Diseases, Devices, and Patients: Exposing BME Students to the Patient Experience

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Introduction

> *I appreciated how open-ended this class was. The professors allowed us to research diseases that were important and interesting to us. We were able to grow as students and not just think about the mechanics of a device or the solution to an equation. We had to deeply think about the patient in the scenario of a disease. This was different from any other biomedical engineering class I've ever taken and I deeply appreciated it. I took more out of this class than any other engineering class I have taken.*
>
> *BMEG 472 student, spring 2016*

> *I really hope you continue this course in years to come. I thought it really put our field into perspective. We're not just making devices to aid in the cure. We are making a device to help save a human being. It has truly impacted me on how I will "innovate" and create in the future.*
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> *BMEG 472 student, spring 2016*

Biomedical engineering students are provided with many opportunities to develop a wide range of technical and design skills. Few students, however, explore in-depth the experiences of patients undergoing device-related interventions and treatments. Furthermore, medical device technologies are frequently developed to address patient needs at the point those needs arise. Hence, engineers involved in device design may not be fully aware of the entire pathway the patient has experienced. Patients are all too often treated as business customers.

In senior design-related experiences, students have a plethora of design-related and design-influencing opportunities including clinical immersion to identify potential targets for senior capstone projects [1-4], working with external clinical mentors [5], learning and applying regulatory and intellectual property guidelines [6], conducting rapid design challenges [7,8], and many more [9]. Furthermore, the design experience may be patient-oriented with students interacting directly with patients [10].

One very common aspect of biomedical engineering senior design experiences is the requirement that students summarize the physiology and anatomy relevant to the specific clinical problem of interest. While this background research effort gives the students a baseline knowledge to propose potential design solutions, the students rarely understand the entire disease pathway leading from the patient in a healthy state to the current diseased state that requires clinical intervention. A more in-depth understanding of the entire disease pathway of the patient may provide for a stronger foundation for generating alternative design solutions.

Another common aspect of senior design is the requirement that students incorporate the clinical and physical needs of the patient pertaining to the problem being addressed. This is generally enough information for the students to propose engineering solutions. Missing from this effort, however, is the student understanding the needs of the patient from perspectives beyond the physical needs, i.e., emotional, financial, employment, insurance, etc. A more holistic understanding of the patient may provide for a more effective design process. In the engineering education field in general, a number of investigations have been conducted to explore the relationship and importance of empathy, self-awareness, and social-awareness in engineering students [11-14]. These studies reveal the importance of empathy for effective innovation and engineering design. In biomedical engineering design, a more in-depth understanding of the entire patient experience may provide for more innovative and effective design alternatives.

The efforts discussed in this paper to address the inclusion of the disease pathway and the entire patient experience into the educational opportunities for biomedical engineering students are one step to more effective integration of the liberal arts and humanities into an engineering education. Previous studies have investigated the vertical integration of the liberal arts in engineering education [15] and the incorporation of liberal education into engineering curricula [16-17]. The efforts described in these studies aim to provide engineering students with more than the mathematical and physical perspectives provided in their curricula. Specifically, the goal is to encourage students to incorporate humanistic perspectives in their efforts such that they are considering the human dimensions of the challenge at hand.

In an effort to expand the perspectives of biomedical engineering students, a new elective course offered in spring 2016 was designed to provide students with the opportunity to explore the comprehensive patient experience including disease cause and progression, clinical diagnosis and treatments, and patient decisions and experiences. The course aimed to complement the technical and professional skills our students receive in our hands-on focused curriculum that provides each student with applied exposure to various core areas of biomedical engineering including mechanics, materials, instrumentation, transport, and medical device design. The course was structured to have one introductory and two in-depth projects that provided students with opportunities to explore and integrate diseases, devices, and patient experiences, and to propose novel health care innovations. To gain insights as to the impact of the course on the students, a culminating reflective exercise was also required of all students. Overall, the course, in many ways, was a prototype course consisting of a range of exercises and assignments that could ultimately be used individually in future courses.

The aim in presenting the course to the biomedical engineering community is to encourage other instructors to help their students consider the individual patient perspective of innovations in health care alongside the broad technical, economic, and business perspectives. In addition to presenting details on the logistics of the course and student assessment, summaries of the assignments that could be used in synergy within a course or introduced piece-meal across several courses are presented. Readers are encouraged to contact the authors for copies of the actual assignments.

Course Description

Diseases, Devices, & Patients was offered in spring 2016 as a new, team-taught, elective course to fifteen biomedical engineering juniors and seniors. The course met twice a week for two-hour classes and was designed to be more seminar-like than a technical course. Along with the seminar-like format, the course was purposefully designed to provide students with an extensive amount of latitude within the bounds of the assignments given by the instructors. As will be seen in the actual assignments, students were gradually given an increasing amount of autonomy as the course progressed and this freedom permitted students to choose their own topics, define their own deliverables, seek and document their own sources, etc. Class time was utilized in a manner that balanced instructors leading class-wide discussions and activities, providing guidance to the students on assignments, and permitting student teams to advance their project work.

The course was launched on the first day by having the students break into small teams to play various versions of The Game of Life. This activity was done even before any discussion of the class occurred. The intent was to get the students into an experience where they had to both make 'life-like' decisions and also react to events of chance. With no context given, the students simply enjoyed the activity. When the activity was done, the class had a visitor who was a recent cancer survivor who came to share his story with the class. After hearing about the disease progression, encountered diagnosis methods and treatments, and his personal experience, the class was asked how they could change The Game of Life to adapt to this guest's story. Immediately, the students began to see how complicated it is to overlay all of the disease steps, experiences and technologies that are intertwined in the treatment of disease in a patient.

Following this introductory activity, the instructors provided an overview of the course and announced the first project, which would be to look at the disease, device, and patient pathways for a specific disease. This was the first of the three main projects in the course, which are described below. Readers are encouraged to contact the authors for copies of the actual assignments.

Introductory Project

Following a class visit by a cancer-surviving individual who provided an in-depth, personal overview of his cancer experience, the students were tasked with exploring distinctly the disease pathway, intervention/ device treatment pathway, and the patient pathway for either breast or prostate cancer. Each student selected which of the two types of cancer s/he would explore. Overall, this introductory project had several underlying goals that aimed to lay a foundation for the entire course. First, this introductory project was to provide opportunities for the students to build skills in examining the disease, device, and patient pathways of cancer. In subsequent projects, students would further refine their skills and apply them to other diseases. A second goal was to have their examination of each of the three areas be conducted in isolation such that the interdependencies of the areas would not detract from the skill building. The examination of how the three areas interact would be in the following two projects. Finally, having all of the students focus their introductory project on cancer provided some boundaries for their efforts and permitted the instructors to more readily identify good practices and approaches. Overall, the introductory project was created to get the class on the same page and set the tone for the class before venturing into a wide range of diseases in the next two projects.

The students began this introductory project by individually drafting a 20-step disease pathway for the specific form of cancer chosen with the pathway progressing from the onset of the disease to the death of the patient. The students then came to class with their pathways and formed teams with the goal of creating a master, draft disease pathway. This pathway was termed the "Do Nothing" disease pathway as specific treatments or interventions were not considered. In the next assignment, each student created an annotated slide that displayed the student's final "Do Nothing" pathway along with detailed information about five student-selected steps of the pathway. Additionally, to seed thoughts for the next assignment related to device-based interventions, students were required to identify five common interventional points where a diagnostic or treatment is frequently utilized. Overall, this "Do Nothing" pathway exploration required each student to explore the disease in a T-shaped effort as each student explored both the breadth of the steps of the disease pathway along with diving deep into particular steps of the process. An example "Do Nothing" pathway is shown in Figure 1.

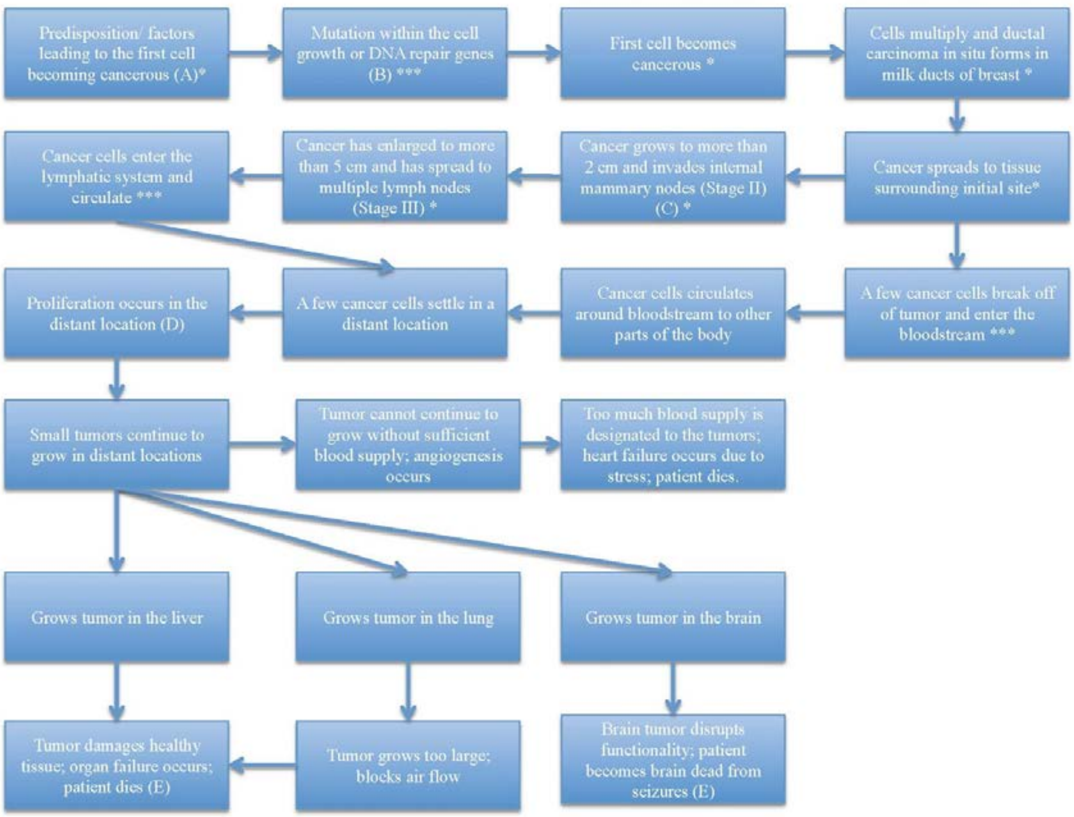

*Figure 1. Example "Do Nothing" pathway for breast cancer. Capital letters, e.g., (A), indicated steps for which students wrote in-depth summaries. * indicated common intervention points and *** indicates a proposed, new intervention point.*

With a general understanding of the disease pathway acquired, class time was utilized in small-group and large-group fashion to draft a rubric-style "Intervention Evaluation Tool", or IET, which could be used to evaluate potential interventions in the cancer disease process. In small teams, students first identified potential components of such a rubric and then, as an entire class, students voted with sticky notes to identify the components that most students believed should be included in the IET. Some of the components receiving a significant number of votes included reliability, risk, cost, success rate, and invasiveness. With this tool, each student returned to his or her disease pathway to identify ten potential interventions from which the student chose five for use with the IET. Evaluation of the five with the IET required students to identify and cite reliable sources to support their analyses. As a reflective portion of the effort, each student was also required to provide an overall analysis of the IET itself and comment on any suggested modifications, deletions or additions to the tool. The final step of this process was for the students to meet back in their groups in class to create a final IET to be presented to the class. Overall, this device or intervention pathway effort provided the students with the opportunity to identify common intervention points, use a class-derived tool to evaluate the interventions, and reflect upon the usefulness of the evaluation tool.

To conclude the Introductory Project, the students next applied their efforts to begin understanding the pathway the patient follows while undergoing a cancer diagnosis and treatment. The goal of this effort was less about understanding the patient experience from a business or technology design perspective, but much more about actually understanding what it is like to be a patient with cancer. Following an introductory discussion in class on what steps of the disease and intervention pathways would be most challenging to patients, students explored what feelings, decisions, conversations, events, etc. patients might experience along the disease and intervention pathways. Students were encouraged to explore the various aspects of the lives of the patients that could be affected such as finances, jobs, family, physical abilities, social interactions, etc. After creating a sequence of at least fifteen of these feelings, events, etc., the students identified three potential personal questions patients may ask at two of the fifteen points and potential resources the average patient might consult to find answers. To wrap-up their efforts, each student wrote a 15 to 20 line dialog between the patient and some other person (e.g., family member, financial advisor, boss, doctor) in which the questions were asked and realistic and factual answers were provided. Overall, this patient pathway effort was designed such that the students began to understand and, in some ways, assume the role of the cancer patient and to see the actual effects of a disease in a way that they likely had not experienced or considered previously. An example patient experience pathway is shown in Figure 2.

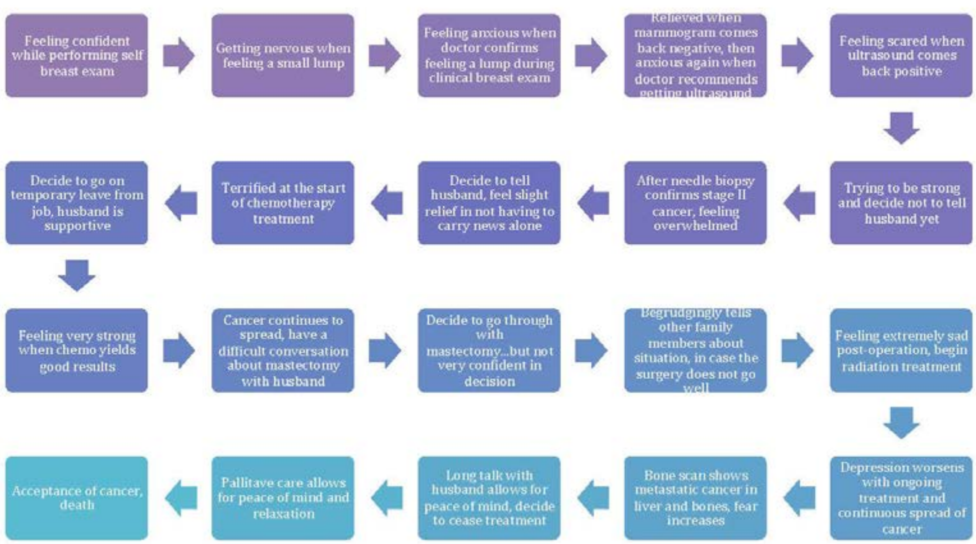

Figure 2. Example patient experience pathway for breast cancer.

At the conclusion of the Introductory Project, students had gained in-depth experience in how to examine the disease, intervention, and patient pathways associated with a disease. With these experiences and the associated tools under their belts, the class then advanced to Project 1 in which students would use these experiences and tools to explore a disease of their own choosing.

Project 1

Unlike the introductory project, Project 1 was structured with the ultimate goal of having the students demonstrate the effective integration of the disease, device, and patient pathways into a single coherent perspective. In moving into this project, the instructors aimed to have the students build upon the experiences and tools gained in the Introductory Project and apply them in a more autonomous effort. Specifically, students were given the option to work individually or in small teams to conduct a deep exploration of a disease of their choosing along with the associated device interventions and patient experiences. The instructors hoped that the students would implement the tools from earlier in the class and also take creative advantage of the opportunity to create a unique deliverable of their own choosing. Teams were encourage to move outside the usual bounds of what are typically considered engineering deliverables. As in the Introductory Project, the students progressed through the disease pathway, the device/intervention pathway, and finally the patient pathway. New to this project, however, was the integration of the three pathway, with this integration revealed in the final deliverable.

Project 1 began with the students identifying the diseases on which their teams (or individual students for those working alone) would focus. Their efforts were stimulated by asking the teams to discuss as a group any illness symptoms the team members had experienced in the past few months. With a list of these symptoms, the team then identified diseases that could realistically cause a patient to have one of the symptoms on the list. For example, if a member of a team had a bad cough in the last month, the team could explore emphysema or other respiratory diseases. Students were encouraged to analyze several possible diseases and then choose one that would lead to a rich learning experience. With the disease identified, disease pathways were created and each team was required to then identify a certain component(s) of the pathway for the creation of an oral deliverable of some kind that showed the team's deep dive into that component(s). After identifying the component(s) to be examined, the team chose who their target audience would be knowing that the audience could not be someone studying engineering, physics, science, or medicine or someone who is a engineer, physician, scientist, etc. An example of a deliverable for this assignment is a children's book designed to explain the basics of Parkinson's to a child (see Figure 3).

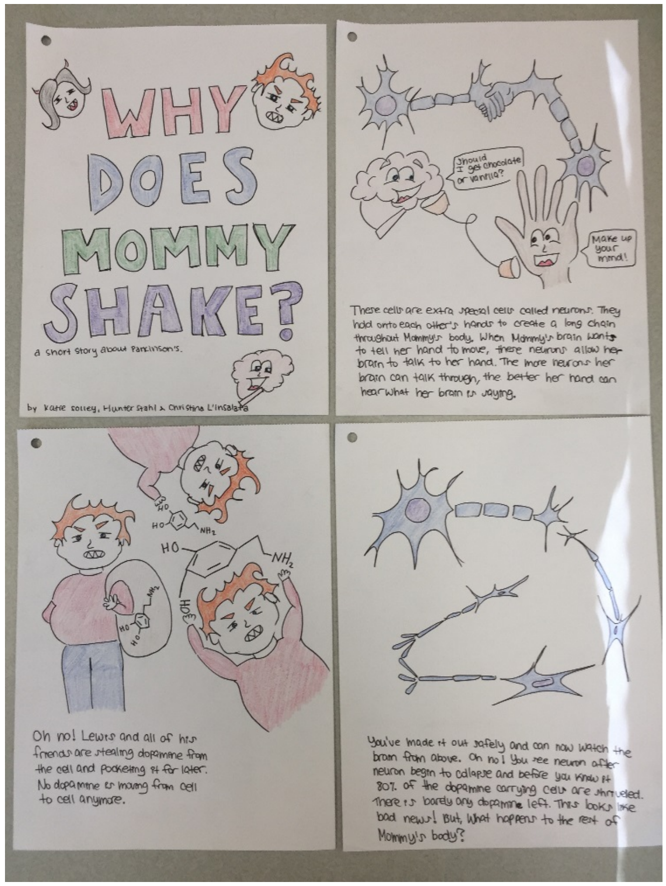

Figure 3. 4 of 17 pages from a children's book aimed at explaining Parkinson's disease to a child.

Following the exploration of the disease, the teams investigated relevant potential diagnostic or interventional devices associated with the disease. To provide the students with a new perspective in comparison to that experienced in the introductory project, teams were tasked with presenting, in oral form, an informed skit to the class. This skit was required to display a realistic technical conversation between a senior technical representative from a medical device company and a clinical engineer in a clinical department. The goal of the skit was for the senior technical representative to be able to demonstrate that s/he is an expert on the chosen interventional device though technically accurate conversations and student-created promotional materials, e.g., pamphlets. Two pages from a pamphlet on a neurostimulator are shown in Figure 4.

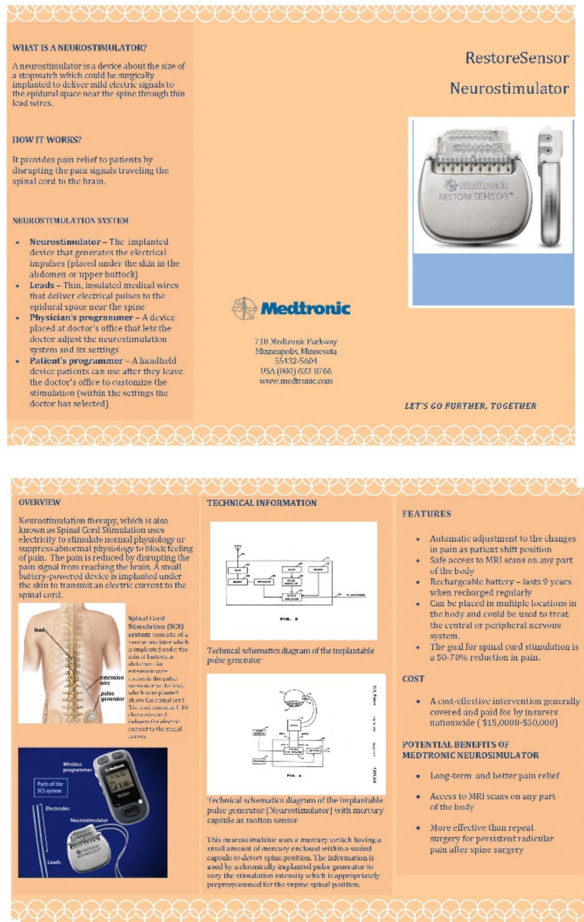

Figure 4. An example pamphlet for a neurostimulator.

With the disease and device pathways explored, the patient pathway or perspective was investigated next. For this effort, students were asked to draft one paragraph personas of fictitious patients who might be going through the chosen disease. Details in the personas included name, age, gender, occupation, location, work, health care coverage, family, and more. With the persona, each student then hand-wrote six one paragraph journal entries that focused on the patient's personal experience at varying points along the disease pathway. The entries were to be meaningful yet realistic in demonstrating a range of emotions, physical reactions, positive and/ or negative experiences, reflective thoughts, roller coaster emotions, empathy, depression, elation, anger, etc. An example of a written journal entry is shown below in Figure 5. Following the written entries, each student was required to convert two of them into one to two minute video journal entries. Students were expected to get into character and film the videos alone in a casual setting. In class, each student shared one video journal entry of their choice with the entire class after providing the context of the situation first. Recognizing that many of the students had taken the assignment seriously and potentially made themselves vulnerable in a class-wide viewing, the instructors laid out expectations of professionalism and respect before any of the videos were shown.

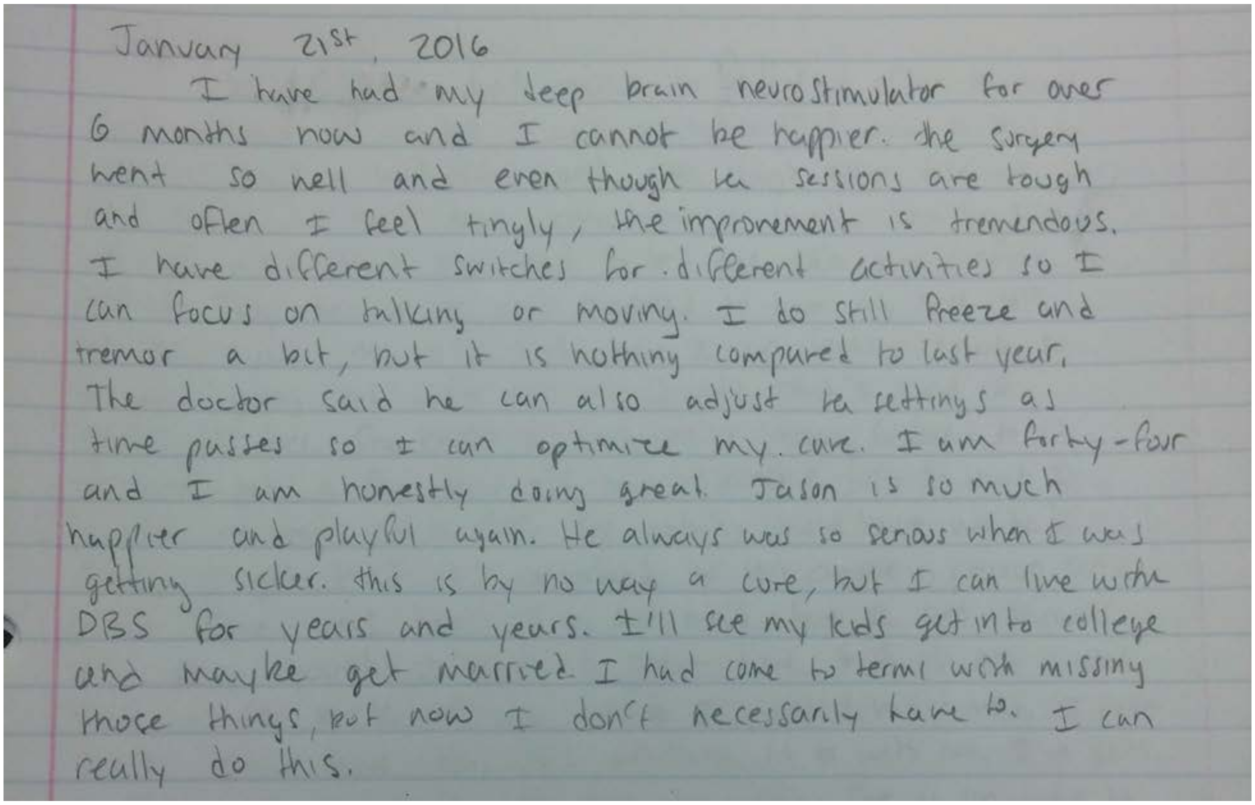
January 21st, 2016
I have had my deep brain neurostimulator for over 6 months now and I cannot be happier. The surgery went so well and even though the sessions are tough and often I feel tingly, the improvement is tremendous. I have different switches for different activities so I can focus on talking or moving. I do still freeze and tremor a bit, but it is nothing compared to last year. The doctor said he can also adjust the settings as time passes so I can optimize my care. I am forty-four and I am honestly doing great. Jason is so much happier and playful again. He always was so serious when I was getting sicker. This is by no way a cure, but I can live with DBS for years and years. I'll see my kids get into college and maybe get married. I had come to terms with missing those things, but now I don't necessarily have to. I can really do this.

Figure 5. Example written journal entry.

Unlike the introductory project, Project 1 was to end with a final, oral deliverable that demonstrated the effective integration of the disease, device, and patient pathways. The only guidelines were to demonstrate how the three areas of expertise gained (disease, device and patient) weave together into a single coherent perspective. After proposing and vetting three potential deliverables with the instructors, students selected the final approach to the assignment and then worked to prepare for the final deliverable session. In addition to inviting faculty from outside the course, students were required to invite, and have attend, a student from outside the engineering college. Example final deliverables included a presentation on Multiple Sclerosis followed by a Jeopardy-like game to ensure audience retention of information presented and a 60 Minutes style video explaining Odontogenic Keratocysts.

Project 2

The final project in the course required the students to work in teams to propose health care innovations that could be interventions ranging from drugs, devices, procedures, policies, and regulations to educational and training modules. These innovations were required to clearly map back to the disease, device, and patient pathways for the chosen disease. In addition to a 20-30 minute final engaging presentation showing the proposed innovation and the integration of the three pathways, teams were also required to submit a concise yet in-depth research report on the proposed innovation including the potential value of the innovation. Example innovations included a proposal for a policy to reduce hospital acquired infections, a plan for first-aid educational programs for children, and a plan for a new non-profit health care organization aimed at tackling health-related challenges of refugee camps. Teams were evaluated by the instructors on their expertise developed, synthesis efforts, and creativity in the final oral deliverable to which each student was required to invite two non-engineers.

These projects covered a five-week span with the students completing periodic assignments along the way to ensure progress and consultation with the instructors. Class time was utilized for a range of activities including class-wide discussions, team-based activities designed to improve student skills, and class-wide review/ presentation of products of the periodic assignments. After vetting several ideas for the project, teams submitted a project proposal that outlined the innovation of interest, an overview of the final oral deliverable, and identified four individuals the team could contact for relevant background information. Another example of the periodic assignments was a requirement that teams submitted a research-based report demonstrating that the team has acquired in-depth knowledge in areas related to the health care innovation. The final oral deliverables, with non-engineering peers of the students again in attendance, were given over two classes at the end of the semester.

Wrap-up Project

With the final major project concluded, the students were asked to conduct one more project for the class. In looping back to the first day when the students broke into small groups and played various versions of The Game of Life, student teams were challenged to purchase a common board game of their choice and convert that game into a health care related game. The game could have opportunities for decisions, chance occurrences, various patient outcomes, disease identification, etc. While this provided a creative and entertaining outlet for the students to apply their skills acquired in the class, the teams took the effort seriously and presented several very effective and background research informed games. Two examples include:

1. Disease Jenga: The students divided the Jenga blocks into two groups and assigned a color (red or blue) to each block. The red blocks related to multiple sclerosis and the blue related to cancer. With the blocks assembled in the Jenga tower, two teams would alternate removing blocks according to the disease assigned to the team. When a block was pulled, the team had to read the information on the block. This information could relate to disease setbacks, e.g., experience challenging radiation therapy for cancer that requires the team to pull more blocks and thus increases the chances of losing the game. Some blocks related to having good days and skipping subsequent terms and thus increasing the chances of winning. With the accurate information on the blocks, someone with little knowledge of the diseases could gain basic knowledge in an entertaining fashion.
2. The Ups and Downs: This game was a modified version of Chutes & Ladders where the students reworked the board to relay the various steps of the disease, treatment, and patient pathways related to breast cancer. While some squares related to chemotherapy treatments or cancer metastasizing, others related to personal event such as marriage or improved health insurance. The player who ‘won’ the game received a cancer cured diagnosis.

The games were presented on the last day of class and played by each of the other teams in the class. Overall, this activity proved to be an effective, entertaining, and informative method for wrapping up the course. Each student gained additional knowledge about diseases, devices, and patients that were generally unknown in great detail to them before playing the games.

Course Assessment

Three primary mechanisms were utilized to evaluate the effectiveness of this new, elective course offered in spring 2016. These include course and instructor evaluations, instructor observations, and student reflection assignments.

Course and Instructor Evaluations

At the end of the course, electronic IDEA course evaluation (http://www.ideaedu.org/) surveys were administered to the students in the class. These evaluations included both likert scale questions as well as open-ended questions to which the students were able to provide types answers.

In one part of the evaluations, the instructors were required to identify three of the provided, generic learning objectives as being essential to the course and three that were important to the course. The six selected objectives and the numerical results are shown in Table 1. The Likert scale scores relate to the level of progress which the students felt they had made over the course (1 = no progress to 5 = exceptional progress). Overall, the students felt that they made substantial to exception progress on the essential objectives and substantial progress on the important objectives. As the assignments in the course were specifically designed to require the students to ask questions, find, synthesize and apply information on diseases, and deliver creative products to demonstrate their acquired knowledge, the positive results on the essential objectives reveal success in these areas in the eyes of the students.

Table 1. Numerical Course Evaluation Results for Essential Learning Objectives

Essential Course Learning Objectives	**Ave. Score**	**Std. Dev.**
Learning how to find and use resources for answering questions or solving problems. (ESSENTIAL)	4.6	0.5
Developing creative capacities (writing, inventing, designing, performing in art, music drama, etc).(ESSENTIAL)	4.3	1.0
Acquiring an interest in learning more by asking my own questions and seeking answers. (ESSENTIAL)	4.3	0.6
Gaining factual knowledge (terminology, classification, methods, trends). (IMPORTANT)	4.0	0.9
Learning to apply course material (to improve thinking, problem solving, and decisions). (IMPORTANT)	4.1	1.2

Developing a clearer understanding of, and commitment to, personal values. (IMPORTANT)	3.8	1.1

(1 - no progress, 2 - slight progress, 3 - moderate progress, 4 - substantial progress, 5 - exceptional progress)

In addition to evaluating the progress made toward the learning objectives, the evaluations also included a range of questions about the course and the instructors. These results are summarized in Table 2. Overall, these evaluations display the positive view of the course held by the students. The instructors are especially encouraged by the level to which the students felt the instructors encouraged them to think deeply. As this course is not one dominated by equations and technical concepts that can require students to think hard, the perception of the students that they had to think deeply may indicate the success of the course to guide the students into thinking more deeply about the non-technical sides of health care.

Table 2. Numerical Course Evaluation Results Course and Instructor Evaluation

Essential Course Learning Objectives	**Ave. Score**	**Std. Dev.**
The instructors displayed an interest in students and their learning	4.8	0.4
The instructors demonstrated the importance of the subject matter.	4.8	0.4
The instructors introduced stimulating ideas about the subject.	4.4	1.1
The instructors encouraged me to think deeply.	4.7	0.6
The instructors provided timely feedback on tests, reports, projects, etc. to help students improve.	4.5	0.7
The instructors encouraged student-faculty interaction outside of class.	4.5	0.7
Overall, I rate this course as excellent.	4.3	0.6

(1 - strong disagree, 2 - disagree, 3 - neutral/mixed, 4 - agree, 5 - strongly agree)

In addition to the numerical evaluations, students were also asked to provide written responses to several questions as a continued evaluation of the course. When asked what elements of the course and instruction were most helpful in accomplishing the learning objectives, themes that arose in the students comments included their appreciation for:

- Being able to choose their own topics
- Learning from other students projects
- The opportunity to learn on their own
- The open-endedness of the assignments
- Seeing the patient perspective of medical devices and health care.

When asked for any recommendations on how to improve student learning in the course, the most common theme was that the students would like for the professors to make the assignments a bit less open-ended so that the students would have a stronger sense for course expectations. While this does contradict the earlier statements by the students expressing their appreciation for the open-endedness, the instructors have discussed ways to perhaps provide more guidance including reviewing an example analysis of a disease to start the course or by providing tighter boundaries on potential deliverables. Some students also expressed a desire for more traditional lecture style classes in which more technical material could be presented by the instructors. Additionally, a few students indicated that the biggest flaw with the course was that they felt that they were doing the same thing over again as the used the same approach on all three projects. Based upon the students' responses provided in the final comments section of the evaluations, most of the students enjoyed the class and recommended that it continue, all or in part, in the future in the biomedical engineering curriculum.

Instructor Observations

When designing this course, the instructors had a clear goal of expanding the viewpoint of biomedical engineering students beyond the development of health care technologies. The aim was to provide students the opportunity to identify, research, and synthesize the ways in which health care technology development is intertwined with the underlying disease states as well as the patient experience along the disease pathway. To accomplish this goal in a manner that permitted students to be heavily invested in their work, the instructors designed the course to be a very much self-guided and self-learning experience for the students. At the conclusion of the course, the instructors made several observations about the course and its impact on the students enrolled.

First, the instructors observed repeatedly in the course that the students 'fed' off of each other's work. Whether it be through the interactions between team members or the observations of the efforts of other teams, the students gained exposure to additional perspectives beyond their own. And with each student and/ or team having a fair amount of latitude in the projects, students gained more from the other students as the personal investment of each student and team raised the impact and quality of the work. In short, with students working on diseases of their choosing or presenting in ways of most interest to them, the impact on the class was observed to be greater. This observation correlates well with some of the comments made by the students in the course evaluations as well as the final course reflection assignment.

When starting with the cancer-based introductory project, the assignments required of the students were much more structured than those in the subsequent projects. This was done to provide a framework for the students to develop the skills needed to analyze the disease, device, and patient pathways. The goal was that the students would then 'run with these skills' and work in a more intrinsic fashion in the latter projects. From the observations of the instructors, many of the students did, in fact, take the gained skills and delve deeply into their work. One great example of this was the video diary entries where many of the students 'became the patient' in terms of emotions, actions, speaking, and content. Furthermore, in relation to the previous observation of students learning from other students work, observation of the class during the watching of the video diaries revealed the genuine impact these videos had on the class. This impact was both an appreciation for how 'into character' some students went as well as the simple emotional impact of the videos.

Finally, the instructors observed the positive effect of the active and project-focused classroom structure. Nearly every day in the class involved students arriving at class with some initial work completed, e.g., draft of a disease pathway, which was then integrated into small group and entire class activities. These activities ranged from content review, to discussing underlying thought processes, to conducting reflections on the meaning of the work. Following the activities, the students would typically leave each class with a draft or starting point for the next assignment. This type of classroom provided for a very dynamic environment in which nearly every student was engaged in every class session. While some comments in the course evaluations revealed a desire for some lecture-style classes, the instructors are considering potential locations in the course where this approach may be effective in relation to student learning.

In the future, the instructors and their colleagues in the biomedical engineering department aim to explore ways to either offer this elective course on a regular basis or incorporate aspects of the course into required courses in the curriculum. Potential improvements for the course include creating actual clinical connections for the students to better inform their efforts, creating an assessment tool for more effectively tracking the depth of the students' efforts throughout the projects, and exploring the potential for incorporating effective lecture-style experiences for the students to better guide them in their pathway investigations.

Student Reflections

The final individual assignment in the course was a course reflection exercise that required students to reflect on how this course has likely affected their ability to make health care-related decisions in the future. Furthermore, the students were asked to consider these future decisions in three roles: 1) as a health care innovator, 2) as a patient, and 3) as a supporter or caregiver for another person traveling along a disease pathway. The students were also encouraged to reflect on how this course may or may not have had an effect on their current approach to their own health care or their approach in the near future.

From the perspective as a future innovator in the health care arena, many students provided reflective comments on how they would work to be sure to integrate the needs, emotions, etc. of the patients for which the innovation is targeted. Some acknowledged that they had never been required or encouraged to incorporate this perspective into their engineering work. Overall, the course appears to have had a strong impact on the students as a whole in terms of exposing them to the humanistic side of health care innovation. And this impact was not just from the business or design perspective of health care technologies, but also from the raw and emotional experiences a patient may undergo. One student expressed her new found perspective that while students generally consider how to 'cure' a disease, the exposure to the patient perspective in the course revealed to her the great value a patient can derive from an innovation the simply makes one step of the disease path easier for the patient. Another expressed how she felt this course will make her a better physician as she heads off to medical school. And yet another student expressed:

> *After taking this class, it is much more obvious how an engineer's decisions actually affect patients. I feel it is easy to get caught up in the engineering design process, trying to make everything work faster and cost less money, but at the end of the day the only point of being an engineer is to help people, and if you lose sight of that you may do more harm than good.*

When asked to reflect from the viewpoint of the patient, many of the students indicated that since they had not personally experienced any significant medical issues personally or in their family, their experiences in this course revealed to them the true challenges patients experience. These challenges ranged from simply finding valid sources of information to dealing with the raw emotions of a patient to being a patient who has to tell a loved one that you have a life-threatening disease. A few students did reflect very deeply on their own personal health care experiences. Overall the students appeared to have realized that they gained a deep perspective for what a patient goes through. Exercises such as the video diaries seem to have had a valuable impact in that students had to assume the role of the patient. One student commented:

> *Having to write and record those journal entries for the first project really struck me for a reason I couldn't quite put my finger on. Even though it was all being done by taking on the persona of a fictitious person, it got me thinking about what it is that these people go through and how each day can be a completely different journey. At the time, I wasn't sure that the assignment would really add anything to the project, but when I was doing it, I actually started tearing up.*

The final perspective was that of a supporter or caregiver. While not a majority of the class, a few students commented on how, even though they had already gone through or were currently going through a family illness where they were acting as a supporter, this course had an impact on them. One student who is currently supporting a parent with dementia issues commented "*I truly think the original cancer assignment helped me because I was then able to do similar research on dementia and Alzheimer's to get more information.*" Another student who had supported her mother through breast cancer commented that "*Nobody realizes it until they're in that position, but being a caregiver for someone you love is not as easy as you think. This class also made me realize this when we did our project on Parkinson's disease.*" Many students commented on being dedicated to researching any health care situation of a loved one so s/he could be an effective supporter and be an informed health care decision maker. One student, however, took it one step further that many students did not see. Her comment was:

> *In the future, I will make the decision to invest myself in learning about any disease a loved one may have so that I can offer as much support as I can. This decision can be daunting and terrifying, because you will learn about the possible outcomes of the disease and pathways it can take.*

This student recognized that while gathering as much information as possible can be one way to support someone, it also comes with the price of knowing all of the potential outcomes.

Conclusions

As modern health care moves in the directions of value-based health care and personalized medicine, engineering curricula should be structured to provide students with opportunities to 'see the bigger picture' of their technical work. High-tech, expensive solutions to health care challenges that produce mediocre efficacy or detrimental patient effects will likely be viewed less favorably in our health care system. Additionally, with the ever-increasing goal of personalized medicine in many clinical arenas, design engineers will be closer and closer to seeing technologies delivered to the individual patient and, therefore, seeing and interacting with the actual person receiving their designed technology.

This new, elective course was a prototype course aimed at introducing students to the humanistic side of health care and health care innovation. Through the development of skills for analyzing the disease, device/ intervention, and patient pathways, students were able to both explore all three areas and integrate their acquired knowledge to understand the overall complexities of health care disease situations. While progressing through the three projects, the students became more independent and self-guided in their work, which was appreciated by many of the students in the course. Based upon the course evaluations, instructor evaluations, and the student reflections, this course has had an effective impact on the students as they venture into a wide range of health care related careers and/ or as health care consumers themselves.

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