A COMPARISON OF INTERACTIVE TEACHING METHODS USED IN BIOENGINEERING/BIOMATERIALS MODULES AT TWO RUSSELL GROUP UNIVERSITIES

T Joyce*, N Dunne

*School of Mechanical and Systems Engineering, Newcastle University, UK
School of Mechanical and Aerospace Engineering, Queen's University Belfast, UK

Abstract: Internationally, biomedical engineering is a rapidly growing field and this is mirrored by an increasing number of dedicated degree courses being developed. The teaching of such multi-disciplinary material to engineering students brings challenges and opportunities. A comparison of interactive teaching methods on bioengineering and biomaterials modules at two Russell group universities was undertaken. Each module was taken by fourth year MEng students as well as taught MSc students therefore cohorts were similar in this respect, as were student numbers. Another similarity is that these modules are not part of bioengineering or biomaterials degrees, but options of mechanical engineering and materials degree programs. At each university, techniques included invited industrial lectures, small group assignments and presentations, alongside traditional lecturing practice. Student feedback showed that the range of teaching approaches were positively received and appreciated.

Keywords; interactive learning, bioengineering, biomaterials.

**Correspondence to: Thomas J Joyce, School of Mechanical and Systems Engineering, Newcastle University, UK. E-mail: t.j.joyce@ncl.ac.uk*

1. INTRODUCTION

Internationally, biomedical engineering is a rapidly growing field and this is mirrored by an increasing number of dedicated degree courses being developed. In the United States, bioengineering is the most rapidly growing field of engineering when compared with all other disciplines including mechanical, electrical, civil, and chemical engineering (American_Society_for_Engineering_Education, 2008). In the UK, many bioengineering and biomaterial courses have appeared at both undergraduate (Joyce, 2009a) and postgraduate (Joyce, 2009b) levels. The teaching of such multi-disciplinary material to engineering students brings challenges and opportunities. For example, challenges include introducing students to a new language associated with medicine and anatomy alongside a need to understand some biological processes. Conversely opportunities include the applications of multi-disciplinary engineering in areas which have a direct and positive impact on people's lives. Both authors of this paper were keen to apply interactive learning methods in their respective bioengineering and biomaterials modules. They believe that such interactivity leads to deeper learning among their students. Moreover, following a constructivist approach the lead author saw his role as acting as

a facilitator and, wherever possible, allowing his students to experience the benefits of peer-to-peer learning within an encouraging and non-hierarchical setting (Kahn and Walsh, 2006). The aim of this paper was to compare teaching and learning approaches at two universities and disseminate these approaches.

2. METHODOLOGY

A comparison of interactive teaching methods on bioengineering and biomaterials modules at two Russell group universities, Newcastle University and Queen's University Belfast (QUB) respectively, was undertaken. Each module was taken by fourth year MEng students as well as taught MSc students therefore cohorts were similar in this respect, as were student numbers (typically 20-30 students per module). Another similarity is that these modules are not part of bioengineering or biomaterials degrees, but options of mechanical engineering and materials degree programs. In the School of Mechanical and Systems Engineering at Newcastle University, the Bioengineering module is a 15-credit module. Prior to the 2008-09 academic year the Bioengineering module was 'traditional' in the sense that it consisted of lectures, tutorials based on question sheets and a written exam which gave 100% of the module assessment. In the 2008-09 academic year, the lead author became module leader and for his third of the module introduced changes based on his pedagogical beliefs and experience. A focus was made on interactive learning rather than data transference. In addition, assessment for his third changed to project-based rather than exam-based. The project concerned a critique of a currently available total joint replacement. Project based learning encourages deep rather than superficial learning (De Graaff and Kolmos, 2007) while studying an artificial joint which is currently implanted into patients conveys relevance to students.

In the School of Mechanical and Aerospace Engineering at QUB, two modules relating to Biomaterials and Biomedical Engineering are offered as optional modules to the final year students on the MEng in Mechanical Engineering and compulsory modules to the postgraduate students enrolled on the taught MSc program in Polymer Engineering. The modules are entitled: (1) Biomaterials and Tissue Engineering; (2) Design and Performance of Medical Devices, and represent 15 ECTS credits. The second author is responsible for 50% of the teaching and assessment of these modules. The aforementioned modules at QUB have been offered from 2008; prior to their introduction (from 2003-2007) a module relating to Medical Materials was offered to the MEng and MSc cohorts. In both cases, these modules were assessed by continuous assessment (20%) and a final written examination (80%). The continuous assessment is a group-based project (n=2-3 students) conducted over 5 weeks, whereby each group selects a research paper from a predefined list. Subsequently, each group has to conduct an extensive literature review and source two additional research papers relating to the initial paper selected, thereafter all three papers are critiqued by the group and the salient points from each paper delivered as an oral presentation. This format of continuous assessment encourages a deeper understanding, greater level of engagement and interaction in the subject. Moreover, this research-led approach also transfers very important skills to the student such as conducting literature review, critically appraisal of research papers, development of presentation skills and encouraging group dynamics.

Within each module, teaching techniques included invited industrial/clinical lectures, small group assignments and presentations, alongside traditional lecturing practice. For example, interactive teaching methods included:

- A small-group exercise to aid anatomical understanding through the use of models of human joints
- A 2-hour visit to the University's Dissection lab to examine cadaveric hip and knee joints under the supervision of the Director of Anatomy
- A small-group assignment based on the analysis of physical examples of total joint replacements
- A small-group assignment based on analysing the engineering drawings related to a two-piece finger prosthesis
- A small-group assignment assessing current literature in terms of contrasting and comparing clinical issues between metal-on-polymer, metal-on-metal, ceramic-on-ceramic and metal-on-metal hip resurfacing prostheses.
- Small group based workshops using relevant 3D models to assist in understanding the anatomical features and characteristics of bone, organs and articulating joints.
- Discussion forums were utilised to encourage debate and rationale thinking relating to the important issues that need to be considered when designing and manufacturing prosthetic implants or medical devices.
- Small group based assignments focusing on pertinent research issues relating to Biomaterials, Tissue Engineering and Medical Devices.
- Preparation and oral delivery of short presentation (10 minutes) based on the research findings of the aforementioned small group based assignment. There was a questions and answers element following the delivery of the presentation and students were actively encouraged to ask questions to the peers.
- Demonstrations of surgical procedures through the application of videos with commentary from surgeons (e.g. orthopaedics and cardiovascular surgery).
- Invited lectures given by practitioners in the fields of orthopaedics, restorative dentistry, cell biology, anatomy and pharmacy.
- Invited lectures given by professionals working with major medical device and biomaterials companies (e.g. biomaterial scientists, bioengineers, intellectual property protection, clinical and regulatory affairs).

As can be seen both authors employed small-group working as frequently as possible as they believed this was a proven method of achieving deep learning within students, as well as it providing a more enjoyable and interactive experience for students and staff alike (Kahn and Walsh, 2006). Moreover they wanted their students to have a significant (rather than a boring or trite) learning experience (Dee Fink, 2003). Such a methodology allowed case-based, problem-based, research-led and project-based learning, where students' learning was organised around attempts to solve original problems that occur within the areas of biomaterials and bioengineering. These methods can help students develop the conditionalised knowledge and understanding that lets them think productively about problems in the discipline (Harris et al., 2002). Equally, both authors regularly employed the skills of practitioners and professionals working in the areas of Biomaterials and Biomedical Engineering. The rationale for adopting this was three-fold: (1) to ensure that students fully appreciated the truly interdisciplinary nature of this subject area, (2) the role that an engineer or scientist has within the field and (3) the

exciting employment opportunities that are available for students who have successfully completed these modules.

For the bioengineering module at Newcastle University the lead author evaluated his third of the module through an open-ended, anonymised questionnaire which was offered at the end of his third of the module. The first part of the questionnaire consisted of ten questions which were to be answered on a five-point scale. These questions to students included: 'the proportion of classes you attended'; 'the difficulty of the module relative to others'; 'the lecturer's interest and enthusiasm for their subject'; and 'your overall rating of teaching on the module'. There was then a section which asked students to give two positive aspects and two suggestions for improvement of the third of the module taught by the lead author. Additional sections then asked students to comment on specific aspects of the module. These included the use of Primal Pictures anatomical software which was used to quickly make students familiar with anatomical and medical terms related to the human body in general and orthopaedics in particular (Joyce, 2009c). Another section requested similar information regarding the use of human joint models. A third section asked for feedback on the interactive, small-group working while a final section requested comment regarding the visit to the dissection lab. Data was obtained for both the 2008/09 and 2009/10 academic years, though the visit to the dissection lab was first introduced in the 2009/10 academic year.

For the Biomaterials and Biomedical Engineering modules offered at QUB the second author evaluated his half of the modules using student questionnaires that were completed anonymously at the end of the 12 week program of study. The first element of the questionnaire consisted of 15 assertions that were to be responded to on a five-point scale. These assertions included: 'module's relevance to my degree programme was explained clearly', 'teaching was effective and relevant to the module aims and objectives', 'good interaction and feedback between students and lecturer', 'workload was appropriate to the module size' and 'rating for teaching of module'. The final element of the questionnaire asked students to comment on the 'most satisfactory aspects of this module', the 'least satisfactory elements' and 'how the lecturer could assist your learning on this module'. Data was obtained for both the MEng undergraduate students and MSc taught postgraduate students during the 2008/09 and 2009/10 academic years.

3. RESULTS

For the bioengineering module at Newcastle University, student feedback from the 2009/10 academic year to two of the specific questions relating to interactive small group working is shown in figures 1 and 2.

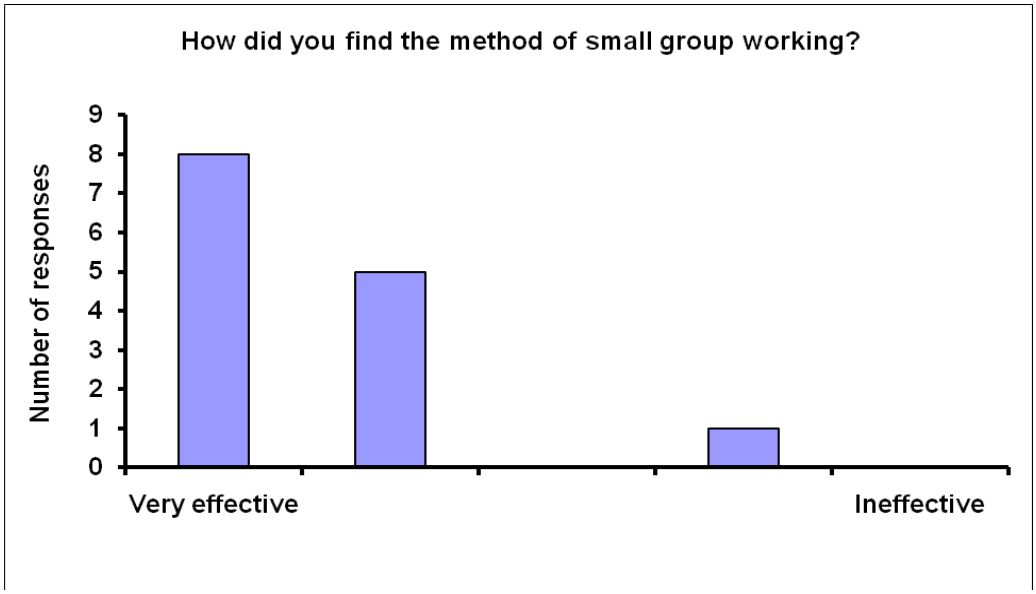

Figure 1 – Student responses to first question on small group interactive learning.

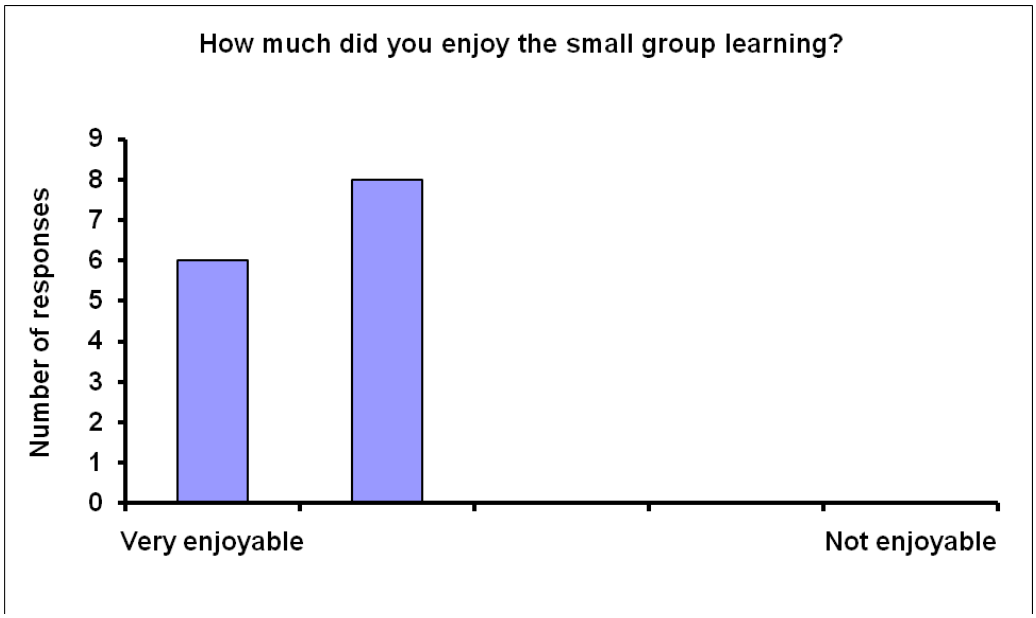

Figure 2 – Student responses to second question on small group interactive working.

Student comments on other aspects of the module included the following. For the interactive Primal Pictures software statements included: 'a really useful tool and very easy to use'; 'excellent and useful software'; and 'good to have access outside of lecture times, gives you chance to play about with it when you're in the right mood to work'. However, students would have preferred some additional developments as indicated by the comments: 'could be improved to include the ability to drag joints to make them move'; and 'would be good if you could zoom out onto a hand/foot/knee from the whole skeleton rather than having to hunt through tabs'. Regarding interaction using the models of human joints, student comments included the following: 'the clearest way to see and understand joint anatomy and movement'; 'good to get hands on, helped to gain an understanding about the scale of the joint'; and 'very interesting to

see models you can touch, the dynamic models were a great addition'. For the visit to the dissection lab and interaction with human joints the greatest praise was received: 'awesome experience'; 'fantastic class, helped to reinforce what we had learnt in classes, good to see firsthand how the materials differ and are similar to those of the prostheses'; 'extremely useful in understanding the joints and creating interest in the module'; 'greater appreciation for the complexity of the human body'; 'great chance to see real examples of joints and their relative movements'; and 'if time permits we should have more of these in future'. Where examples of 'two good features' of the module had been requested, student comments included: 'completely new and different from other modules in conventional (Mechanical) modules'; 'hands on use of models/making class think'; 'varied teaching methods helped to spark interest (talk and medical school visit)'; 'interactive learning, medical school, models, primal pictures software, etc'; 'interesting project'; 'lecturer's interest'; 'the structure of lectures'; 'the models shown for explanation'; 'very interactive'; and 'lecturer very enthusiastic about his subject'.
For the Biomaterials and Biomedical Engineering modules at QUB, student feedback from the 2009/10 academic year to two of the specific questions relating to interactive small group working is shown in figures 3 and 4.

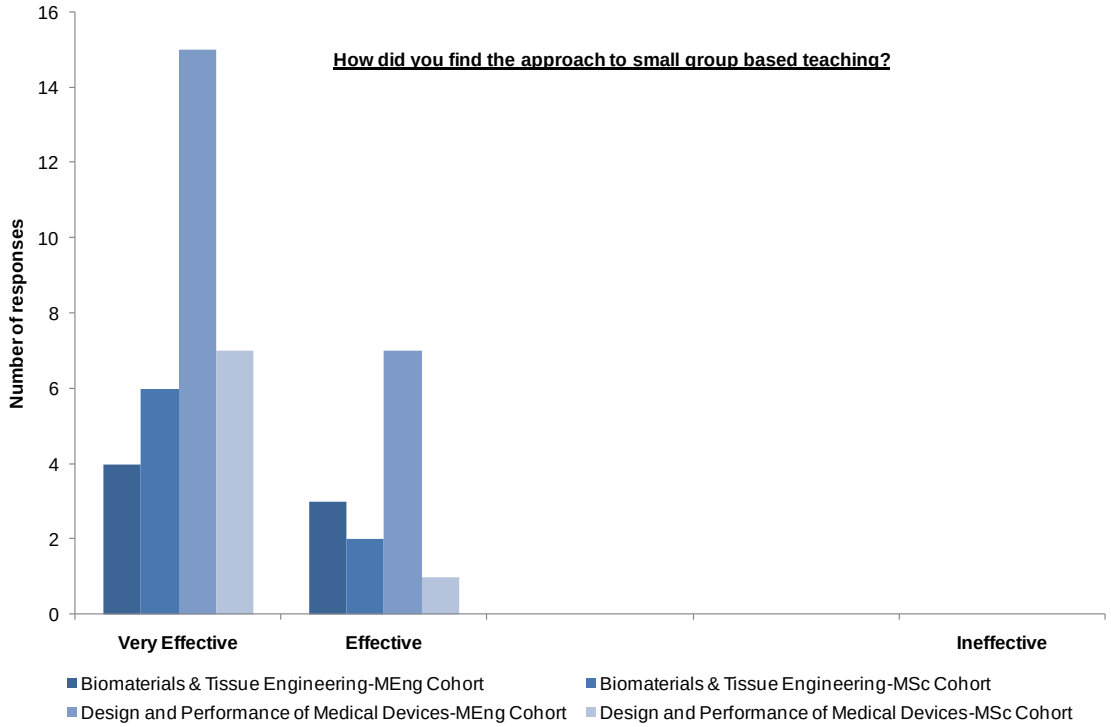

Figure 3 – Student responses to question on small group based teaching.

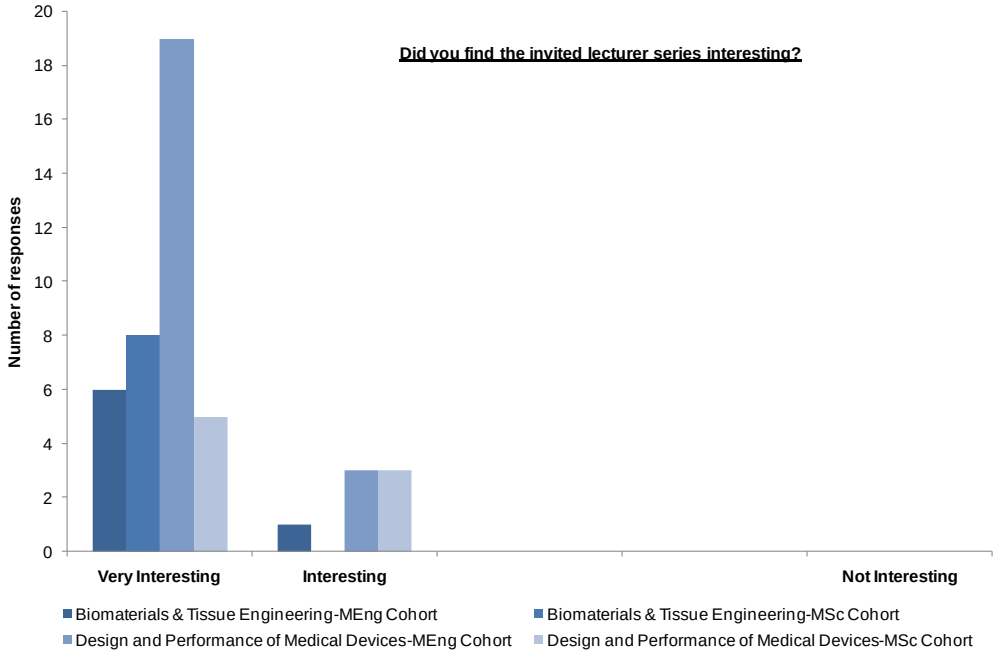

Figure 4 – Student responses to question on invited lecturer series.

Student comments relating to other positive aspects of the Biomaterials and Tissue Engineering module included the following. 'Good insight into biomaterials and applications', 'excellent teaching approach to use of materials in medicine', 'loved learning a complex new area', 'enthusiasm of lecturer and his experience made the module very interesting', 'really enjoyed the research based assignment...might even do a PhD now', 'found the discussion on what makes bone very interesting', 'engaging subject matter with many real world examples', 'enjoyed the research based coursework that allowed for development of new skills', 'program of guest lecturers very interesting', and 'all topics were extremely interesting and completely different to the rest of the Degree programme ... loved it'. With respect to the Design and Performance of Medical Devices module, student comments on the positive aspect of the module included: 'stimulating learning experience for the student', 'loved the real world applications to engineering', 'module provided greater understanding of how complex joints are', 'greater understanding of how medical implants are designed to work in the body', 'enjoyed the videos showing the role of an orthopaedic surgeon', 'a lot of useful and relevant examples shown during the module, enjoyable and very interesting learning experience', 'enjoyed the pace of the module and the found the lecturer very interesting, wholly different to other modules', and 'good student-lecturer feedback'. Comparing the comments and feedback from the undergraduate MEng and postgraduate MSc students taking the modules, it was observed that both sets of students had similar positive views. However, the postgraduate MSc students did make reference to the fact that they needed to spend additional time on the computational elements of the modules, particularly with respect to the Design and Performance of Medical Devices module. Specific comments included: 'some of the formulae relating to measurement of wear was challenging', and 'numerical questions in tutorials took longer to understand, but got there in the end'. These comments are not surprising as the students enrolled on MSc degree program in Polymer Engineering are materials scientists, chemists, biologists and chemical engineers and therefore would not be as proficient at engineering calculations when compared to their MEng

undergraduate peers. The least satisfactory aspect regarding both modules delivered at QUB can actually be seen as a positive, that is a number of students (n = 6) would have liked to have experienced these modules earlier in their Degree programme. Student comments relating to this point included: 'would have liked to have had this module earlier in my degree', 'stimulating subject, why did we not have this module in second year', and 'would have been good to experience topics like this earlier in course'.

4. DISCUSSION

The authors of this paper are bioengineers and this specialisation facilitates some of the teaching approaches undertaken. For example, the setting of student assignments based on the very latest research papers chosen by staff. Also, the two authors have a wide network of industrial and clinical collaborators whom they can invite to participate in modules. Despite these caveats staff and students both report positive learning experiences from the various bioengineering and biomaterials courses. One issue the lead author recognises is that of cultural differences between students. While UK and European students may be familiar with showing initiative and being relaxed with small group working, for some students from different educational backgrounds, where perhaps knowledge is expected to be received from the knowledgeable Professor, such interactive learning methods can be disconcerting. This may be why a small number, one per year to date, comment negatively on the five-point scales regarding small group working. However, as the questionnaires are deliberately anonymised, it is difficult to validate this assertion. Overall though, as can be seen from student comments, the majority of students have enjoyed and benefited from small group and interactive learning.

5. REFERENCES

American_Society_for_Engineering_Education (2008) *Engineering by the numbers*. Available at: http://www.asee.org/publications/profiles/upload/2007ProfileEng.pdf (Accessed: 18 August).

De Graaff, E. and Kolmos, A. (eds.) (2007) *Management of change. Implementation of problem-based and project-based learning in engineering.* Rotterdam: Sense.

Dee Fink, L. (2003) *Creating significant learning experiences: an integrated approach to designing college courses.* San Francisco: Jossey-Bass.

Harris, T. R., Bransford, J. D. and Brophy, S. P. (2002) 'Roles for learning sciences and learning technologies in biomedical engineering education: a review of recent advances', *Annual Review of Biomedical Education,* 4, (1), pp. 29-48.

Joyce, T. (2009a) 'Currently available medical engineering degrees in the UK. Part 1: undergraduate degrees', *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine,* 223, (4), pp. 407-413.

Joyce, T. (2009b) 'Currently available medical engineering degrees in the UK. Part 2: postgraduate degrees', *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine,* 223, (4), pp. 415-423.

Joyce, T. J. (2009c) 'The knee bone connected to the thigh bone: Teaching anatomy to engineering students using anatomical software', *01*, 19, pp. 9-10. [Online]. Available at: http://www.medev.ac.uk/external_files/pdfs/01_newsletter/0119_lo_res.pdf

Kahn, P. and Walsh, L. (2006) *Developing your teaching: ideas, insight and action.* Abingdon: Routledge.