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1 WIP: Developing Health Informatics Competency in Undergraduate Biomedical Engineering Students using Active Learning Approaches

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Introduction

The field of health informatics has been advancing at a rapid pace, driven in large part by the proliferation of electronic health record (EHR) systems, the growing use of medical and consumer health devices, and the massive amounts of data that these systems and devices generate [1]. The COVID-19 pandemic has not only accelerated the growth in data and devices but has also validated their importance in modern healthcare. The principal focus of health informatics is on the interoperability of systems and devices and the data that they produce and exchange [2].

Whereas several universities offer degree programs and graduate courses in health informatics, very few institutions, Wentworth Institute included, offer courses in health informatics to undergraduate Biomedical Engineering (BME) students. BME programs, at most schools, train students in electronic circuits, sensors, clinical instrumentation, biomechanics, and signal processing and systems analysis. Other than in senior capstone courses, BME students do not get too many opportunities to apply and integrate the concepts and skills learned in background courses. This paper explores how inclusion of health informatics competencies in undergraduate BME education using active learning enables students to integrate and reinforce material learned in other subjects and gives them skills which can be applied elsewhere in their education and career.

Course Structure and Evolution

Medical Informatics and Telemedicine is an elective four credit course for Wentworth Junior and Senior level BME students. It is offered twice every academic year with an average enrollment of fifteen students per offering, taught by one of the authors. The course consists of three lectures and one lab per week, where students, individually and in groups, over fourteen weeks, learn about and explore different aspects of health informatics. The course trains students to think cooperatively and at a systems level to address challenges and opportunities in medical informatics and telehealth. Active learning interventions used in the course build off real-world scenarios such as the role of telehealth in a COVID-19 world, and deployment of mobile electronic health record systems in Louisiana after Hurricane Ida. Students analyze the scenarios by applying their systems, electronics, and devices skills as well as by using methodologies including flowcharting, “end-to-end” diagraming, and mapping of the “patient journey” and “data journey” [3]. In the process, students uncover important issues like privacy, data integrity, information security, risk, decision making, ethics, regulations, and social disparities in access to care and outcomes. Students find that exploration of these issues, adds context and meaning to their training as biomedical engineers.

Over the past four years, the course has evolved from a traditional lecture/lab course with timed paper/exam-based assessments to a project based active learning rich course with open-ended activities and untimed assessments. Examples of interventions implemented to address three learning goals of the course are summarized in Tables 1-3. Active learning interventions include case studies, cooperative groups, jigsaw teams, discussion forums, and rich media content creation and sharing [4],[5],[6]. These approaches are more reflective of what students would encounter in real-life scenarios and workplaces, where problems are not always fully defined, choices are not totally clear, and effective team communication and collaboration are essential [7], [8].

Table 1: *Learning Objective 1:* Demonstrate ability to transmit, receive, and collect health data with instruments, devices, and software tools.

Key active learning interventions: **case study, brainstorming, cooperative groups**		
Task: Teams of three to four students have three weeks to design a health informatics system to address a challenging global health scenario of relevance at the time of the course offering.		
2018 challenge: reduce high maternal and newborn mortality in Nairobi, Kenya. Goal: develop mobile app for health data acquisition and tracking of wellbeing of mother and newborn.	**2019 challenge:** triage care for those injured in Haiti earthquake: develop mobile tool to collect patient information and assign follow up care.	**2020-21 challenge**: track COVID-19 vaccine supplies, manage vaccination scheduling, and follow up with mobile tool.
Deliverables: teams create a detailed report and presentation which maps the patient and data journeys, and describes the process workflows. Teams prototype a mobile app utilizing the Dimagi/Commcare software development platform [9]. The teams give a final presentation to the rest of the class and to a representative from a global health technology organization, when available. Students are assessed on completion of all the tasks with a performance rubric. This activity is a highlight of the course as reported by students in end of semester course evaluations.		

Table 2: *Learning Objective 2:* Gain hands-on experience with electronic health record (EHR) systems and explore their adoption, implementation, usability, clinical decision making, workload, and failures.

Key active learning interventions: **hands-on technology, simulation, jigsaw discussion, peer review**
Tasks: In this three-week-long activity, students, individually, begin by creating fictitious patients with health conditions on an open-source EHR, and explore various clinical workflows and treatment scenarios. In the second week, students implement and test clinical decision rules on the live EHR. In the third week, students analyze the benefits and challenges of EHR systems through analysis and reflection of a case study they read. This last part constitutes their midterm exam.
Deliverables: Students create reports with graphics of relevant inputs/outputs from the EHR. They also respond to reflective questions on workflow, usability, and challenges in using the systems. As part of the midterm exam, students answer ten reflective questions, shown in Appendix A, in a discussion forum on the learning management system (LMS). Students are also asked to comment on posts by two other classmates and contrast them with their own responses. The benefit of having the assessment done outside of class is that students have time to formulate their responses and to review and comment on other's responses at their own pace. Participation in the online discussion forums enables students to practice evaluation and critical thinking in a professional, collaborative environment. By doing so, students learn by taking each other's perspectives.

Table 3: *Learning Objective 3:* Design health informatics system and perform device integration to enable interoperability of devices and data.

Key active learning interventions: **case study, hands-on technology, inquiry learning**
Tasks: As part of the telemedicine component of the course, students learn to operate a Littman 3200 digital tele-stethoscope, interface it to their computers, capture and record heart sounds, transmit the data, upload it to the EHR, and review the heart sounds remotely. Students typically comment in their end of semester course evaluations that this is one of their favorite activities because it was experiential, utilizing their own physiological (heart sound) data.
Deliverables: As their final exam, students document their design and evaluation of a complete end-to-end tele-health system for use in a ride-sharing vehicle as a multimedia portfolio in the LMS. Assessment is based on the clarity and level of detail provided in their workflow diagrams, system designs, analysis of privacy, data security, and transition of care plans for the patient being transported. Students also record two one-minute-long audio instruction guides, one geared towards a technician, and another one to a patient/passenger

Data Collection and Analysis Plan

Thematic analysis of data from surveys is being conducted to assess the key premise of the paper "*how inclusion of health informatics competency in undergraduate BME education using active learning enables students to integrate and reinforce material they learned in other subjects and gives them skills which can be applied elsewhere"* [10]. An eight-question free-response survey, shown in Appendix B, was sent via Qualtrics to students who have taken the course in the past two years and will be sent to students in the upcoming two offerings of the course in 2022. This will encompass six offerings of the course, totaling under 100 participants.

Preliminary Results

Complete answers from ten anonymous respondents to two most directly relevant questions are included in Appendix C. Highlights from thematic analysis of the responses is shown below.

Q2 How does this course relate to courses you have taken previously? Explain in what way it extends or does not extend concepts learned before. Preliminary results indicate that study of health informatics invokes concepts from student's prior electronics and computer science courses and provides context and application of these concepts.

Q5 Which concepts or methods learned in the course have been useful to you and have been applied in other courses since? Give examples if possible. All ten respondents reported that they have applied concepts learned in the course elsewhere. Thematic analysis reveals that process mapping and flowcharting tools have been useful to most students who have taken the course. HIPAA and data security were also mentioned by several respondents. Coding of responses will be conducted to further stratify results and identify how the concepts were applied [11].
One concrete takeaway is that training in process mapping tools, like flowcharting, one of the tools emphasized in the course, may be beneficial for students to learn early on in their education.

Discussion

At the moment, one limitation of the study is that there is no data from students who did not take the course to compare with. A modified survey is being formulated to address this lack of baseline data and will be distributed in parallel to the two upcoming offerings of the course.

Another limitation is that the health informatics course utilizes a wide array of active learning interventions, which, as a whole, seem to be highly effective, based on preliminary data reported here, as well as by direct student reports. This study was not set up to discern the effectiveness of any specific active learning intervention. This is something which may be of interest, particularly to provide actionable takeaways for other educators. An extension of the study may tap into this.

Conclusions and Future Work

Preliminary data from this research indicates that inclusion of medical informatics in the BME curriculum provides context for students to integrate their prior learning and increases their ability to perform system level analysis of challenging health informatics scenarios as well as in other related disciplines. The results also provide evidence that developing health informatics competency in undergraduate BME students using active learning approaches adds important skills and value to the student's education. It is expected that with the additional data collected during the upcoming two offerings of the course, the preliminary results will be confirmed. Extensions of this research may include long term analysis, in the form of more rigorous triangulation of historical data, such as course assignments, projects, assessments, and lab reports from earlier offerings of the course.

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Appendix A:

Part I*: Reflecting on Atul Gawande's "Why doctors hate their computers" respond to the following:*

1. Why the title of the article? Do you think the title is justified? Explain and be specific.
2. What is the "Revenge of the ancillaries" within the context of the article? Give an example.
3. Give an example of the "massive monster of incomprehensibility" presented in the article.
4. What are the tradeoffs of having live scribes in the exam room vs. offline remotely?
5. Explain how artificial intelligence (AI) can be implemented in the context of the article.

Part II*: Reflecting on Melinda Ashton's "Getting rid of stupid stuff" respond to the following:*

6. Why the title of the article? Do you think the title is justified? Explain and be specific.
7. List the three "nomination categories" formulated by the team and give an example of each. Describe their resolution if there was one.
8. How would you say the Gawande and Ashton articles relate to each other? Did the Ashton article change your views on Gawande's or did it reinforce your views?

Part III*: Concluding thoughts*

9. If you oversaw the EHR at a large hospital, what would be three key learnings from the articles and how would you implement them?

10. Describe any unanswered questions or aspects which were not considered by the articles which you think would have been important to consider. (for example, both authors are MD's, would the perspectives be different if the articles had been written by other healthcare professionals, like nurses, or a software developer, or a biomedical engineer?)

Appendix B:

The full questionnaire sent out to students who took BMED 4800 Medical Informatics and Telemedicine in the past two years.

Q1 How would you define medical informatics?

Q2 How does this course relate to courses you have taken previously? Explain in what way it extends or does not extend concepts learned before.

Q3 Do you see connections between this course and your prior circuits and electronics courses?

Q4 Do you see yourself pursuing careers in fields related to this course?

Q5 Which concepts or methods learned in the course have been useful to you and been applied in other courses since? Give examples if possible.

Q6 Course delivery: if you took the course online fully or partially, please comment on how that format worked for you. Did you feel the course worked well in that format?

Q7 Did the course give you new perspectives on non-technical aspects such as bridging social disparities, privacy, security, ethics? Please elaborate with examples if possible.

Q8 Would you recommend this course to others? If yes, how would you describe what you gained most from the course? What was most useful?

Appendix C.

Student responses to the questions selected to support the premise of the paper.

Q2 - How does this course relate to courses you have taken previously? Explain in what way it extends or does not extend concepts learned before.

This course related to other courses to varying degrees. For instance, it relates heavily to the biomedical electronics and instrumentation course. Many of the discussions I had in this class related back to conversations from the biomedical electronics class, such as those about surrounding HIPPA policies and data transference between hospitals.
It requires the student to apply basic knowledge of statistics, computer science, and electronics which are all classes we had taken prior to this course
This course brings perspective on potential applications for management and computer related skills gained in other classes and tackles a branch of medical engineering not previously seen. While taking this course I learned how o interpret patient data and test data, to assess testing, to use data to facilitate healthcare, ethics, data access, and a potential career path for biomedical engineering,
This course ties all the courses I have taken before in. With previous knowledge of computer science, anatomy, and circuitry it's a course using all elements into one.
This course wasn't similar to any courses I've taken before but was more a mixture of courses such as computer science and any other BioMed elective.
I feel like the course built on the big picture understanding of what we learned in other classes like ecad and computer science. (electronic analog circuit design)
This class is pretty straight forward. I slightly built upon BMED 2500 however stands independently from other classes.

I think it extends our ability to analyze the data the comes from different forms of medical devices and studies and teaches us to better understand what we are working with

It relates to other courses that I have taken previously in helping me understand that the data of medicine is just as important as the acts of being able to work on and produce medical equipment and products.

This course extends the ideas learned in courses such as "Anatomy and Physiology" and "Medical Imaging" by highlighting how the information that is taught in these previous courses is stored and how medical professions use the information.

Q5 - Which concepts or methods learned in the course have been useful to you and been applied in other courses since? Give examples if possible.

I took it last semester, so I haven't taken classes since, but as stated it does relate strongly to my coop current coop, as I work in the healthcare industry and work with patients and patient systems such as Epic.

I believe this course gave me a better insight on how information is transferred but more importantly why it is transferred

One skill learned in this class that I applied in other classes has been flowchart and diagram making. I also had the opportunity to use telemedicine in a project for healthcare accessibility.

AI, creating paths for new tech, design

The ability to make in-depth flowcharts is a concept I learned that has become very useful. It allows you to break down a big assignment or task into a process which makes it easier to complete.

our data flowcharts from this course built a fundamental understanding of pathways and critical thinking skills that were able to transfer to signal pathways in signals and systems.

How to build a flowchart using different shapes and what to outline.

I use flow charts and Brain maps for everything now

Being aware of HIPPA and its regulations

The concept of data safety and HIPAA compliancy has been extended into the Senior Design course. One specific example is by making sure that the project or device being developed in Senior design takes into consideration patient data safety and how to ensure that the patient data is not given to the wrong person.