

Biomedical Engineering, Co-education of Biomedical Science and Engineering Students

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Abstract

Biomedical engineering is a multidisciplinary field where engineers, scientists, physicians and other health workers are required to work together and to communicate effectively. This can be a difficult task, as concepts which are common knowledge in one discipline are often foreign to people working in another area.

At Charles Darwin University a new biomedical engineering unit was introduced, which is both a core unit for biomedical science students and an elective for engineering students in their final year. The unit aims to offer a broad perspective on biomedical engineering. Teaching a diverse group provides opportunities as well as challenges. Students can learn from each other and gain experience working in multidisciplinary teams. The necessity to communicate between the two different groups encourages critical thinking and develops communication skills. There are, however, also a number of difficulties associated with the diverse background of the students. Since the knowledge base of the two groups of students does not overlap it is a major challenge to ensure that the content of the lectures is comprehensible and sufficiently interesting for all students. Choosing assessment methods in such a way that none of the two groups has an unfair advantage over the other group poses another problem.

This paper describes the approaches taken to maximise the advantages associated with the diversity of student backgrounds and to overcome the problems mentioned above. Experiences during the first year the unit has run have been positive. Evaluations showed that students enjoyed the subject and felt that the cooperation with students from another discipline enriched their learning experience. The lectures were considered useful and interesting. Students considered the methods used for assessment fair and their results did not indicate that one group had an unfair advantage over the other group.

Introduction

Biomedical engineering is a multidisciplinary field involving engineers, scientists, physicians and other health workers. By working together, traditional boundaries of science, medicine and engineering can be crossed and new areas can be explored (Panitz, 96). Ideally this leads to a form of synergy where by looking at problems from different perspectives new solutions are found. The cooperation between engineers or physicists and physicians or biologists can be very successful and has in a number of cases led to ground breaking research and even Nobel prizes. In order to achieve this, however, people with diverse areas of expertise have to be able to communicate and work together effectively.

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Effective communication can be a difficult task as concepts which are common knowledge in one discipline are often foreign to people working in another area. Engineering programs tend to be largely prescribed with little room for subjects outside the discipline of engineering. Because most engineering units after first year have prerequisites, they are not accessible to students from other disciplines who do not have these prerequisites. As a result engineering students do not usually study together with students from other disciplines. The same holds for medical students and, to a lesser extent, for biomedical science students. The result of this “professional isolation” is that people graduating in different disciplines are out of touch with the knowledge base of people working in a different field. The problem is not just that people from different backgrounds have different knowledge, it is also that they have no clear idea what people from other disciplines know or do not know. This may lead to miscommunication and misunderstandings.

Biomedical engineering at Charles Darwin University

Biomedical Engineering is a fast growing discipline (Panitz 1996, Graduate and Undergraduate Engineering Programs 2004). Biomedical engineering can be taught at different levels: as an undergraduate degree, as a master by coursework or research or as part of a Ph. D. project. Different approaches to teaching are possible, from a broad based subject, which gives an overview of the different areas of biomedical engineering to specialist topics (Da Rocha Brito & Ciampi 2001, Gonzalez & Leiffer 2002, Giuffrida, 2004, Corwin & Weinbaum 1997). Teaching methods are also variable, ranging from the more traditional methods to project based learning. Although biomedical engineering is a multidisciplinary subject, it is unusual that engineering students study together with students from other disciplines.

Charles Darwin University, the only university in the Northern Territory, is a small university. While on the one hand the geographical isolation of the university makes it desirable to offer a wide variety of courses, the small size means that many units need to be co-taught in order to be economically viable. It was decided to turn this necessity into an advantage by offering a new biomedical engineering unit to both engineering and biomedical science students. It is hoped that this will lead to improved communication and interdisciplinary collaboration.

The unit, ENG429 Biomedical Engineering, is a core unit for third year biomedical science students and an elective for engineering students in their final year. The aim of the unit is to offer a broad perspective of biomedical engineering and to enable students to identify, formulate and solve problems at the interface of engineering and biology. The unit consists of two hours of lectures and two hours tutorials/practicals per week for 13 weeks.

A wide range of topics are covered: introduction to biomedical engineering, anatomy and physiology, bioelectric phenomena, biomedical sensors, bioinstrumentation, biosignal processing, physiological modelling, cardiovascular mechanics, biomaterials, tissue engineering radiation imaging, ultrasound, nuclear magnetic resonance, biomedical optics and lasers, rehabilitation and assistive technology, moral and ethical issues.

Students

ENG429 Biomedical Engineering was introduced in 2004. During the first year half of the students enrolled in the subject were engineering students and the other half were biomedical science students. As mentioned before, the engineering students were fourth year students who had chosen the subject as an elective. This meant that these engineering students had nearly completed their studies. For some of them this unit was the very last part of their undergraduate degree. The biomedical science students were in the second or third year of their studies. While the unit is a core unit of their degree, there is some freedom in the curriculum and students can choose whether they want to do the unit in second or third year. All students had completed anatomy and physiology and a variable number of other units.

From the description above it can be concluded that the students enrolled in ENG429 consisted of two very distinct groups. The engineering students had a wide knowledge of engineering but knew very little about the human body. The biomedical science students had a considerable amount of knowledge of the human body but knew almost nothing about engineering. While the biomedical science students had all completed first year physics, they did not have a strong mathematical background. The biomedical science students also had other interests than the engineering students. While the engineering students were primarily interested in technology, the biomedical science students were mainly interested in methodologies to diagnose diseases and cure patients. Both groups had an interest in biomedical engineering, but for the engineering students this was mainly driven by the technical challenges involved in applying engineering to the human body whereas for the biomedical science students it was driven by a desire to have sufficient technical knowledge to treat patients. Finally, the engineering students had known each other for years and the biomedical science students also knew each other well but the two different groups had not met before.

Opportunities

A number of examples of multidisciplinary classes have been described in literature. Thigpen et al. (2004) describe a design course for mechanical engineering, electrical engineering, marketing and art students. Park et al. (2002, Riley et al. 2003) teamed engineers with technical documentation specialists to enhance their learning experiences. Hiley and Carter (2003) developed a teamwork project for students in construction management, surveying and civil engineering. Newell and Cleary (2004) combined chemical and civil engineering students in materials research. Examples in other disciplines include a project about the 1918 influenza epidemic for microbiology, psychology and archaeology students (McFadden et al., 2003), a course for mathematics and art students about perspective (Frantz, 2004) and courses for combined groups of business and computer science students about e-commerce (Antón & Earp, 1999, Dhamija et al., 1999).

Teaching a diverse group provides opportunities as well as challenges. Baron (2005) gives the following list of advantages of interdisciplinary teaching and learning:

- It is reflective of life which is not segmented into discrete disciplines;

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- It allows for the use of multiple approaches and applications of skills for problem solving;
- It can provide a broader context for new information;
- It allows for a broad use of diverse experiences and knowledge bases;
- It encourages creativity and creative thinking;
- It allows for greater flexibility;
- It allows for teaching improvement through joint planning and mutual observations;
- It provides for a heightened level of collegial communication;
- It opens up possibilities for an expansion of course offerings with minimal or no additional resources;
- It can provide expanded opportunities for the application of theory;
- It provides a good introduction / foundation for various disciplines;
- It allows for the use of diverse perspectives;
- It helps develop tolerance of ambiguity;
- It can enhance the ability to synthesize and integrate information;
- It can integrate the new information environment that tends to be less linear and more cross-disciplinary.

Students can gain experience working in multidisciplinary teams and have the opportunity to learn from each other. In this case each group of students had already a considerable amount of relevant knowledge and skills. If the students can succeed in combining their knowledge and skills in a useful way they may achieve things together, which could not have been achieved separately. Good communication will facilitate the transfer of biomedical science concepts into engineering and engineering approaches into biomedical science.

Biomedical science students may, during the course of this unit, be provided with new tools to solve problems medical or biological problems. Engineering students will be able to apply their Engineering skills to biological or medical systems for the first time. Each group may obtain a new perspective and learn to look at old problems from another point of view. The necessity to communicate between the two different groups could encourage critical thinking and help the students to develop their communication skills.

Challenges

There are also a number of difficulties associated with the diverse background of the students. In order to understand problems at the interface of biology and engineering, students need at least some understanding of both areas. The unit needs to include some

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anatomy and physiology in order to give the engineering students a basic insight in the functioning of the human body. The biomedical science students, however, have already learnt this. How can anatomy and physiology be taught to the engineering students without wasting the time of the biomedical science students? The unit also includes topics like bio-instrumentation and bio-signal processing. This means that the biomedical science students need to learn the basics of signal processing, common knowledge for the engineering students. How can the lectures be conducted in order to make sure that the content is comprehensible and sufficiently interesting for all students? It is desirable that the lecture content is suitable considering the level of knowledge of the students. Since the knowledge base of the two groups of students does not overlap this is a major challenge.

Assessment poses another problem. What assessment methods can be used to prevent one group from having an unfair advantage over the other group based on their prior knowledge? Should the two groups be assessed in the same way? If not, how can we ensure that the students obtain a base of common knowledge?

Approach

Below, the approach taken to maximise the advantages associated with the diversity of student backgrounds and overcome the problems mentioned above, will be described.

Lectures and Tutorials/Practicals

The aim of ENG429 is to offer a broad perspective of biomedical engineering and to enable students to identify, formulate and solve problems at the interface of engineering and biology. The unit consists of two hours of lectures and two hours tutorials/practicals per week for 13 weeks. A wide range of topics is covered during the lectures, including anatomy and physiology, bioelectric phenomena, biomedical sensors bio-signal processing, biomaterials, imaging techniques, rehabilitation and assistive technology and moral and ethical issues related to biomedical engineering.

As mentioned before, the different background of the students posed a challenge for the lectures. It was unavoidable that there would be some overlap with other subjects in biomedical science and engineering. It was attempted to conduct the lectures in such a way that each lecture would either provide new information or offer a new perspective of previously learned material for all students.

An example is the anatomy and physiology component of the subject. For the engineering students, this was new material but the biomedical science students had already completed two anatomy and physiology subjects. It was decided to teach anatomy and physiology in an engineering context. For the engineering students this was the natural way of looking at things but for the biomedical science students it provided a new perspective. For example, bone structure was considered from a materials engineering point of view. This approach also provided insight in the difficulties involved in constructing artificial joints. Another example is the mechanism of nerve conduction and muscle contraction. While the biomedical science students had learnt this before, the physical principles underlying these phenomena were more emphasised than they had been in their earlier anatomy and physiology lectures. In addition, where possible, diseases related to topics studied were mentioned and explained. In the evaluation, the biomedical science students said that the overlap of Biomedical Engineering and the subjects they had done before was not a problem

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because the material was presented in a different context. They felt they gained a deeper understanding than they had had before.

The biomedical signal processing component posed another challenge. As the final year engineering students had already completed a number of related units to signal processing such as Signals and Systems, Digital Signal Processing and Control. The biomedical science students knew nothing about signal processing and had only a limited mathematical background. It was decided to involve the engineering students in the teaching process. They had to explain in simple words the essence of Fourier series and Fourier transforms. In doing so, the engineering students found that even though they were very capable in applying signal processing techniques, it was not easy to explain these to a group of students with limited mathematical knowledge.

A similar approach was taken when the engineering students needed to learn about cell division. The biomedical science students explained the various stages of cell division to the engineering students.

A common approach for multidisciplinary teaching is a project where students from different disciplines are working together to achieve a common goal (e.g. Newell & Cleary 2004, Hiley & Carter 2003, Privitera & Grood 2004, Thigpen & Glakpe 1999). For this subject it was decided to do a series of small projects, rather than one large project. There were two reasons for this choice. The first reason is that in this way a larger range of topics could be covered. The second reason was that the engineering students were simultaneously doing their final year thesis, some of them in biomedical engineering. It was not considered desirable that students should divide their efforts between two large projects.

Assessment

Assessment consisted of three parts: tutorial assignments, which included the small projects, a mid semester exam and a final exam. For both the mid semester exam and the final exam, the students were given a number of questions from which they were allowed to select the questions they wanted to answer. All students had to answer some questions outside their discipline. The week after the mid semester exam a tutorial was given to the students called "Filling in the Gaps". The tutorial consisted of the midterm exam questions, which the students had chosen not to answer during the exam. Some students did remarkably well in this tutorial. One biomedical science student, who had tried to avoid answering engineering related questions during the exam scored 95 out of 100 when he had to answer these same questions in the tutorial.

Students considered the method of assessment fair and the results indicate that neither group of students had an unfair advantage over the other group. The average mark was similar for both groups.

Experiences

Experiences during the first year the unit has run have been positive. Evaluations showed that students enjoyed the subject and felt that the cooperation with students from another discipline enriched their learning experience. One student enjoyed the subject so much that he changed his final year thesis topic to biomedical engineering.

All students considered the lectures generally useful and interesting. In the evaluation, the biomedical science students said that the overlap of Biomedical Engineering and the subjects they had done before was not a problem because the material was presented in a different context. They felt they gained a deeper understanding than they had had before. Many students mentioned that the integration of engineering and biomedical science was the strength of the subject. When asked whether any of the lectures could be removed one biomedical science student mentioned the introductory genetics lecture. This lecture had been followed by a specialist lecture about sequencing machines, which he considered very interesting. The introductory lecture, however, did not contain any new information for him. The engineering students however said that this lecture had been very useful and that they would not have been able to follow the lecture about sequencing machines without it. The engineering students did not think that any of the lectures were useless, but they did suggest making the unit Signals and Systems available to biomedical science student so that they would be able to obtain a better understanding of signal processing techniques. Both groups of students appreciated the wide range of topics covered in the subject.

Students considered the methods used for assessment fair and their results did not indicate that one group had an unfair advantage over the other group.

Key words: Multidisciplinary, Biomedical Engineering, Technology, Innovation, Project Based Learning, Teamwork

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