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PRACTICE PAPER

Learning to be a sport and exercise 'scientist': evaluations and reflections on laboratory-based learning and assessment

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Abstract

This paper offers a critical and personal review of the theoretical rationale for employing the activity-based laboratory report to assess and enhance student learning within the sport and exercise sciences (SES). With reference to Biggs' (2003) concept of constructive alignment, it is suggested that the experience of active laboratory research and the written report are fundamental to the training of future sport and exercise scientists. Such activities contain critical aspects of 'scientific learning' that should be continually assessed, both formatively and summatively. An activity-based laboratory research project is subsequently described for the Level 2 undergraduate student where student feedback is also presented. It is concluded that the activity-based laboratory report should remain at the forefront of student assessment in all science-related disciplines, and the author urges those institutions involved in teaching SES to ensure that active student laboratory experience and report writing are commonplace.

Keywords: Active learning; Constructive alignment; Critical-thinking; Problem solving

Introduction

Sport and exercise science (SES) is primarily concerned with the scientific study of sporting excellence or how regular exercise promotes health and well-being. The subject encompasses the sub-disciplines of physiology, psychology, biomechanics, sociology and motor learning; students will typically direct their attention to one of these as their studies develop. Although SES is undergoing rapid growth as an academic discipline, available educational research directed towards improving the teaching of SES is limited (Morton, 2007a).

One of the many educational aims of the BSc Sports Science degree at the author's institute is to 'equip students for postgraduate study and/or research in the field of sport and exercise'. Crucial to this objective is that students have a sound understanding of the scientific process and also of how science can benefit society. It has long been suggested that public understanding of science is 'appalling', an effect attributed to the inability of the educational system to train students to become interested in actively knowing rather than passively believing (Michael, 2006; Volpe, 1984).

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Based on Biggs' (2003) concept of 'constructive alignment', it is therefore essential that both teaching methods and assessment are appropriately aligned to support appropriate learning of the course objective, namely that of the scientific process. It should be noted that it is assessment that dominates students' thinking during their time at university (Entwistle, 1991; Ramsden, 1992). From their perspective, it is assessment that determines what and how they should learn rather than the curriculum specifics (Struyven, Dochy, & Janssens, 2005). This phenomenon, referred to as 'backwash', results in surface learning (Crooks, 1988; Frederiksen & Collins, 1989). In an effort to combat this effect, it is suggested that the trick is to align the assessment to what students should be learning (Biggs, 2003). If our educational goal is to train the scientists of tomorrow, then the experience of active laboratory research and the subsequent written report are fundamental to this process. These activities contain critical aspects of 'scientific' learning (hypothesis generation, research design, data collection, analysis and interpretation) and should continually be assessed throughout the course of an undergraduate degree programme.

The present paper provides a personal and critical review of the theoretical benefits of employing the activity-based laboratory report to assess and enhance student learning within SES. I begin by providing an overview of the traditional tutor-led laboratory experience. A rationale for utilising an activity-based student centred approach and an example of such an approach to learning and assessment (specific to the discipline of physiology and to the science of soccer) are then presented. Finally, I close by outlining some student feedback appraising this approach and by providing some take-home messages to institutes involved in teaching SES.

The traditional method of laboratory demonstrations

Traditional methods of laboratory experience involve instructor demonstrations where students typically gather around equipment of interest. In these cases, students quickly become uninterested and often leave the laboratory having had limited time to experiment with the equipment and with poor understanding of how such tools are employed in the research process. Where they are given adequate time, it is often a 'cook book recipe' approach where step-by-step methods are followed. The laboratory skills necessary for the variables routinely measured in exercise physiology (for example, maximal oxygen uptake, lactate threshold, blood pressure, etc) are not mastered after brief instruction or limited practice. This teaching method is in direct contrast to the requirement that students should be active, independent learners and problem solvers rather than passive recipients of information (Michael, 1989, 2006). Furthermore, students do not develop a sound understanding of the scientific process and show a lack of appreciation of the importance of controlled experiments, mistakes that can happen in the laboratory, the variability of human physiological responses and methodological limitations. Following limited demonstrations, they are typically provided with 'textbook' data and are subsequently expected to produce first-class written reports. For logistical reasons, I have used such an approach in the past, and whilst the students have undoubtedly became better communicators, they have not become better scientists. This is a classic example of a poorly aligned system.

Why shift towards the activity-based laboratory report?

By contrast, an activity-based laboratory report, where the students are given ownership for the research design and data collection process, promotes a deep approach to learning, as students are actively involved from the outset (Kolkhorst, Mason, DiPasquale, Patterson, & Buono, 2001). It is this concrete experience of action which helps students to remember concepts or physiological phenomena long term, rather than just until the next test (Woodhull-McNeal, 1992). Randall and Burkholder (1990) described a series of experiments in which students became excited by being able to *do* experiments rather than observe demonstrations. They distinctly recall how the students were 'puzzled' when they brought their records to instructors because they didn't look like those in the textbook. Randall and Burkholder further commented, "What a pleasure it was to assure them that this was because their records were better than those in the textbook …we had no problem holding the students' interest and excitement for learning under such circumstances" (S5).

Furthermore, other active approaches to learning such as 'problem-based learning' and 'group-based tasks' are also typically well received by SES students and have been shown to facilitate student engagement and enthusiasm (Duncan & Al-Nakeeb, 2006; Duncan, Lyons, & Al-Nakeeb*,* 2007). With this approach, the authors reported increased student autonomy, independent thought, critical thinking skills and greater acquisition of practical/employability-related skills compared with traditional lecture-type activity.

It is important to note that although students may not achieve the outcomes initially hypothesised (or observed previously in the textbook) when in the laboratory, this can be equally educational (Woodhull-McNeal, 1992). In this regard, active laboratory experience can increase student awareness of mistakes that can happen in the laboratory, which may be due to 'sloppy' technique. Their appreciation for the rigorousness required in the laboratory is enhanced and they improve their troubleshooting ability, a mindset beneficial for research (Woodhull-McNeal). Furthermore, students (who potentially are the next generation of decision-makers) can actually learn whether (or not) they want to become scientists in the first place (Woodhull-McNeal).

Following data collection, students are required to perform statistical analysis procedures. University students typically approach this element of study with a sense of 'anxiety' (Onwuegbuzie and Wilson, 2003) and are often intimidated by computers and statistical software packages (Woodhull-McNeal, 1992). More specifically, SES students are also known to display low levels of self-efficacy towards statistical components of study (Lane, Davenport, Milton, & Williams*,* 2003). Nevertheless, several authors have observed that the concept of data ownership allows students to approach this element of science with greater enthusiasm (Kolkhorst et al., 2001; Woodhull-McNeal). Furthermore, Lane, Hall, & Lane (2004) argue that for SES students the focus of research methods modules should be related to 'sport' data to enhance enthusiasm for this component of study.

The final end-point of the data collection and analysis period is the written description and critical evaluation of the findings. The written laboratory report is the primary vehicle of communication amongst scientists and a well-written paper is certainly one of reviewers' key criteria which are assessed when judging the scientific merit of a research paper (Buenos, Kirk, & Hall*,* 2003). It is therefore important that students experience the process of writing in the conventional scientific format of 'Introduction, Methods, Results and Discussion'. Aside from a scientific perspective, the process of report writing is also a skill that is highly relevant in many graduate jobs.

It has been suggested that the above teaching strategy may be effective in improving the ability of students to design scientific experiments and may also improve their critical interpretation of data (Myers & Burgess, 2003). This teaching strategy is therefore effective in developing fundamental scientific skills such as hypothesis generation, research design, data collection, critical interpretation of data and scientific writing. Furthermore, it places less emphasis on teaching 'facts' and greater importance on theoretical concepts. Such approaches to laboratory teaching are particularly effective in small groups (Springer, Stanne, & Donovan*,* 1999) and typically receive positive student feedback (Kolkhorst et al., 2001; Myers & Burgess, 2003; Modell, 1996; Randall & Burkholder, 1990; Woodhull-McNeal, 1992). An activity-based laboratory approach to learning and assessment is therefore a classic example of a well-aligned system for any science-related discipline, providing that students perceive the task as meaningful and relevant (Brown, Bull, & Pendleburry*,* 1997).

Activity-based learning and assessment model

The present and subsequent sections detail an activity-based laboratory approach to learning and assessment currently employed at the author's institute for Level 2 undergraduate students. The model is designed to foster students' ability to design, conduct, analyse, interpret and present scientific data and to expand upon 'textbook' material typically taught at Level 1, whilst simultaneously preparing the student for their independent and inquiry-led piece of research in their Level 3 major project. The model serves 20 to 30 students at a time, is specific to the discipline of exercise physiology and is further targeted to the 'science of soccer'. The module is entitled 'Scientific Fundamentals of Soccer' and uses texts (Reilly & Williams, 2003) and research papers (Drust, Reilly, & Cable, 2000a, 2000b) authored by staff members of the host department as core reading material.

Background

Module title: Scientific Fundamentals of Soccer

Module aim: To examine the physiological responses to soccer-specific intermittent exercise and to analyse the effects of nutritional strategies and environmental stresses on such responses

Learning outcome 1: Critically evaluate the physiological and metabolic response to exercise, specifically the soccer-specific intermittent exercise pattern

Learning outcome 2: Critically evaluate the impact of environmental stresses on the physiological responses to exercise and specifically the soccer-specific intermittent exercise pattern

Coursework title (laboratory report): Critically evaluate the laboratory-based soccer-specific treadmill protocol as a simulation of soccer match play. What effect does high ambient temperature have on the physiological responses?

Soccer is an invasive field game that is characterised by intermittent activity patterns (Reilly and Thomas, 1976). This separates it from sports with continuous exercise patterns, thus making the physiological demands more complex. These irregular activity patterns make it harder to study in a laboratory setting. Several investigators have tried to replicate the physiological demands and activity patterns of soccer by employing motion analysis studies and subsequently by devising treadmill exercise protocols incorporating these activities. Drust, et al. (2000b) devised an exercise protocol that can be performed on a programmable motorised treadmill, which incorporates the majority of activities observed in a game (for example, walking, jogging, cruising, sprinting) and at similar speeds to those typically seen in real soccer match play. Such a protocol therefore allows the physiology of soccer to be studied with the rigorousness that can be provided in the laboratory. The first aim of the assessment task is to critically evaluate the validity of this protocol in terms of its ability to simulate the physiological demands of soccer match play.

Soccer is routinely played in environments in high temperatures. For example, the World Cups of USA 1994, Japan and Korea 2002 and Germany 2006 were all played in high ambient temperatures. It is therefore imperative that sport scientists have a sound understanding of the impact of heat stress on the physiological responses to the intermittent exercise patterns observed in soccer. Such knowledge will allow for the development of acclimatisation and nutritional strategies to offset the influence of heat stress during competition. The second aim of the assessment task is therefore to examine the effect of high ambient temperature on the physiological responses to the intermittent exercise patterns typically observed in soccer match play.

In view of the contemporary nature of the research exercise and the direct practical applications of the findings, students often report that they approach this particular learning and assessment model with a greater sense of value, enthusiasm and excitement than other assessment procedures. In this instance, those warnings offered by Randall and Burkholder (1990) and Brown et al. (1997) on the importance of utilising a task deemed as 'meaningful and relevant' are overcome from the beginning.

Methods

A typical course syllabus detailing the appropriate sections relevant to the activity-based learning and assessment model is shown in Table 1. In the opening two weeks, students are familiarised with related physiological background. In Week 3, a seminar centring on the research design process (for example, ethical concerns, risk assessment, controlled experiments, hypothesis generation, etc) is delivered in which students discuss and debate an appropriate methodological approach to undertaking the investigation. The course instructor will intervene where appropriate and the session ends with an agreed methodology to implement. Weeks 4–6 focus on learning laboratory techniques and the data collection process. The students are split into seven groups of four for these sessions (depending on student numbers; in the last academic cycle there were 28 students enrolled on the module). One person from each group acts as the exercising subject for the data collection process. The data collection process is organised into a randomised crossover design in that subjects will perform the exercise protocol in normal ambient conditions and in elevated temperatures similar to those of previous World Cup environments (this is achieved by performing the exercise protocol in an environmental heat chamber). Various physiological measurements are recorded during exercise (oxygen uptake, heart rate, blood lactate, rectal temperature, etc). The remaining three subjects are involved in recording the necessary measurements from the subject after completing the relevant training in Week 4. The course instructor and laboratory technicians are also present during these sessions to provide guidance and aid troubleshooting where needed. In Week 7, students participate in a workshop session concerned with data analysis and report writing. The session begins by having students perform a worksheet task related to data analysis and presentation and is conducted with the aid of appropriate computer software. They are subsequently provided with examples of previous reports and are asked to critique and assess such accounts using the marking criteria and guidelines that have been provided. By the end of this session, students typically report that they are well informed about the specific criteria required in a typical laboratory report. The relatively small group sizes (student numbers <30) ensure that staff can monitor progress and learning and provide formative feedback throughout. Formative assessment is achieved throughout the course period via class tasks, active reviews (Morton, 2007b) and individual tutorials. Relevant content from each week's activity is included in the final written report and is therefore assessed in the final summative assessment.

Week	Topic	Content	Formative Assessment	Summative Assessment
1	Physiology of intermittent exercise	Interactive lecture examining history and recent research developments in this area	Q&A – question and answer teaching approach; related tasks and active review	Relevant content to be included in final written report
2	Physiology of exercise in the heat	Interactive lecture examining history and recent research developments in this area		
3	Seminar: designing the experiment and scientific writing	Group discussions, agreement of the experimental design and scientific writing		
4	Lab work: familiarising with laboratory techniques	Students provided with training for techniques to be used for data collection		
5	Data collection	Supervised data collection process	Efficient data collection	
6	Data collection	Supervised data collection process		
7	Workshop: data analysis guidelines and report writing	Workshop tasks related to analysis and report writing	Q&A; related tasks and active review	
10	Assessment hand-in date			

Table 1: Typical course syllabus for the activity based approach to learning and assessment for a level 2 cohort of students (for a module specific to the physiology of soccer).

Model evaluation

Following completion of the laboratory experience and submission and assessment of the final written report, all students completed an open-ended questionnaire designed to assess the following constructs: relevance of the task, the laboratory experience, knowledge of the research process and time required for preparation and writing of the final report. Students typically reported that they found the task highly relevant and engaging (mainly due to its practical application to soccer) and that this particular lab had more opportunities to 'get involved' than conventional labs. It was strongly felt that the 'hands-on' approach was beneficial in facilitating learning. Students also reported that they were more informed about the rigorousness required in the laboratory and deemed themselves to be more effective written communicators. Many students also commented that the lab had prepared them for what was expected in their final year major project. Surprisingly (to the staff involved in module delivery), the majority of students did not complain about the length of time required to complete the coursework task, although some students felt that the feed-forward 'assignment preparation' sessions could have been delivered with more time to spare before the assessment hand-in date. Finally, several students reported they would like to see this approach to learning and assessment employed more frequently in subsequent modules. Specific examples of students' evaluations are included below (25 per cent of student responses were randomly chosen according to Altman, 1991).

> This lab had more opportunity to get involved either in carrying out the testing or participating as a subject. This makes it more interesting and easier to learn because the session was more interactive in nature. Putting theory into practice makes it feel like learning has been worthwhile.
>
> It was a really good task, because international tournaments take place in hot and humid conditions, we can now understand what happens to our bodies during this experience. It was a huge difference between reading and doing the experiment, it gives me a clearer understanding.
>
> It was clear, interesting and highly relevant to the course. It provided links to other modules and gave me potential ideas for my dissertation in 3rd year.
>
> There was more opportunity to get involved, it was more interesting to know exactly why and how everything was taking place. I would say I am definitely a more critical thinker and it has helped me write more concisely. What I have learned most is the importance of well-conducted labs and the conciseness that is needed when writing and presenting reports.
>
> It allowed good first-hand experience of physiological research and its requirements; it gave me good preparation towards my third year major project work. The smaller groups enabled more opportunities to interact and get a better idea of what was happening and why.
>
> I have learned the importance of thorough lab work and the process involved in conducting a research project.
>
> There was small groups involved so this helped in giving more hands-on experience. Seeing physiological testing in practice is more interesting and allows a clearer outlook. I particularly enjoyed writing up the report and comparing my own ideas and data to the published literature. It has shown me how to critically analyse data.

The positive feedback obtained here is similar to that noted by those authors who also used active approaches to learning in the classroom compared with traditional lecturer-focused activities (Duncan & Al-Nakeeb, 2006; Duncan et al., 2007). Collectively, these studies suggest that SES students appear to enjoy an active approach to learning in both the classroom and laboratory and that such approaches are beneficial for facilitating learning of key skills inherent in the scientific process.

By far the biggest contributor to the model's success is the relatively small class size, which ensures that all students are actively involved and there is an appropriate student-teacher ratio permitting reasonable one-to-one communication. That is not to say that such approaches to learning and assessment cannot be employed in larger modules. Indeed, I have been involved in running similar projects in modules where student numbers are in excess of 100. However, such cases are considerably harder to manage logistically and of course require greater staff resources in the laboratory, the classroom and in marking the final written report. Furthermore, having witnessed such an approach, I am never convinced that students receive the same educational benefits as when working in smaller groups.

When employing this approach to learning and assessment, it is essential that the laboratory is housed with sound instrumentation and resources. Indeed, the present model is aided by a variety of equipment (for example, environmental heat chamber, treadmills, heart rate monitors, gas analysis systems, blood collection/analysis kits, thermoregulatory analysis system). It is therefore acknowledged that institutions are limited in the laboratory experience they can provide. Nevertheless, experiments can be conducted with minimal equipment (cycle ergometers, heart rate monitors and fluids, etc) with which students can still receive the benefits of 'meaningful' learning from engaging in an active approach.

The delivery of the present model requires thorough planning and is the product of teamwork from a variety of individuals. It is therefore of paramount importance that staff involved in the delivery and assessments are well trained, committed and fully briefed and enthused by the project. The importance of such a level of time investment should not be overlooked and such efforts are the backbone of successful student learning. Woodhull-McNeal (1992) previously noted this point when stating, "When student and teacher leave the laboratory each day, both should be tired but intellectually gratified that time and effort were well spent" (S7).

Summary and conclusions

The present paper has provided a brief review of the theoretical rationale for why an activity-based approach to learning and assessment should be employed in SES. An activity-based model for an exercise physiology-centred module within SES has been described that is specific to the physiology of soccer. However, the paper should not be limited in its application to this discipline. The principles of alignment (where the written report is used as the final end-point summative assessment of learning) can be readily transferred to any sub-discipline of SES or to any scientific discipline. It is strongly recommended that those institutions involved in teaching SES make a concerted effort to ensure that active laboratory experience and report writing remain at the forefront of student learning and assessment. Indeed, if we really want to educate students in 'learning to be a scientist', I believe that it is crucial that active laboratory experiences are a central theme of the curriculum.

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