionals, especially doctors, who consistently "experience high intensity of work, conflicting time demands, and heavy professional responsibility, often in systems where physical and social resources are deficient, and there is the ever-present threat of medicolegal action"[4]. This combined with empathetic grief for patient's pain and loss leaves doctors with immense stress leading to burnout and psychological strain. Proper professional and emotional support could improve the health of our health care network, improving care and general wellbeing for the professionals and their patients. The positive impact of efforts to reduce burnout can be shown by Figure 1. Voluntary work from undergraduate students could relieve day to day problems and improve patient care as well as alleviating the workload of health care professionals.

Positive impacts of undergraduate research on students

For students in the STEM field, undergraduate research has been shown to have a great impact on generating interest in STEM careers and Ph.D. program expectations[5]. Undergraduate research has also been shown to increase a wide breadth of skills, with instruction-based research reporting greater skill gains and research with a presentation component reporting greater oral and written communication skill gains[6]. A large part of the success in undergraduate research is attributed to the freedom of direction in research, where students are encouraged to discover how to solve problems[7]. This autonomy allows students to apply their learnings from the classroom to real-world situations and has shown holistic results for their future. A post summer research experience survey conducted by David Lopatto with students representing 66 different academic institutions indicated that students reported gains in independence, intrinsic motivation to learn, and active participation in courses taken after the summer undergraduate research experience[8]. The survey also reported a higher learning gain from underrepresented groups, demonstrating a need for inclusion and diversity in research. Overall, student research experience has demonstrated great results for students' holistic growth to prepare for post-graduate plans and should be formatted to be an accessible and applicable opportunity for any student's interests.

Surplus of skilled and motivated engineers

The University of Virginia has over 17,000 undergraduate students with over 300 students majoring in Biomedical Engineering[8]. A majority of these students are willing to participate in extracurricular activities that enhance their skills and knowledge outside of the classroom. Whether it's volunteering at the UVA Hospital, participating in research labs, or working at BME startups, there is a wealth of students actively engaging and looking for further opportunities to promote innovation and help the UVA community. By capitalizing on the technical and social skills of the undergraduate population, researchers and professionals can tap into this network as a perpetual workforce. One of the major obstacles to this is the lack of transparency between professionals and researchers needs and connecting with students. While there are several resources available to connect the two, many of them are either not well known or the website is hard to navigate.

Consequently, there are unmet needs in the UVA medical department that go unfulfilled due to this disconnect.

Current Innovations

Current undergraduate research networks and design-solution oriented collectives including the Undergraduate Research Network (URN), Undergraduate Student Opportunities in Academic Research (USOAR), Forge formally known as Hackcville, and Engineers Going Global (EGG) lack up to date information on project opportunities, easy access to get involved, administration of projects, and resources for holistic development of professional skills necessary for post-graduate success . These networks fall short in increasing accessibility to design projects due to lack of brand awareness, limited scope of opportunities, and absence of a student mentorship throughout the program. URN and USOAR are oriented towards in-lab research experience, which disregards students' aspirations for technical solution based projects typically found in post-graduate industry work[9,10]. These networks have limited accessibility due to specific application deadlines, scope of projects, and applicant requirements, which compromises their inclusivity for all students looking to pursue research experience. The project-based network of EGG allows for students to pursue solution based design research with direct application, however their scope is primarily based outside of the Charlottesville community, making it difficult to observe direct impacts[11]. Forge tackles the education of professional skills through workshops and classes, along with an internship program that trains students before placing them in a professional setting[12]. But their system falls short with the program only lasting the summer and scoping specifically to computer science with data analysis and UX design, limiting project diversity.

Principles of proposed network

We aim to differentiate ourselves from other research networks through the types of projects we offer, personalized project management, and other opportunities offered outside of projects. Almost every other research network is mainly offering classic in-lab research under a faculty advisor on an ongoing project. We are building a solutions-based project network where students will work together in a Co-op styled project promoting team design thinking. Each project will aim to build student experience in a professional setting while designing a solution that will directly impact the UVA community. Our initial target addressable market is the UVA Health network. We hope to improve the lives and work of healthcare professionals. We also understand that some problems are universal and we will incorporate a project writeup into every group's plan. We will publish results for students to see a complete overview of their work and to provide a solution to anyone with a similar problem.

We are constructing our network with five assumptions as the basis of success for our pilot program. First, that students are interested in independent engineering design projects. Second, that clinicians have projects and ideas in need of engineering student help. These two assumptions are the foundation of project outreach and team formation for our network. Our third assumption is that students want to work on projects with a local impact. Fourth, that biomedical engineering students are deeply interested in a direct advisor connection with clinicians. The validation of the third and fourth assumption will prove our competitive advantage to similar networks and programs, and further validate our student outreach model for the network. Our last assumption is the basis of our work as network builders. We are assuming that students and clinicians are interested in the bureaucratic work we aim to provide in connecting both parties, facilitating meetings, preparing deliverable templates, and more. If we are able to validate all assumptions, then the mission of the network will be fulfilled, as well as secure its spot in the current UVA network.

The circumstances of this year have presented unprecedented restraints for our project. The COVID-19 pandemic has limited our ability to connect in person and facilitate in-person lab time for design projects. The limited access has also removed many resources available to students such as 3D printers, injection molds, waterjet cutters, laser cutters, etc. Additionally, the pandemic has increased the workload and strain on healthcare professionals, leaving less time for meetings. Although these restraints pose limitations, we have worked to build our network around these weaknesses. With limited lab access, students have not been able to continue their previous research and thus are looking for new projects. The increase in available student engineers provides more help for healthcare professionals looking for assistance as their workload has increased. By focusing on computer aided design (CAD) projects, we can still provide students with free education licenses to begin prototyping their solutions virtually. Alternatives to our projects include our plan for a semester not affected by COVID-19. We hope to have students working in-lab together on their design projects and shadowing healthcare professionals in the hospital. On top of this we could implement open office hours in labs to help students learn how to use 3D printers, laser cutters, and

injection molds to expand their professional repertoire. These alternatives provide a plan for future semesters of the program.

Hypothesis

We aim to create a network between the UVA Health and research system and engineering undergraduates to solve real world problems and provide access for students to receive hands-on experience. We think this opportunity is invaluable for students that are aspiring biomedical engineers, and along the way professionals will receive meaningful help. Through our platform, students will connect with health professionals to develop solutions for pertinent design projects. In combination with this network, we will create, maintain, and document engineering design projects in a web format to create an archive of all generated solutions, tutorials, and available projects.

Compared to current research networks in the UVA community, our goal is focused on accessibility and design-centric projects. An increase in design-centric projects will allow for students to get hands-on experience building out their design and seeing a completed project. It also allows for professionals to receive help with problems that arise in the workplace. We believe students are actively searching for design projects and professionals have countless problems that can be solved. They just need a network built to connect the two entities

Aims

Aim 1: Build a portfolio of projects encompassing a variety of design solutions

A. Project acquisition of design problems meeting the interest of engineering students

B. Mobilization of resources to provide students with clear project objectives and tools/skills needed to design solutions

C. Develop deliverables and slide decks to update professionals on project progress

Aim 2: Connect engineering undergraduates and UVA Health and Medicine professionals

A. Actively promote Proto to undergraduate students from all majors through email databases, information sessions, guest presentations, and social networking platforms.

B. Obtain a selection of at least 30 students that are interested in participating in a design-based project through Proto.

C. Collaborate with medical professionals and researchers to identify specific needs and craft a design project that is realistic and will result in tangible results.

Aim 3: Develop a website application displaying project listings and archive of all generated solutions

A. Configure wireframe outlining visual representation that represents structure of website and optimizing user interface experience

B. Deploy website and create informative content regarding Proto's initiative and the past, current, and future projects available.

C. Track website traffic of users and impressions through Google Analytics to measure appeal and attraction for our platform

Materials and Methods

Participants

Our initial interest survey was sent out to all third year BME students through the IDEAS Lab listserv. This target population was recruited for the pilot program of Proto as third year students have completed a year's worth of BME courses and acquired proficiency in technical skills. Of the 127 students, we received 11 responses from the interest form. Three students expressed interest in participating on a project team in the future, while eight students expressed interest for projects beginning in the spring semester. Following the initial interest survey, we sent out a project preference survey, outlining three different projects with UVA physicians and one forum style Personal Protection Equipment (PPE) project. All participants were matched to their first-choice project, with two students working on a project as their Capstone project

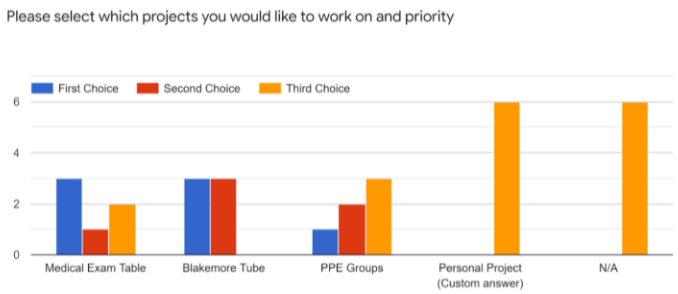

Fig. 2. Student Placement Survey Results. All of the students who participated in the network this semester were able to work on their first choice projects. We aim to continue to have students join their first choice to make sure that every student is passionate about their work.

and three students filling out each of the remaining projects (Figure 2).

Procedures

To communicate the purpose of Proto, we defined the mission statement as: To harness the immense untapped potential of UVA engineering students and identify unresolved design problems faced by healthcare professionals in order to reduce workplace burnout. The mission statement is composed of three categories, first to build a pipeline of engineering students and design solutions addressing healthcare problems. Second, to foster mentorship from healthcare professionals and upperclassmen providing clinical expertise and experience. Third, to create a meaningful experience that facilitates team building skills and impact driven results for a local impact. With this guiding mission statement we designed our procedures for constructing our network through four main steps: Network Building, Project Briefs, Project Outlines, Measurable Results.

Network Construction

At the start of the Fall 2020 semester, we compiled a list of potential contacts that may have design-based projects for students to work on. These individuals ranged from engineering professors to graduate students to physical therapists to surgeons. After reaching out to these professionals, we conducted initial meetings to gather preliminary project information to outline project briefs. These project briefs included the project description and deliverables that prospective students would work on during the spring semester. After developing the project briefs, we sent them back to the clinicians for approval on design guidelines and specifications. We selected three projects from our pool of prospective design problems that clinicians proposed: redesign of the incentive spirometer, reconfiguration of the standard physician examination table, and development of the Blakemore tube training device.

We decided to select 3 projects with 2-3 students filling out each team. With more than 3 students working on a project team, roles and responsibilities may become diluted thus diminishing meaningful learning experiences. The selected projects were chosen based on the most applicable skills and knowledge taught in the BME curriculum. After each project was successfully outlined, these projects were advertised and filled with three undergraduate students per project.

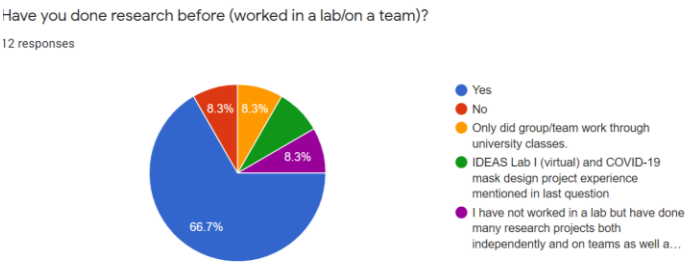

Fig. 3. Student Experience. From our initial student interest survey we asked students several questions, including their prior experience with research. We identified research as a gateway experience to our design projects. Most students who showed interest in Proto have prior research experience. This validates our assumption that students have engaged in research and are looking for a new independent experience.

Fig. 4. Proto Student Marketing Flyer. Above is our student interest flyer that we distributed to a class of 60 3rd year students. The flyer was designed to communicate the mission of Proto in a marketable way to encourage student interest.

Our initial outreach email to third year BME students included an infographic shown in Figure 4, a short summary of our network, and a Google form interest survey. The interest survey inquired student information on interests, prior experience, dream projects, expectations, and start date. This form was used to validate our assumption that students were interested in working with clinicians to solve health related design problems (Figure 3). A follow up email was sent to interested students to complete a project preference survey ranking the three projects. As mentioned previously, each student was placed in their first-choice project, rounding out each project with 3 students. We decided to forgo the forum style PPE project for this spring semester as it received the lowest interest from students, and we wanted to focus our attention and efforts on projects that worked directly with clinicians.

In our initial general body meeting with all participating students, we outlined project guidelines and expectations as well as overviewed the engineering design process. Each project had a curated timeline of deliverables and meetings. Students were expected to meet with the

Proto advisory team biweekly as informal check-ins to give updates on project progress and ask clarifying questions. They were also encouraged to meet with their clinical advisor once a month to present deliverables and utilize clinical expertise. In addition to project expectations, we discussed the importance of the engineering design process. The three phases of the engineering design process were outlined as follows: research, discovery, and design. In the research phase, students will conduct contextual research focusing on history of the device, epidemiology, medical intervention and procedures, user behavior, prior art patent search, and current market options. Students will be able to have a new understanding of clinical problems, to identify market opportunities, and to summarize the background of design problems. In the discovery phase, students will gain a deeper understanding of how the clinical problem affects both clinicians and patients. Lastly, in the design phase, students will begin to construct a solution from background research and customer discovery interviews. Students will spend the most time in this phase of the process to articulate their iterative design process through visual models, computational models, and narratives.

For our first two projects we worked with Dr. Morikawa, the clinical director of UVa Family Medicine, on the incentive spirometer and physician examination table. The incentive spirometry is an industry standard to assist patients for deep inhalation to re-expand the lung and facilitate drainage of secretions. The device plays a critical role in treating patients with respiratory illnesses. Especially with the ongoing pandemic, respiratory illnesses are more rampant among vulnerable populations. It is urgent to develop a new incentive spirometer that is user friendly, intuitive, attractive, and fun to engage to promote continued use of the device. Our other project with Dr. Morikawa is the redesign of the standard physician examination table. Examination tables are staples of any healthcare facility. This medical equipment is essential for patient care and comfort as well as optimizing the productivity of medical staff. The current examination tables found in physician's offices take up almost half the room, are too heavy to move, and are hard for patients to climb up and sit on. The redesign will increase functionality by designing adjustable features to accommodate access to the table as well as promote greater mobility. Our last project is the Blakemore Tube training device, which is a medical device used for treatment of medical complications involving the gastrointestinal tract (GI tract). The project is advised by Dr. Shah, a physician working in the gastroenterology and hepatology division. Correct use and placement of the tube can halt gastrointestinal bleeding caused by esophageal varices. Doctors will employ the Blakemore tube to stop the bleeding and buy more time to appropriately treat the patient. The placement of the tube and inflation of the balloon is a difficult procedure as it is done without imaging guidance. One clinical issue that has been identified is the difficulty of training medical students for this procedure. The Blakemore Tube training device will provide medical students a way to practice the procedure and prepare for any clinical complications.

Results

The beginning of the Spring 2021 semester marked the launch of the pilot semester of Proto, with the three design teams beginning work in February. We have met bi-weekly with each of the project teams to discuss their work as well as talk about any questions they might have in navigating the project, their third-year classes, internships, etc. To have a clear outline of what could be expected as a deliverable, we designed document templates based on the fourth-year biomedical engineering capstone class. Our basis in this decision was to provide the students with work that would directly lead into their capstone the next year. We attribute this success to the fact that each student was assigned to their number one choice project. Since these projects are still in progress, we are waiting on completed data to report on their self-reported satisfaction with the network as a whole. We will also be surveying the advisors to better understand how we can serve them as network builders.

Project Updates

Incentive Spirometer Redesign

Our first project team was the Incentive Spirometer Redesign project under Dr. Morikawa. The project consists of two third-year undergraduate students who are working on this project as their capstone for biomedical engineering. They have an unusual situation as they began their work in what is typically the second semester of the capstone year. This allowed us the opportunity to design their Proto

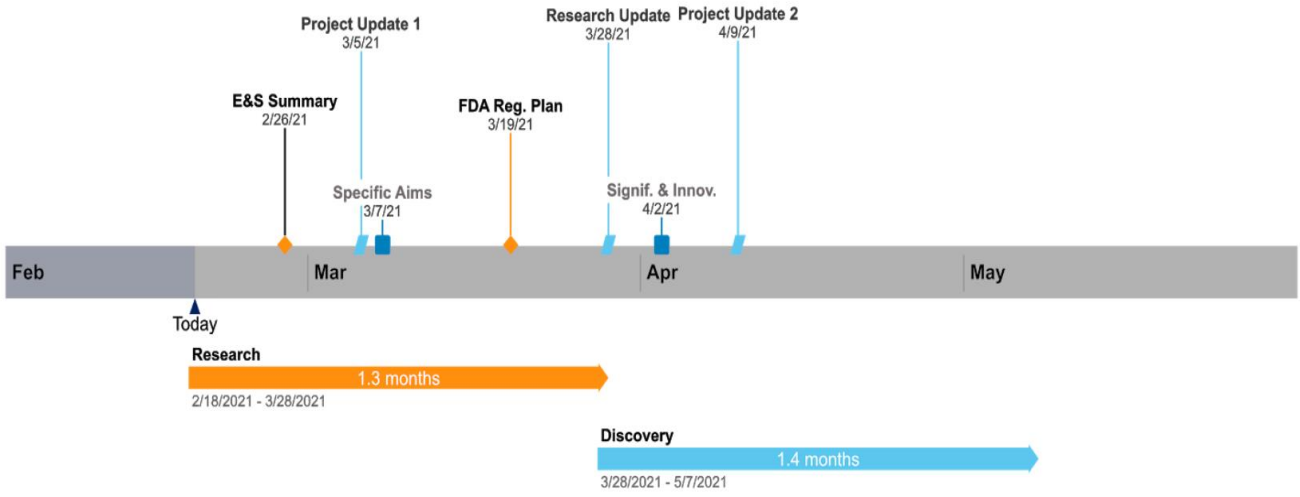

Fig. 5. Incentive Spirometer Team Timeline. To ensure the team's success on their project, we devised a timeline to clearly communicate our expectations as well as the expectations of their advisor and Capstone class. The team expressed interest to continue their work with Proto over the summer, allowing for the Prototype phase to begin in their Fall semester. They have stuck strongly to the timeline as they are about to finish their Discover phase this May. We aim to use this timeline as a template for our other Proto projects.

timeline based on the work we had done for our capstone the previous semester. Their timeline, shown in Figure 5, consists of the deliverables for the Research phase of the design project as the bulk of the semester. However, this team has already completed this phase and is well into the discovery portion of the project. The team meets with Dr. Morikawa once a month and with the Proto advisory team twice a month.

The team is working with Dr. Morikawa to identify a design that is novel and can be effectively prototyped. After multiple sessions with Dr.Morikawa and several customer interviews, they have identified a specific design aspect they wish to improve through innovation. They are currently looking at ways to increase user engagement with the incentive spirometer by redesigning the device to emulate a retro game. While a patient is inhaling the gauges will interact as a game piece. By making the device a fun game, more patients will feel inclined to continually use it. They have begun designing drafts of 3D CAD models by using Autodesk Fusion 360. They plan to print their first prototype this summer to begin early testing and to continue the iterative process.

Examination Table Redesign

The Examination Table Redesign team has met with Dr. Morikawa monthly this semester. They have met with the Proto advisory team twice a month as well. Their current goal is to examine the functionality and feasibility of designing a more sleek and accessible examination table. During our next meeting, we plan to discuss empathic engineering design to further develop the conversation about delivering dignity through design. We think it's an important consideration since Dr. Morikawa mentioned during our initial meeting the hassle and clumsiness patients must encounter when trying to get onto the table. Sometimes elderly patients need additional support to get on the table whether it be by a helping hand from a nurse or a step stool. Empathy driven design will emphasize the importance of user experiences and attitudes to ensure patients are comfortable and at ease during a doctor visit.

The team is currently transitioning from the Research phase to the Discovery phase of their project. They have completed prior art research on patents for existing examination tables and have done market research to identify what is currently available to healthcare professionals. The team is working to interview customers, such as healthcare workers, patients, hospital administration, to better understand how different users interact with the table. Their goal is to have the project's design criteria complete by the summer to begin drafting designs for prototypes.

Blakemore Tube Training

The third Proto team is working with Dr. Shah in the UVA Digestive Health clinic to improve a teaching module for residents learning to utilize a Blakemore Tube. Doctors will sometimes employ the Blakemore Tube to stop esophageal bleeding and buy more time to appropriately

treat the patient. However, the placement of the tube and inflation of the balloon is a difficult procedure as it is done based on the doctor's own knowledge and feel. One clinical issue that has been identified is that training medical students for this procedure is difficult. To address this issue, the team is working to develop a medical device that better simulates the Blakemore tube placement to train medical students at UVA.

The team has met with Dr. Shah and the Proto advisory team throughout their Research phase and identified the user needs and design criteria for the project. They have begun working on their first prototype designs after seeing a tutorial of Dr.Shah using a Blakemore Tube training module that he believes can be improved. Following their visit in April to the cadaver lab with Dr. Shah, the team identified potential design improvements for the module. They are currently working to create a more realistic esophagus to create a teaching experience that better emulates the actual procedure. They are currently designing a CAD model of the esophagus and researching materials that best emulate the mucosa (pink tissue) lining the muscle of the esophagus.

At the end of the fall semester, we began student outreach with our current project portfolio to fill our research teams. We have expanded our outreach this semester to encompass graduate and medical students as well as surgical residents to fill the role of clinical advisors. Currently, we are closely working with a cardiac surgical resident who is willing to be our point of contact to reach these demographics. He has provided insightful suggestions and recommendations on how to adapt our current outreach material to gear it towards clinical advising and novel solution ideation.

Discussion

Proto and the associated capstone work completed this past academic year were focused on developing a successful network where biomedical projects were identified and biomedical solutions were found. This was done with a focus on undergraduate student engagement and health professional outreach. Our results show that we were able to confirm the five assumptions that we set out on for this project.

Students are interested in independent engineering design projects

As discussed, we were able to validate the assumption that undergraduate students are eager to take part in projects that provide them with extracurricular professional experience and something to add to their professional portfolio. We found that the limiting factor was not the ability to recruit students to projects, rather it was the capacity for the Proto team to handle such volume during the early stages of the pilot program. In order to ensure the success of the program it was advisable for Proto to keep the number of projects to a manageable number while logistics are polished during this stage. We have already garnered interest from new students looking for summer design projects.

Clinicians have projects and ideas in need of engineering students

We found that there was not a shortage of healthcare professionals that were eager to join this network and present projects, thus confirming our assumption. The preliminary Proto network reached 23 professionals. This number is estimated to be lower than it would be in a year unaffected by the ongoing coronavirus pandemic. Although we were only able to oversee three projects during the spring semester, we firmly believe that in future semesters Proto will be able to handle a larger influx of project offerings from clinicians. Each clinician has also provided more than three project ideas each and we are currently looking towards expanding our project count with our current advisors as well as outreach to new healthcare professionals.

Students want to work on projects with a local impact

Throughout the spring semester we found that undergraduate students are keen on engaging with the local hospital and community. The projects offered in the pilot program were advertised as a small-scale effort with local healthcare professionals. The lack of corporate structure or brand name did not impact the student interest and commitment we received.

Biomedical engineering students are deeply interested in a direct advisor connection with clinicians

Feedback from our current student engineers overwhelmingly confirmed our assumption that students in biomedical engineering value an advisor connection with a clinician. Students emphasized that the knowledge and insights that clinicians provided on the subject matter were unparalleled to any other information they could find during their research phase. Furthermore, there was an excitement and willingness from each Proto team to take the initiative

to schedule future meetings with clinicians or schedule times for in-person observation or lab visits.

Students and clinicians are interested in the bureaucratic work we aim to provide

Lastly, we were able to confirm the assumption that the work that we put into Proto was appreciated. Students appreciated the foundation that we provided with project goals, resources, advice, and correspondence. Furthermore, clinicians valued our oversight of each project team, whether that be with logistical planning, resource allocation, or troubleshooting questions, they had more time to focus on their primary job.

As alluded to, Proto has its own degree of untapped potential. The work done this past year was in the midst of many obstacles preventing smooth operation. The foundation is set for Proto to continue to serve as a beneficial network to engineers and healthcare professionals, however, we are focused on ensuring that Proto is sustainable. One of the most important next steps in our vision is to complete a website that advertises Proto. Past and current projects will be showcased, new projects will be displayed and seeking attention, and there will be a forum for all individuals to discuss design projects or ideas that they have. Also, as the current Proto advising team graduates we have worked to create a transition for the next advising team consisting of two UVa graduate engineering students. The new team will work to oversee the current projects as well as continuing outreach to draft and staff new teams.

Based on our pilot program, we see the potential Proto has for a lasting impact at UVa. As the network grows, we hope to begin other Proto networks at nearby universities such as Virginia Tech and Virginia Commonwealth University. There is also the need and market to branch outside of biomedical engineering to service other professionals with projects. These avenues can be, but are not limited to, local businesses and non-profit organizations. As the student involvement in the network grows, Proto can grow to service local community engineering problems, that provide accessible design solutions to community members. This branch into industry may create the potential for Proto members to be involved in micro-internships through the network, possibly gaining a professional position from the experience. Lastly, in-line with Proto's emphasis on professional development for undergraduate students, it would be valuable to establish technical workshops led by local professionals, clinicians, and engineers. A large part of the network is to facilitate an exchange of ideas and information that benefits all. We hope for these workshops to be open for members and non-members alike, to come together and learn from each other. The power of this network lies in the connections it facilitates and from the success of its pilot semester, we see great potential for Proto to be a powerful resource for students and healthcare professionals.

End Matter

Author Contributions and Notes

The authors declare no conflict of interest.
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