ELSEVIER

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 34 (2012) 260 – 265

Procedia Engineering

www.elsevier.com/locate/procedia

9th Conference of the International Sports Engineering Association (ISEA)

Developing sports engineering education in Australia

Paul R. Medwell*, Paul N. Grimshaw, Will S. Robertson and Richard M. Kelso

School of Mechanical Engineering, The University of Adelaide, SA 5005, AUSTRALIA

Accepted 02 March 2012

Abstract

This paper presents some examples of teaching material used in Australia's first sports engineering degree programme. In an Australian context, the field of sports engineering education is very young. Despite the growth of sports engineering degree programmes, there is no clear description outlining sports engineering as a discipline. Although sports engineering programmes typically incorporate aspects of existing courses in the broad fields of mechanical and electronic engineering, there are other skills that are specifically required for sports engineers to possess. Over many years, traditional engineering fields have developed a plethora of quality teaching textbooks and course syllabi. Due to the recent growth of sports engineering as a field, there is a distinct lack of such material. One approach of dealing with this issue is to adopt the use of blended learning, merging suitable refereed scientific publications with traditional engineering theory, to problems applicable to sports. A number of international journal and conference series are dedicated to sports engineering, and these offer a wide breadth of up-to-date material; however, the suitability of this literature for educational purposes is not clear. In light of this gap, sports engineering in the Australian education system requires a clearer definition, and also some examples of suitable teaching material. These issues will be explored in this paper, and some solutions will be addressed. Although the paper is focussed on the Australian system, the broad findings are applicable world-wide.

Keywords: Sports engineering education

1. Introduction

With the emergence of sports engineering as a recognised engineering Bachelor degree, the first example in Australia being the University of Adelaide, there is a growing need for suitable teaching material. Over many years, traditional engineering fields have developed a plethora of quality teaching

* Corresponding author. Tel.: +61 (0)8 8303 5460; fax: +61 (0)8 8303 4367.
E-mail address: paul.medwell@adelaide.edu.au.

doi:10.1016/j.proeng.2012.04.045

textbooks and course syllabi. Due to the recent growth of sports engineering as a field, there is a distinct lack of such reference texts, and even if such texts existed, many aspects of them would quickly become outdated. A number of international journals (e.g. [1,2]) and conference series (e.g. [3]) are dedicated to sports engineering, and these offer a wide breadth of up-to-date material; however, the suitability of this literature for educational purposes is not clear. One approach of dealing with this issue is to adopt the use of blended learning, merging suitable refereed scientific publications with traditional engineering theory, to problems applicable to sports.

In the context of sports engineering education two key issues arise:

1. How to incorporate sports engineering into traditional subject areas?
2. How to develop skills specific to sports engineering?

1.1. Combining sports engineering with fundamental skills

Developing core fundamental engineering skills in the areas of mathematics and dynamics is important for sports engineers [4]. To encourage student interest, it is necessary to ensure that teaching material is both interesting and relevant. Fortunately, sport provides a wealth of examples that are suitable for inspiring students in the areas of science and engineering [5]. In particular, there are countless examples that are well suited to apply the fundamental principles of the equations of motion in a sporting context [6]. As an example, the dynamics of a lawn bowl trajectory [7] has been used as a sporting application for teaching both secondary and tertiary level mathematics students [8]. The ability to extend sports into the areas of mathematics and physics not only aims to increase interest in the specific discipline of sports engineering, but engineering in general [9].

1.2. Specific sports engineering skills

Beyond the inclusion of sports into traditional education fields such as mathematics and physics, the specialised field of sports engineering requires a diverse range of skills to be developed in graduates, including some unique to this discipline. Although sports engineering programmes typically tend to incorporate aspects of existing courses in the broad fields of mechanical and electronic engineering, there are other skills that are specifically required for sports engineers to possess. The ability to interactively process and analyse data is a useful skill that may not be fully covered in more traditional engineering subjects. One particular focus within this area that many graduates will find invaluable is the ability to write computer programmes incorporating a graphical user-interface (GUI).

The benefits of introducing students to GUIs for educational purposes in engineering have been discussed by others [10], who note that GUIs enable an interactive visual approach to problem solving and thus can reinforce understanding of the governing theory. In the context of sports engineering, this concept should be taken one step further. Beyond the fundamental skills of understanding a particular theory, using computer programming to solve and present results is, in itself, another important skill to develop in sports engineering graduates. This could be done by considering GUI development as a stand-alone learning outcome and presenting material from a specific programming or GUI-development book such as that by Smith [11].

Encouraging students to develop their own GUIs teaches them valuable programming skills that may not be covered in more traditional subjects. This new-found skill will then enable them to build upon their theoretical understanding of the problem that they are modelling through experimenting with their completed GUI. Interactive GUIs enable key parameters to be easily varied, and the effects to be shown immediately. Returning to the trajectory for the lawn bowl from §1.1, following the derivation of the equations of motion, these may be used as the basis for GUI development [8].

1.3. The University of Adelaide

The School of Mechanical Engineering at University of Adelaide offered Australia's first sports engineering degree in 2008. The first cohort of students graduated, with honours, at the end of 2011 with the degree Bachelor of Engineering (Mechanical and Sports), accredited by Engineers Australia. This paper provides an opportunity to reflect on the degree programme and provide some insight into the content and structure of sports engineering degrees, in particular in Australia.

2. Degree Structure

The University of Adelaide's Bachelor of Engineering (Mechanical and Sports) is a four year degree. The structure of the first year is essentially the same as the other five programmes offered within the School of Mechanical Engineering (Mechanical, Mechatronic, Automotive, Aerospace, Sustainability). At higher year levels, the number of sports engineering specific courses (subjects) increases, culminating in the final year honours project. The key courses that are unique to the sports engineering degree are: Sports Engineering 1, Sports Engineering 2, Sports Engineering 3, Sports Materials, and Engineering Biomechanics. Other courses are shared with other degree programmes offered by the university. The essence of these courses may be summarised as:

- *Sports Engineering 1*: Biomechanics, Instrumentation, Sensors, Mechatronics, Matlab®.
- *Sports Engineering 2*: Sports equipment design and testing, GUI development, legal issues.
- *Sports Engineering 3*: Sports aero- and hydro-dynamics, stadia design, sustainable design.
- *Sports Materials*: Biological materials, advanced materials, composites, solid mechanics.
- *Engineering Biomechanics*: Structure and mechanics of the musculoskeletal system.

Within these courses specifically created for the sports engineering degree, new course material was introduced, and forms the basis for the remainder of this paper.

3. Approach

As outlined in the introduction, developing a sports engineering curriculum consists of two main areas: integrating sports engineering with traditional subjects (with a basis in mechanical engineering in our case), and developing unique sports engineering content. This section provides some example teaching methodologies of each of these approaches, and also includes some sample laboratory and assessment tasks.

3.1. Fundamental engineering skills

All mathematics (maths) and physics students will be familiar with the concept of projectile motion and the subsequent parabolic trajectory. Since these concepts form the basis for analysing many sporting activities, there is already a clear and definite link between traditional maths and physics and the teaching of sports engineering. Obviously, more detail is required in order to expand this to university-level sports engineering degree programmes, but demonstrates the inherent link that sport has to the fundamental engineering skills.

Combining sports engineering with the traditional subjects of maths and physics can be achieved in two ways; both by adding sporting applications to the existing maths and physics courses, and also by adding maths and physics to the newly derived sports engineering courses. The latter may prove easier, as the former relies on other university departments (who typically incorporate engineering students for such courses) to change their teaching material. As such, it falls on the sports engineering teachers to develop and integrate maths and physics into sports engineering courses. Nonetheless, wherever possible it would be advantageous for sporting applications to be integrated into the traditional maths and physics subjects. This would have two key benefits. Firstly, the sports engineering students would obtain a greater level of education and feel more comfortable with knowing that their skills are indeed more widely recognised. Secondly, by teaching all of the maths and physics students about sports engineering they will have a better appreciation for what the degree entails. This would prove an excellent mechanism by which sports engineering could be promoted more widely throughout the university community – perhaps even encouraging students from other streams to join sports engineering.

Despite the advantages of incorporating a greater level of sports engineering in traditional engineering subjects, this is unlikely to see wide-spread implementation. For the moment it will be the domain of sports engineering lecturers to include maths and physics examples that have a sporting application to their courses. One example that has been shown to have merit is the derivation of the equations of motion for the trajectory of a lawn bowl. Whilst these equations have been previously been presented by Cross [7], and more detailed descriptions have been presented by others (e.g. [12]), these are not necessarily ideal for fundamental-level teaching. Other attempts to study ball precession in an educational context [13] are also not as well suited as they lack the clear link with sports. Alternatively, a study of an unbiased ball has been used as a teaching tool [14], but does not include the additional level of complexity, and interesting trajectory, of the lawn bowl. Cross [7] only provides the basic outline for the lawn bowl trajectory, leaving significant scope for in-class demonstration and assessment. Furthermore, following the mathematical derivation, students' computing skills can also be developed by programming and analysing the results through the development and use of a graphical user-interface.

Beyond university-level education, throughout the derivation of the lawn bowl trajectory there are many important steps that pose an interesting problem for students in mathematics and physics. Aspects of this derivation are also appropriate for secondary school students in mathematics and physics, thus promoting and enthusing them to consider sports engineering studies at university level. This issue is important to ensure that prospective students recognise that sports engineering is indeed a legitimate career option and that they will learn key fundamental skills.

3.2. Sports engineering skills

As discussed in §1.2, sports engineering graduates require a range of skills, some of which are beyond the scope of existing courses. One of the particular areas that students will benefit from is in the development of computer graphical user interfaces (GUIs), which are seldom taught in other subjects, particular within mechanical engineering.

The University of Adelaide uses Matlab® extensively throughout various engineering courses, and it is therefore an obvious platform for developing GUI skills. There are countless examples that could be used as the basis for creating a GUI, though the lawn bowl trajectory is an ideal candidate. Building on the maths and physics learned during the derivation of the lawn bowl trajectory outlined above, a GUI can be created. The resultant GUI enables students to interactively plot the trajectory, and assess the influence of the various parameters governing the lawn bowl. Beyond skills in creating a GUI, numerous other aspects of Matlab®, and other more general programming skills, can be taught. Further details on the development and application of a lawn bowl trajectory GUI has been presented previously [8].

Beyond the development of GUIs, there are numerous other skills that a sports engineering graduate ought to possess. The exact specifications will depend on the host institution, and the context of the degree.

3.3. Laboratory Classes

Laboratory classes are an important aspect of any engineering education, especially for sports engineering. Throughout every course at the University of Adelaide students are exposed to laboratory classes. Laboratory and practical sessions also form an integral part of the specialised sports engineering subjects, with each subject typically incorporating at least two different laboratory classes. Laboratory classes span a wide range of topics, commensurate with the wide range of skills required from a sports engineering graduate.

One of the laboratory classes that receives particularly positive feedback is the 'ball testing and dissection practical'. In this laboratory students are given a range of different sporting balls, of various quality, and are asked to test for the conformance against relevant standards and regulations. Part of this laboratory involves dropping the balls onto a large timber plank which is fitted with an accelerometer. From the time between bounces, the coefficient of restitution is estimated, and compared against the 'expected' values obtained from their research. Whilst relatively simplistic, students are exposed to physics experimentally, and gain 'hands on' working knowledge of accelerometers, amplifiers and power supplies. Data is recorded to a computer with an analogue-to-digital converter, and thus students learn some issues related to interfacing peripheral components. Signal and data processing is also a critical component of this class. Furthermore students can visually "see" the effect of noise that they so often are taught but seldom have a good grasp of. As such, albeit a simple experiment, there are many highly valuable learning outcomes.

Following-on from experimental testing of the performance of a range of sporting balls, students then dissect the balls to gain experience in the construction and materials used. Comparisons between different brands and quality (price) can be related to manufacturing techniques, and the measured performance of the balls. This also provides an opportunity to teach the students about the use of common hand tools.

Another laboratory class where the students gain practical skills is one which involves the calibration of a load cell. Students are provided with a force transducer and need to design a relatively simple circuit to allow measurement of force, requiring them to apply some working knowledge of simple electric circuits. This laboratory class also incorporates soldering. Beyond the practical skills, following the laboratory session, students are then required to develop a conceptual design of a piece of sports engineering apparatus that incorporates the force transducer that was used in the class.

The laboratory classes outlined above are only a brief snapshot of the many and varied sessions that are taught in the sports engineering courses, and are combined with dozens of other practical classes in other more traditional engineering subjects.

4. Student Feedback

Student feedback is an important aspect of teaching, to ensure that the material is appropriately delivered [15]. In accordance with the University of Adelaide's policy on student evaluation of learning and teaching [16] students regularly complete questionnaires. The student feedback from the sports engineering courses has been generally very good and encouraging. This reinforces that the teaching methodologies adopted are well received. Some examples of student comments are listed below:

- "Material taught in this course is very useful"
- "Very interesting. It's a course about stuff that I came to uni to do."
- "Interesting and engaging assignments."
- "Course is interesting and promotes learning."
- "…was actually motivated to read papers for once."
- "Focus on sports related topics and how course material can be used in the field. Enjoyable."

- “Real-life examples of studies that have been conducted to improve sporting performance in some capacity. Learning how what we are learning immediately relates to the sporting field. Labs are very interesting and useful”.

Evident from this feedback is how appreciative the students are that the blend between traditional material and sports engineering have been integrated. This provides confidence that the teaching methodologies proposed are successful.

5. Conclusions

Sports engineering is a young discipline of engineering that has yet to establish a comprehensive suite of teaching material. Over the coming years the quality and consistence of teaching resources will become available. In the interim, courses will need to be developed from existing literature, both in the form of conventional textbooks and also the use of peer-reviewed conference and journal series. This paper has provided some examples of teaching methodologies used for sports engineering education, and is intended to spark similar practices elsewhere.

References

[1] *Sports Engineering* (ISSN (print): 1369-7072, ISSN (online): 1460-2687).
[2] *Sports Technology* (ISSN (print): 1934-6182, ISSN (online): 1934-6190).
[3] *International Conference on the Engineering of Sport* (International Sports Engineering Association).
[4] Jenkins, P.E., Plaseided, A. and Khodaee, M., ‘UCD Sports Engineering Program’ *8th Conference of the International Sports Engineering Association (ISEA): Procedia Engineering* 2010; 2: 2757-2762.
[5] James, D.M. and Haake, S.J. ‘Using Sport to Educate and Enthuse Young People About Engineering and the Physical Sciences’, *The Engineering of Sport 2006*; 6: 273-278.
[6] Rydakov, R., Nyashin, Y., Ilyalov, O. and Podgaets, R. ‘Problems of Sport Engineering in Teaching Theoretical Mechanics’, *8th Conference of the International Sports Engineering Association (ISEA): Procedia Engineering* 2010; 2: 2763-2768.
[7] Cross, R., ‘The trajectory of a ball in lawn bowls’ *American Journal of Physics* 1998; 66(8): 735-738.
[8] Medwell, P.R., Brooks, L.A., and Medwell, B.S., ‘Analysis of the Lawn Bowl Trajectory as a teaching tool for Sports Engineering: development of a graphical user-interface’, *5th Asia-Pacific Congress on Sports Technology, Procedia Engineering* 2011; 13: 531-537.
[9] Cooke, A. and Taylor, A.M.B., ‘Sports Engineering in Education: A Methodology for Educating Engineers and Promoting Engineering Careers’, *IEE 2nd Annual Symposium on Engineering Education* 2002; 1: 12/1-12/7.
[10] Azemi, A. and Yaz, E.E., ‘Using Graphical User Interface Capabilities of MATLAB in Advanced Electrical Engineering Courses’, *Proceedings of the 38th Conference on Decision and Control, Phoenix Arizona, USA* 2009; 359-363.
[11] Smith, S.T., ‘MATLAB: advanced GUI development’, Dog Ear Publishing, LLC, 2006.
[12] Brearley, M.N. and Bolt, B.A., ‘The Dynamics of a Bowl’, *Quarterly Journal of Mechanics and Applied Mathematics* 1958; 11(3): 351-363.
[13] Guest, P.G., ‘Rolling Precession’, *American Journal of Physics* 1965; 33: 446-448.
[14] Hierrezuelo, J., Catolicos, B.R. and Carnero, C., ‘Sliding and rolling: The physics of a rolling ball’ *Physics Education* 1995; 30: 177-182.
[15] Cannon, R. and Newble, D. ‘A Handbook for Teachers in Universities and Colleges (4th edition)’, RoutledgeFalmer, 2000.
[16] http://www.adelaide.edu.au/policies/101, ‘Student Experience of Learning and Teaching (SELT) Policy’. *The University of Adelaide.* Last viewed 20th December, 2011.