AC 2011-473: AN INNOVATIVE INTERDISCIPLINARY STUDENT PROJECT: ENGINEERING AND NURSING

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An Innovative Interdisciplinary Student Project: Engineering and Nursing

Abstract:

Typical projects involving engineering students identified as 'interdisciplinary' usually involve different disciplines within engineering. Projects that are truly interdisciplinary can be discovered when faculty from different areas of campus work together toward the development of a project involving students from outside their respective discipline. This paper presents results of one such arrangement.

During a tour of a new nursing laboratory, engineering noticed possible design improvements in various manikins (life-sized anatomical human models) in the nursing laboratory. A team of first year engineering students was given the opportunity to work with an upperclassmen engineering student, all with an interest in biomedical engineering and faculty from nursing and engineering toward design improvement in Noelle™, a manikin who simulates birth through both cephalic presentation and malpresentation; head or feet first.

The students were charged with nearly all aspects of the project including preparing a proposal, documenting progress, reporting to faculty and community on the status of the project and a final poster presentation and engineering report.

The final project involved two specific redesigns. First, a microphone that simulates fetal heartbeats was repositioned and rewired since the cords were often damaged during the birth simulation. Second, both the umbilical cord and its attachment point to the baby manikin was redesigned because the original attachment point weakened the umbilical cord and often led to a broken and unusable cord. The attachment into the baby manikin was fitted with a push-lock connector and the free end of the umbilical cord was capped off in order to fit comfortably into the new attachment point.

This report offers information to allow similar Universities, especially those without a formal biomedical engineering undergraduate program, to explore the implementation of similar interdisciplinary projects. It includes a description of the working arrangement between faculty in nursing and engineering with the student team of engineers, description of deliverables from the student team, results of the design implementations, and discussion of professional skills developed through the process. The report will also include testimonials from the students with a self-assessment of the value of the project.

Biomedical Engineering options at a small, private university:

Ohio Northern University, like other smaller, private Universities, has engineering programs in Electrical and Computer, Mechanical and Civil Engineering. Students with an interest in Biomedical Engineering are offered two alternatives: a Biomedical Option (through Electrical or

Computer Engineering) or a Biomedical Sciences minor (through Mechanical Engineering) [1]; both options offer students an opportunity to take coursework and some laboratory work in the biomedical area well into their plan of study. Implementing a full scale biomedical engineering program is not feasible without significant additional recourses or an affiliated medical school. There is little opportunity to work in a laboratory setting on projects related to biomedical engineering in the first year of study, as is the case for most if not all engineering programs.

Engineering faculty met with faculty from the Department of Nursing while pursuing opportunities for undergraduate student research projects and, together, an undergraduate research and development opportunity was formed.

Department of Nursing

The undergraduate baccalaureate nursing program at Ohio Northern University was initiated in 2005 and most recently became its own department. This program has identified strong academic offerings and is currently accredited nationally through the Commission on College Nursing Education (CCNE). The program moved to new facilities and established new laboratory spaces and equipment. The nursing laboratories are outfitted with many innovative pieces of nursing equipment including the use of low to high fidelity manikins. The manikins contribute to student learning as each mannequin has heart, lung, and bowel sounds in addition to being able to instill or remove body fluids from multiple orifices.

Laboratory, facility and curricular upgrades allow the ONU department of nursing to improve student learning, recently cited as one of four recommendations by the Institute of Medicine [2].

During a tour of the new nursing facilities, a birthing manikin was demonstrated. Two potential design flaws were immediately evident to the engineering and nursing faculty members. First, a speaker used to create the sound of a fetal heartbeat was wired to a control box very close to the mechanism which pushes the baby during delivery. The second was the attachment of the umbilical cord to the baby: as the baby rotates inside of the manikin, excessive force can cause the cord to rip out of the baby, causing damage to the cord. Rather than a redesign, the manufacturer offered umbilical cords and speakers for sale to replace damaged units.

Establishing the undergraduate research project:

The redesign offered a distinctive opportunity for a student project. Since this was a unique opportunity, it was decided:

- The project would be offered outside of any coursework rather than implementing it as an independent study or similar course
- No pay or credit would be offered
- The rewards would be intrinsic: the opportunity to learn via a self-directed project and the potential of presenting your results.

Identifying interested students:

The lead engineering faculty member emailed the faculty involved in different biomedical options in the college, asking for a few names of students who may be interested and had the ability to lead an extracurricular project. These students were emailed to determine their interest, and one junior Mechanical Engineer volunteered to lead the project team.

As the leader was identified, the first-year engineering cohort was emailed to determine if there was interest among these students. Four students replied and the team was scheduled to visit the nursing laboratory for an extensive demonstration. Noelle™, the birthing manikin, was demonstrated.

The participating students met with the lead faculty member from engineering and nursing, and the project team consisting of one junior and three freshmen was formed and named "Team Nursing".

Student self-direction of the project:

Although the project had been identified by the faculty from nursing and engineering prior to establishing it as an undergraduate project, the student team was free to define the project in their own terms given the specified criteria, including a requirement to finish the design by the end of the academic quarter.. The team was tasked to submit a project schedule (and regular updates) to the lead faculty. They were expected to meet regularly, and offered access to the nursing laboratory when needed. The junior was initially identified as the team leader, and the engineering faculty member was identified as the lead faculty.

Reporting requirements:

Team Nursing was also tasked to present their results in a variety of forms, including a final written report and a poster presentation in an undergraduate research symposium. In addition, it was anticipated that an academic paper would be submitted for publication.

Presenting Technical Results:

In addition to a paper summarizing the results of the project, Team Nursing presented their results through two venues: a research poster presentation at an undergraduate research symposium and through a final technical report presented to engineering and nursing.

Undergraduate Research Symposium:

Team Nursing submitted and was accepted to present at a campus-wide Undergraduate Research Symposium, which is typically a venue for teams from Pharmacy and the physical sciences. The team developed and presented a research poster (Figure 1). They received very positive feedback not only for their project, but for their presentation skills and enthusiasm.

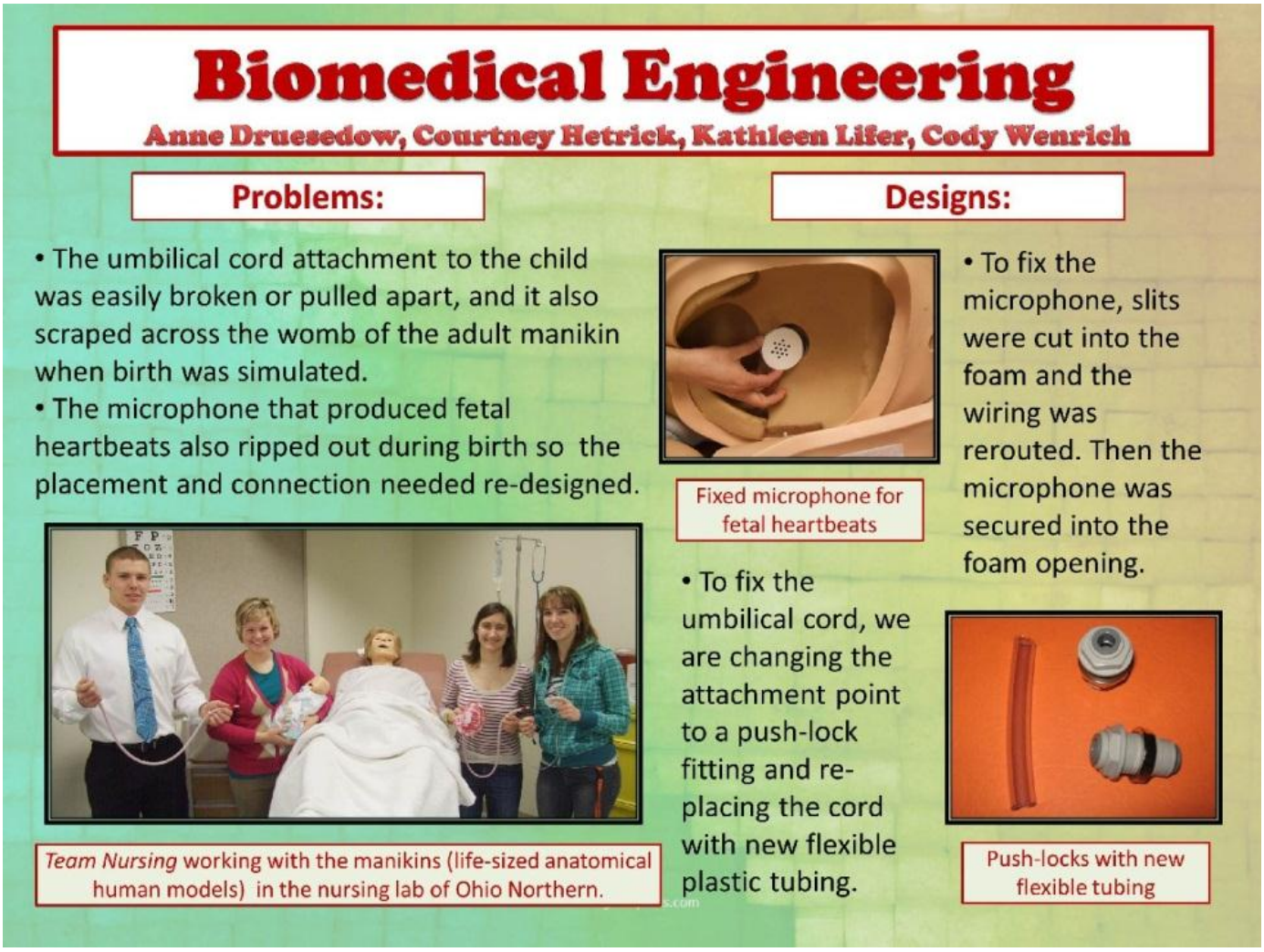


Figure 1: Team Nursing poster presented at Ohio Northern University Undergraduate Research Symposium

Final Report:

The technical description of the team's accomplishments was presented to engineering and nursing in a technical report. This report details the results of the two design implementations and a brief conclusion from the perspective of the group. The report is presented below.

Bio-Medical Redesign for Ohio Northern University Nursing Lab

Bio-medical Engineering Students:
Anne Druesedow
Courtney Hetrick
Kathleen Lifer
Cody Wenrich

Introduction

The objective of this project was to redesign the manikin Noelle™ in the nursing lab of Ohio Northern University. Noelle is a manikin who simulates birth through both cephalic presentation and malpresentation; head or feet first.

This project involved two different redesigns. First, the microphone that simulates fetal heartbeats needed to be repositioned and rewired due to the fact that the cords were often pulled out in the birth simulation. Second, both the umbilical cord and its attachment point to the baby manikin needed to be redesigned because the original attachment point weakened the umbilical cord and often led to a broken and unusable cord.

Both redesigns were successfully completed and tested. The microphone was rewired and repositioned so that no destruction can be done to the electrical cables. The underlying structure of the umbilical cord was inserted into new flexible tubing using only one of the existing attachment points. The attachment into the baby manikin was fitted with a push-lock connector and the free end of the umbilical cord was capped off in order to fit comfortably into the new attachment point.

Review of the Design Process

The design process for every project is similar. First, the team had to identify all the problems. Then these problems were analyzed and possible solutions were generated. An appropriate solution was chosen, and then finally implemented and tested; however, In order for a solution to be successful, constraints must be in place to make the design practical and efficient.

The main problems identified included damage to the microphone and its wiring, and broken umbilical cords due to the baby twisting in simulation and pulling the cord out of its attachment point. Because our team was not building a manikin from scratch, the manufacturer's design had to be carefully analyzed in order to understand what changes could be made without destruction of the product. It was decided that both the microphone and the umbilical cord could be fixed.

To fix the microphone, only one solution seemed obvious. The microphone would be removed from the abdomen of Noelle and then slits would be made into the foam of her stomach so that the electrical cords could be safely rerouted behind the foam. Placement of the microphone wires behind her abdominal foam would keep them protected from any objects that could catch on the wires and pull them out of place.

To fix the umbilical cord two possible designs were generated. First, the original attachment points for the umbilical cord could be used, and only the umbilical cord itself would need to be redesigned. This would involve changing the connection points to something that was durable but would still fit into the original attachments. The other design included changing only the attachment point on the baby and slightly modifying the connection point on one end of the umbilical cord.

Once the preferred design was identified, technological changes were made to the microphone, the baby manikin, and the umbilical cord. Team members had to completely support both designs and these designs had to be carefully thought out because changes could only be implemented once. Redesigning another manufacturer's product doesn't leave much room for error.

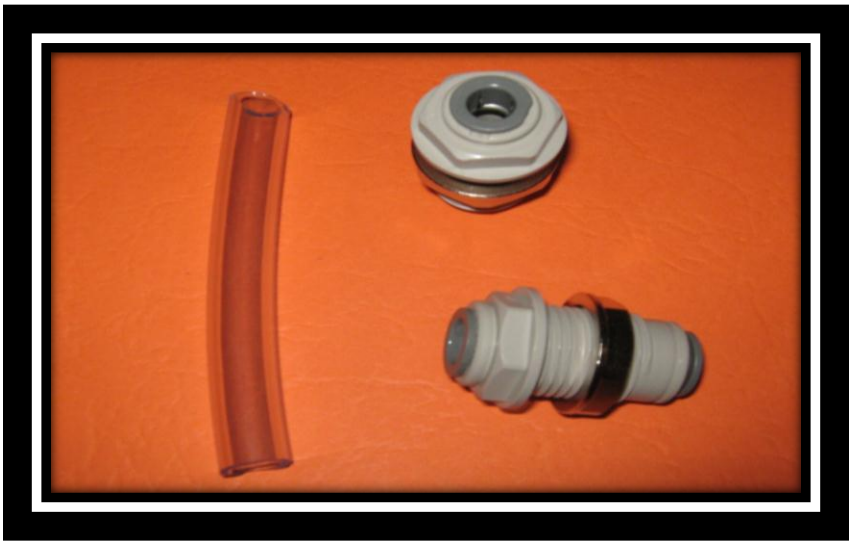
Final Design Specifications

The final design for the microphone was completed first. The microphone was disconnected and the foam was gently removed from the abdomen of the manikin Noelle. Then a small slit was cut into the foam where the microphone is allowed to rest. The microphone was then positioned into the foam and the wiring was rerouted behind the foam. The foam was replaced into the manikin's stomach and the microphone was reconnected. The figure below shows the microphone being replaced into the foam where the cords can be safely protected from any moving parts.

[Report] Figure 1: Fetal microphone in the abdominal foam of the manikin Noelle after the redesign.

The second stage of the redesign involved two different steps. In the first step the baby manikin was evaluated and it was determined that a push-lock fitting would be the best choice for the new connection point. The old attachment point involved a plastic connection ring. This ring was removed from the manikin and a new hole was drilled into the manikin using a $47/69^{th}$ inch drill bit. Then the newly drilled hole had to be fitted with threads so the push-lock connector could be screwed into the manikin. A push-lock connector of $3/8^{th}$ inches was screwed into the baby manikin. The second and final step involved redesigning the umbilical cord so that it would attach properly into the new connection point. The old umbilical cord material was inserted into $3/8^{th}$ inch tubing, and the existing end that plugged into the model placenta of the manikin remained

unchanged. The free end of the umbilical cord was capped off using electrical tape. The free end just needed to be secured to stop the cord material from creeping into the tubing, since only the plastic tubing is needed to form the connection point. The figure below shows the tubing and the push-lock connector that were used in the redesign of the umbilical cord and the baby manikin.

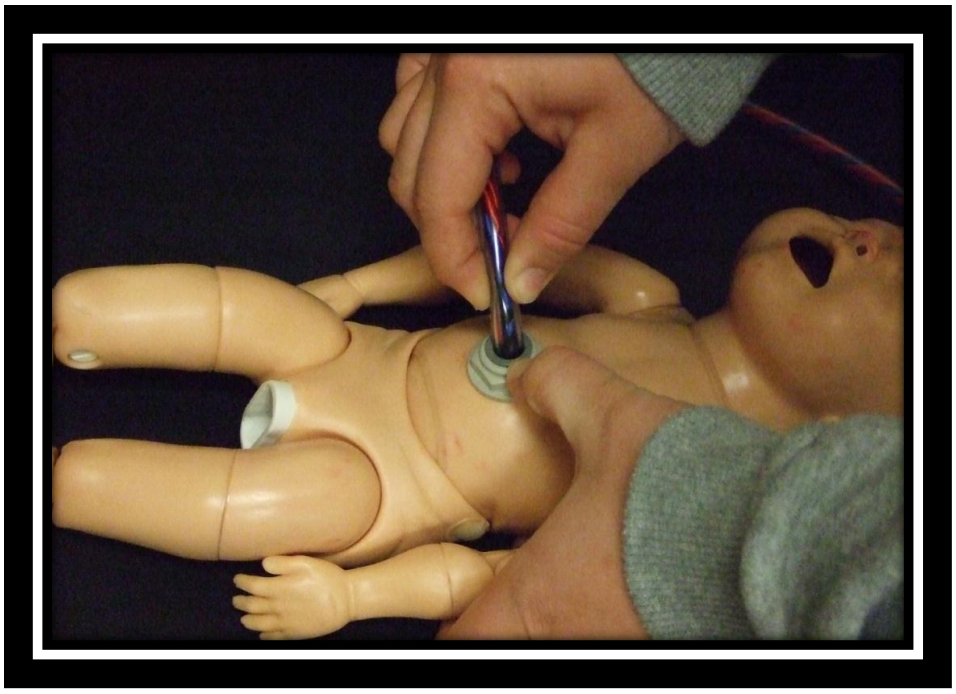


[Report] Figure 2: 3/8th inch flexible plastic tubing used for the umbilical cord and 3/8th inch push-lock connectors used as the new attachment point located in the baby manikin.

Results

The wiring for the microphone kept getting caught on the baby, the wire was threaded through the foam in the manikin's belly and the microphone was imbedded flush into the foam. After completing this first redesign, the nursing department started Noelle's birthing procedure to test if the wiring got caught. The baby came out easily and the microphone and wiring were still intact. Also, the nursing department tested their ability to hear the heartbeats given off by the microphone to make sure they could still here them. The solution for the microphone was a complete success shown by these positive test results.

The umbilical cord for the baby kept getting ripped out of the attachment point before our redesign. The nursing department needed a more durable fixture. The old insertion fixture was removed from the body of the manikin and a new push-lock connector was inserted in its place. This allowed the umbilical cord to stay in place and the new attachment point was larger so it is now easier to unhook the cord without damage to the cord. After this was put together, the nursing department tested the birthing process again. The demonstrated birth was successful because the umbilical cord did not get tangled inside Noelle's abdomen nor did the cord detach from the new connection point. This new design was also successful because the cord was easily removed from the baby after the birthing process was complete. Since both of our solutions were tested, we were able to conclude that both were successful.



[Report] Figure 3: The newly redesigned baby manikin with the push-lock connector in place for umbilical attachment.

Team Nursing Conclusion

This opportunity was very interesting and we all learned a great deal. These two problems gave us the chance to get an idea of what we want to do in our future careers. This project also allowed us to work outside of the engineering program and work with another department.

[Report] Figure 4: Group members, commonly referred to as "Team Nursing" in the nursing lab of Ohio Northern University with the manikin Noelle.

We were faced with two problems that needed to be fixed for the nursing department. One problem was with the microphone that was used to hear the baby's heartbeat and the other problem was with the umbilical cord that was being ripped apart.

For our solutions, the first thing we did was reroute the microphone wire through the foam of the belly of the manikin, instead of being loose in the womb. Next, the umbilical cord was fixed by using very flexible tubing and a push-lock fitting. The push-lock fitting allowed the umbilical cord to stay in place during the birthing process, but still was easily ejected from the baby after it was out of the womb. Testing was very successful for both solutions. Therefore, the microphone and umbilical cord solutions worked out very nicely. The microphone is no longer being pulled by its wire getting caught on the baby as it is delivered. Also, the umbilical cord is no longer being ripped apart after only a few uses. These solutions have lifted a lot of frustration for the nursing department and saved them money since they do not have to keep buying new umbilical cords and microphones.

Assessment:

The success of the project can be assessed from a technical view as well as success as a student project.

Technical Assessment:

Overall, the project was successful. The wiring change for the fetal heart beat was very successful: the wire can no longer become entangled in the drive mechanism. The new fitting for the umbilical cord required modification of the baby: specifically, the attachment for the old fitting was drilled out and a new fitting was added. The new fitting is fully functional and technically, an improvement. However, the current implementation certainly has an unnatural appearance, and may not be an ideal redesign. Both implementations were very cost efficient and required no additional training or resources to use.

Assessment as a student project:

From the engineering perspective:
Team Nursing was an outstanding success. The team of three first year students and one junior successfully planned their project and reported their plan to the advisor, scheduled and held meetings, redesigned and implemented their solutions and successfully reported their results.

One major lesson learned from the perspective of a faculty advisor is to maintain steady communication and require approval before physical modifications are made. The team implemented the new umbilical cord design prior to approval; ideally, each step of the redesign would be approved by the faculty advisors.

The team members were able to experience a hands-on project dealing with biomedical engineering in an institution without a formal biomedical program – an example that could certainly be disseminated to other similar institutions. The project allowed the team to develop professional skills including effective speaking and written communication. The opportunity to

perform a project as a team (with guidance from faculty) gave real-world experience to the students.

From the nursing perspective:
As the nursing program is new and faculty are eager to use all of the equipment in the laboratory, concerns have been expressed related to the ability to excel at understanding and troubleshooting all of the laboratory equipment. The engineering project was of assistance to the nursing faculty in looking at redesign of equipment that has been problematic. Nursing faculty expertise does not lie in redesign and reengineering equipment, which is why the project was beneficial to both departments. The project allowed engineering students to use their critical thinking skills and creativity, while nursing students benefitted from the improved devices. This collaboration was also relevant as it opens the door for future projects and enhancement of the nursing laboratories while allowing for learning opportunities for students.

From the students' perspective:
One of the first-year students emerged through the project as the team leader, taking significant responsibility for the success of the project. Her testimonial follows:

> Overall, the project was a success. We met the redesign goals of fixing the fetal microphone and the umbilical cord attachment. The changes we implemented were cost effective and will also make the manikin easy to use for the nursing faculty and students. Our redesign should also be durable and last a long time also saving the nursing department a lot of money.
>
> As a team leader I learned a lot about communication and group politics. As the leader, it is important to make sure your team stays on task and completes their assignments in a timely manner. Sometimes members of the group would fall behind or not finish their part and it was important to work together to meet the deadlines and finish the project successfully. We had some difficulties finishing due to the timing of the project being in the spring around midterms and before finals, and I learned that sometimes in order to get things done, you have to do them yourself. I think part of the problem was that even though we are all engineering majors we had very conflicting schedules due to sports, class, and age differences. Those who worked hardest made this project a priority.
>
> This project was very important to me. After graduation I would like to work in the biomedical engineering field or possibly go to graduate school to get a more specialized degree in biomechanics or drug delivery. This project not only improved my teamwork skills but it also gave the opportunity for experience in a research-like project. With this experience, I can continue to build my knowledge and use this when applying for other research and internship positions. I hope to complete another project with the nursing and engineering departments again this year involving the trauma manikin and stomach fluid filtration.

Other quotes from team members include:

"This beginning level project was a unique opportunity to be introduced into a small part of the biomedical engineering field. It was a great building block for opening other doors into the research and engineering field as we start our sophomore year."

"I was excited to be involved with this innovative manikin redesign and the first inter-department project. I hope that with the success of our project future generations of students will be provided with the same opportunity to expand their knowledge and put their engineering skills to use."

"I learned a lot from this project in not just engineering concepts, like how things move and work together, but also about myself as a person. I was given a great opportunity to develop my leadership and communication skills."

Conclusion:

This project allowed a team of engineering students to work with faculty from engineering and nursing to improve laboratory equipment used by nursing students. The project was quite successful.

The details of the project can be used by similar institutions to offer experiences in biomedical engineering where a formal program is not feasible.

The success of the project has led to a second round, with a new set of students and new design challenges.

References:

[1] URL: Ohio Northern University website, http://www.onu.edu/: accessed 1/1/2011.

[2] Committee on the Robert Wood Johnson Foundation Initiative on the Future of Nursing, at the Institute of Medicine, National Academy of Sciences, Engineering, and Institute of Medicine, 2010. *The Future of Nursing: Leading Change, Advancing Health*. Washington, D.C., National Academies Press.