Blended Learning Approaches for Statistics Teaching

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Abstract

The teaching of statistics at university is challenging because many students have negative perceptions towards the subject and it requires students to integrate mathematical concepts, the process of statistical inference, and their applications to real world problems. Blended learning approaches have the potential to meet these challenges and facilitate student learning in various ways. This chapter reviews established and emerging practices in blended learning for statistics teaching at university. Various blended learning approaches including wikis, vodcasts, dynamic collation of class responses, discussion boards, blogs, interactive computer-based exercises, on-line tutorials, and social media are reviewed in terms of their methods of application, student perceptions, and effectiveness to enhance student learning outcomes. The future role of blended learning in statistics teaching is also considered in the context of emerging trends in higher education. Recommendations for using blended learning approaches in the statistics curriculum are also made. It is concluded that the most effective blended learning approaches are those that take a student-centred approach, are integrated seamlessly within the curriculum, and make use of technologies that are reliable and user friendly.

Introduction

Blended learning is the purposeful application of technology within the curriculum of a face-to-face (f2f) subject with the aim to enhance student engagement and learning (Garrison & Kanuka, 2004; Picciano, 2009). It can take many forms, from the simple delivery of a lecture for on-line viewing to the use of sophisticated technologies that allow interaction over the internet in real-time. Blended learning has been applied in a range of subject areas. Statistics is a subject that may gain significant benefits from a blended learning approach. Indeed, the Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report (Aliga et al., 2005) included the key recommendation to use technology as a means to develop the conceptual understanding of statistics. However, statistics is a subject that can elicit anxiety (Onwuegbuzie & Wilson, 2003; Zeidner, 1991), is generally associated with negative attitudes (Finney & Schraw, 2003; Tremblay, Gardner, & Heipel, 2000), is a threshold subject in many degree programs (e.g., Hood & Neumann, 2013), and often results in students focussing on assessment rather than learning (Onwuegbuzie, DaRos, & Ryan, 1997). Such factors must be taken into account when using a blended learning approach in statistics teaching.

This chapter reviews established and emerging practices in blended learning approaches to statistics teaching. The focus is on blended learning practices in higher education. Significantly, in this context, statistics is often taught in degree programs where the students lack a background in science, technology, and mathematics. Accordingly, the nature of learning statistics is first considered to highlight the unique challenges that teachers face with this subject. Next, the theoretical basis of blended learning is reviewed. Evidence supporting the effectiveness of blended learning is considered across a range of subject areas before focusing specifically on statistics. Various blended learning approaches, including wikis, vodcasts, dynamic collation of class responses, discussion boards, blogs, interactive computer-based exercises, on-line tutorials, and social media are reviewed in terms of their methods of application, student perceptions, and effectiveness to enhance student learning outcomes. Following a review of these approaches, recommendations are made and conclusions are drawn in the context of current and emerging trends in higher education.

Learning and Teaching of Statistics

Statistics is a compulsory subject for many university students, not only in the “hard” science, technology, and mathematics disciplines, but also in the “soft” social sciences and business (e.g., Mallow et al., 2010; Ridgway, Nicholson, & McCusker, 2007). For example, students in undergraduate psychology must take two or more subjects in statistics (American Psychological Association, 2007; Australian Psychology Accreditation Council, 2010; British Psychological Society, 2012). Statistics subjects include content on research methodology along with descriptive and inferential statistics of varying degrees of complexity. In addition, students are taught to use statistical software to conduct analyses and to write research reports using the APA publication style (American Psychological Association, 2010) or other style guides. GAISE recommendations (Aliga et al., 2005) call for teachers to emphasise statistical literacy, reasoning, the use of technology, the use of real data, and to incorporate active learning approaches. The overarching learning outcome should be the ability to think statistically and to apply this knowledge to solve real-world problems (Garfield & Ben-Zvi, 2008; Pearl et al., 2012).

Unfortunately, a high percentage of students hold negative views and experience high levels of anxiety towards statistics, which hinders their engagement and learning (Galli, Ciancaleoni, Chiesi, & Primi, 2008; Griffith, Adams, Gu, Hart, & Nichols-Whitehead, 2012; Onwuegbuzie & Wilson, 2003). Anxiety is detrimental to learning because it interferes with cognitive processing and consequently with learning and achievement (Ashcraft & Kirk, 2001). As a result, teachers have developed specific interventions to target statistics anxiety, such as humour (Neumann, Hood, & Neumann, 2009) and psycho-educational workshops (Hood & Neumann, 2013). In addition, presenting material via interactive ‘hands-on’ activities, rather than through traditional didactic lecturing has been shown to reduce negative perceptions regarding statistics (Lovett & Greenhouse, 2000; Moore, 1997).

The use of technology to provide interactive, realistic, and relevant learning opportunities has been shown to improve student learning (Ball & Pelco, 2006; Forsythe & Archer, 1997) and to foster attitude change about the content (Simonson & Maushak, 2001). For example, interactive simulations have been shown to promote understanding of a range of statistical concepts (Shaughnessy, 2007). Students also report that interactive simulations are interesting and motivate them to learn (Neumann, Hood, & Neumann, 2012). A blended learning approach may, thus, provide an excellent vehicle for integrating technological tools into statistics lessons in a way that corrects students’ negative perceptions and improves their learning of statistics.

Blended Learning

Blended learning is the pedagogically-driven and planned integration of technology or media with traditional f2f learning activities (Picciano, 2009). The broad definition of blended learning, in which the technological or media applications supplement existing traditional f2f teaching, is contrasted with the narrow view, in which the technological applications replace some to all components of f2f teaching (Picciano, 2009; Twigg, 2003). Garrison and Kanuka (2004) make the distinction between technology enhanced subjects, in which technological applications are simply added to an existing f2f approach, and blended learning design, which requires more careful consideration of how to best integrate the technological and f2f environments (see also Gedik, Kiraz, & Ozden, 2013). As such, blended learning approaches need to take into account a range of factors such as the subject area, student characteristics, desired learning outcomes, assessment practices, and available technological infrastructure.

Picciano (2009) proposed a multimodal model describing how technological and f2f approaches can be purposefully integrated to meet the specific pedagogical objectives and activities in a given subject. He suggested that effective blended learning approaches should meet the six basic pedagogical objectives of (i) content, (ii) social/emotional, (iii) dialectic/questioning, (iv) synthesis/evaluation, (v) collaboration/student generated content, and (vi) reflection. Picciano (2009) argued that teachers must carefully consider their pedagogical objectives and how best to apply technology versus f2f teaching in order to meet them most effectively. Content delivery is a primary pedagogical objective for which multiple technologies can be used. For instance, interactive technologies have been used for dynamic visualization of statistical concepts (Pearl et al., 2012). In contrast, an objective to give students social-emotional support might be best accomplished using a f2f approach, such as small group workshops that addresses statistics anxiety (Hood & Neumann, 2013). Different learning modalities, thus, suit different pedagogical objectives. However, it is important that students experience a seamless blend of technological and f2f approaches.

There is evidence that taking a blended learning approach positively influences student learning outcomes. For example, compared to traditional f2f approaches, greater gains were reported in student engagement, satisfaction, and achievement from blended learning approaches than from purely online approaches (Chen, Lambert, & Guidry, 2010; Dzuiban, Hartman, & Moskal, 2004; Means, Toyama, Murphy, Bakia, & Jones, 2010). A recent meta-analysis suggested that blended learning approaches confer an advantage in academic performance of one third of a standard deviation over f2f teaching (Bernard, Borokhovski, Schmid, Tamin, & Abrami, 2014). However, other factors, such as the way computer support is provided and the interaction between the student, teacher, and content, can influence the magnitude of these pedagogical benefits. Moskal, Dziuban, and Hartman (2013) also caution that the successful application of blended learning requires a careful alignment between the goals of the university, teacher, and student. Nevertheless, the weight of studies showing the benefits of blended learning (Bernard et al., 2014) indicates that it should be used where possible.

In addition to pedagogical benefits, blended learning approaches have several practical advantages. These include economic and administrative advantages (Enders & Diener-West, 2006). Direct supervision by academic staff while students engage with the technology or media is not required, yet learning is comparable and generally better than in supervised f2f classes (Enders & Diener-West, 2006). Another practical advantage is that many blended learning tools already exist and are freely available. This is particularly true for statistics applets, shockwave programs, mobile apps, and other simulation tools (e.g., through the Consortium for the Advancement of Undergraduate Statistics Education, www.CAUSEweb.org). Moreover, many universities use subject management platforms, such as Blackboard, that can host additional tools needed for blended learning without additional costs. Blended learning also better meets current students' expectations, whereby the traditional large f2f lecture theatre style delivery of teaching is seen as having less value than immersive, hands-on simulations (Johnson, Adams Becker, Cummins, & Estrada, 2014). Finally, the flexible access afforded by blended learning approaches is also perceived as an advantage by students, many of whom work or have other responsibilities (Hood, 2013).

Blended Learning in Statistics Subjects

The application of blended learning in the teaching of statistics offers a natural extension to the curriculum because of the widespread use of statistical analysis computer software. Indeed, Garfield and Ben-Zvi (2008) stated that teaching statistics without using some form of technology is hard to imagine. Providing students with technology that requires active engagement with real data to answer meaningful research questions also embraces the spirit of inquiry-based learning (Greeno, Collins, & Resnick, 1996; Johnson et al., 2014) and is considered an authentic learning experience (Herrington, Oliver, & Reeves, 2006). These pedagogical considerations are supported by evidence showing positive outcomes when blended learning is used in research and statistics subjects. For example, McVey (2009) found that blended learning resulted in better final exam marks than a f2f approach in a research methods subject. Song and Slate (2006) conducted a qualitative evaluation of a blended learning approach in which students reported that the technology reduced their statistics anxiety and helped their learning. In contrast, Ward (2004) found no difference in academic performance between blended learning and f2f versions of a statistics subject. However, the lack of a significant difference may be attributed to the fact that both versions used online interactive statistical applets that allowed dynamic visualisation of abstract statistical concepts and, thus, incorporated technological aids to learning.

The discrete timetabling of f2f classes (e.g., 2-hour lecture timeslots) means that opportunities for interaction and questioning are limited as the first priority is generally delivery of content (Hew & Cheung, 2003). In addition, the pace of delivery of that content is also determined by the time available, so there is less scope for repeating material or presenting it at a slower pace if needed. As a high percentage of students have statistics anxiety (Onwuegbuzie & Wilson, 2003), and anxiety is known to consume memory and attentional resources, this interferes with cognitive processing (Ashcraft & Kirk, 2001). Similarly, the traditional f2f didactic instruction might not provide students with sufficient time to process material deeply enough for conceptual understanding. The asynchronous nature of many online tools in a blended learning environment means that students can proceed at their own pace or repeat the activities if needed (Copley, 2007; Robinson & Hullinger, 2008; Williams & Fardon, 2007). This flexibility of access means that students can better manage their anxiety and learning. For example, they can choose to access small amounts of material at a time as a means of managing their anxiety. If anxiety is interfering with their focus and memory, they can repeat the learning activity until they have fully understood it. In support of this, asynchronous blended learning options for statistics subjects were reported as preferable to f2f delivery by students with greater statistics anxiety (Hood, 2013).

Blended learning tools can allow for numerous opportunities for student collaboration and interaction (Dziuban et al., 2004; Gedik et al., 2013). These tools also require individual students to directly interact with the material that they might otherwise avoid in large f2f classes when the teacher simply demonstrates activities. Direct interaction with material that might induce anxiety or for which students have negative attitudes has the potential to dispel preconceived ideas and engage the student more deeply. Visualisation tools that allow dynamic linking (e.g., tools that visualise the change in the regression line and correlation coefficients when dots on a scatterplot are dragged to different points) provide opportunities for enhancement of students' statistical literacy, reasoning, and thinking, as well as their conceptual understanding (Pearl et al., 2012).

In the following sections, some of the main blended learning approaches used in statistics subjects are introduced. In most cases, teachers have merely described the tool or method of application in statistics teaching, as is often the case with an emerging pedagogical practice. However, more recent work has evaluated the effectiveness of the approaches in terms of changes in student perceptions towards statistics or in student learning outcomes. Such evaluations are essential to adequately evaluate the efficacy of blended learning in statistics teaching. It is also important that the blended learning approach is applied within a coherent framework. In this respect, the approaches may be best framed within the pedagogical objectives outlined in Picciano's (2009) multimodal model of blended learning.

Wikis

The pedagogical objective to develop collaboration among students can be achieved through using a wiki (Picciano, 2009). A wiki refers to interlinked web pages that are editable and readable by users (Konieczny, 2007; Leuf & Cunningham, 2001). Editing is done via a web browser, thus avoiding the need for special editing software. Students are able to add material, modify or edit existing material, add images or video, create new pages, link to existing pages, or write comments. Pages are also searchable, although the storing and searching of mathematical work can pose several logistical challenges (Lin, 2010). Previous versions of the document are typically stored and can be retrieved if needed and users can obtain e-mail alerts when pages have been modified (Schwartz et al., 2003). Ben-Zvi (2007) suggested that wikis could be used in statistics teaching to promote collaboration through writing activities, writing a glossary of statistics terms, discussing and reviewing topics, statistics projects, reflective writing, and assessment tasks.

Various case studies of wiki use in statistics teaching have been described. For example, a wiki has been used to promote conceptual understanding by requiring students to work collaboratively in writing a wiki textbook on statistics (Strasser, 2007). Peterson (2009) used wikis in an undergraduate maths subject to provide materials such as the syllabus, homework, assignments, solution to maths problems, and additional resource materials. Students were also required to complete assignments using wikis, including developing a glossary of terms. Carter (2009) described how a wiki was used to facilitate communication between students and teachers, and also between students. Finally, Neumann and Hood (2009) effectively used wikis to encourage students to work collaboratively in analysing data and write a research report.

Few formal evaluations of wiki use in statistics teaching have been published. In a study by Peterson (2009), students reported that the wiki facilitated collaboration and had advantages in offering a novel approach to learning. The disadvantages were primarily the demands of learning how to use the new technology, problems with text formatting, and the creation of math notation. Neumann and Hood (2009) conducted a comprehensive assessment of their application of wikis in collaborative data analysis and report writing. Their design compared a wiki group with a control group (individual work), with classes allocated randomly to one of the groups. Performance outcomes on assessments did not differ between students who worked in groups via a wiki and those students who worked individually. However, students who used wikis had higher self-reported cognitive engagement and engagement with fellow students and attended more classes than those who worked individually. Although most of the focus on evaluating teaching approaches is on academic performance, the results suggest that wikis can have the additional benefit of increasing engagement.

The increased collaboration and engagement by students who use a wiki in a statistics subject (Neumann & Hood, 2009; Peterson, 2009) is consistent with the Constructivist Theory of Learning (Piaget, 1971). In social constructivist learning, students acquire new knowledge via the interaction between their existing knowledge and new experiences. Learning is self-directed and is the responsibility of the learner as knowledge and meaning are constructed by them (Parker & Chao, 2007). A constructivist learning environment is characterised by the features of action and manipulation, construction and reflection, and is challenging and cooperative, and collaborative and conversational (Parker & Chao, 2007). All of these features should be incorporated by teachers who wish to use wikis in the teaching of statistics. For example, using a wiki to write a textbook on statistics would require students to negotiate the tasks, construct the content, edit (manipulate) content written by others, and discuss the ways to improve the textbook. Importantly, in such applications the role of the teacher should be one of facilitator rather than a teacher in the traditional f2f sense.

Computer-based Interactive Exercises and Simulations

Achieving the pedagogical objective of synthesis and evaluation in a blended learning approach (Picciano, 2009) is possible in a statistics subject through the use of computer-based interactive exercises and simulations. These exercises can be accessed via an internet connected device using a web browser or they may exist as an app on a mobile device. In terms of the latter, access to statistical learning tools via a mobile device may enhance motivation to study because of the greater convenience, flexibility, and mobility (Mayrath, Nihalani, & Perkins, 2011). Interactive exercises present students with simulations of statistics concepts or allow them to manipulate data and examine its effect on the calculated statistics. For example, an interactive exercise for the concept of correlation might show a scatterplot and the calculated correlation coefficient (Lane, 1999). Students can draw a line of best fit to describe the linear association or change the strength of the association and see the effect this has simultaneously on the scatterplot data and the correlation coefficient. In other applications, students can conduct virtual studies and analyse the resulting data (Malloy & Jensen, 2001), examine the concept of statistical inference (Meletiou-Mavrotheris, 2003), understand central tendency (Morris, Joiner & Scanlon, 2002), and examine general linear models (Dunn, 2004).

The application of interactive exercises in teaching statistics has largely been examined in isolation, rather than considering their impact as part of a wider blended learning curriculum. Nevertheless, it has been argued that their use will improve student learning through a better integration of content knowledge and its application in statistical analysis and interpretation (Meletiou-Mariothersis, 2003; Morris & Scanlon, 2000; Neumann, 2010). Such integration is facilitated when students are guided through the interactive exercise via instructions and review questions (Neumann, 2010) or when they are part of an on-line textbook (e.g., see http://cast.massey.ac.nz to view the Computer-Assisted Statistics

Textbook). In addition, interactive exercises may enhance learning by strengthening the links between individual statistical concepts (Meletiou-Mariothersis, 2003; Morris & Scanlon, 2000) and in correcting misconceptions that would adversely affect teaching (Morris, 2001).

Although interactive exercises may be used to teach statistics, they can also be used to assess student learning. Neumann (2010) described an approach in which an interactive exercise was combined with instructions and a set of multiple-choice questions. The questions formed part of the assessment requirements for the subject. Importantly, students were unable to answer the questions based on their pre-existing knowledge of statistics. Rather, students were required to discover the answers through their interactions with the exercise. Furthermore, in some questions students had to combine their declarative knowledge of statistics and their experiences with the interactive exercise. In a qualitative evaluation, Neumann et al. (2012) reported that students found that the approach provided more than just an alternative to traditional assessment methods. The students reported that it improved their understanding of statistics, demonstrated practical applications, were a visual aid to learning, and were interesting and engaging. These findings indicate that interactive exercises may have multiple benefits when applied as part of a blended learning curriculum.

Vodcasts and On-Line Recordings

The use of vodcasts and related forms of on-line recordings can meet the pedagogical objective of delivering content in a blended learning statistics subject (Picciano, 2009). The combination of pictures and spoken word to teach mathematical concepts has been used since at least the time of Euclid. In contemporary teaching, vodcasts are video recordings that combine pictures, animations, video, and audio components. Students can access these recordings online for streaming or for download. A number of software applications (e.g., Echo 360, Adobe Presenter, and iSpring) allow teachers to produce quality recordings using a standard computer and without a great deal of specialist knowledge. Powerpoint presentations can be recorded with voice over narration and this can be augmented with a camera feed of the presenter speaking. Some software applications allow the capture of all computer desktop activity so that the teacher can demonstrate the use of statistical software or work through statistical problems.

Students can interact with the content delivered by vodcasts in various ways to suit their individual learning needs. Vodcasts can be used for learning new content, to revise selected content, or to catch up on missed content. Importantly, in each case students are able to control the pace of content delivery. As a result, vodcasts complement the wide array of individual learning styles and student abilities typically observed in a large statistics class (Copley, 2007; Sankey, Birch, & Gardiner, 2012). Hood (2013) also demonstrated individual differences in students' intentions to use vodcasts in a statistics subject. Higher self-regulation for learning, preference for critical thinking, and greater reliance on rehearsal were associated with intentions to use vodcasts of lectures. Poorer achievement in prior statistics subjects and greater extrinsic motivation were associated with intentions to use vodcasts of laboratory classes that involved hands-on statistical analyses.

The limited research evidence suggests that vodcasts can enhance learning for the kind of complex content inherent in statistics subjects. Lloyd and Robertson (2012) found that students who viewed a vodcast tutorial on independent groups t-tests completed a subsequent test more accurately and in less time than a control group given printed instructions and screenshots for the same analysis. Similar results were achieved by Wang, Vaughn, and Liu (2011). In both studies, the authors attributed the improvement in performance to the reduced cognitive load as a result of the multimedia delivery of complex content. Sweller (2010) has argued that complex content is learned more effectively when every effort is made to minimise the cognitive load imposed on the learner by the instructional procedures or methods of presentation. Chandler and Sweller (1992) have shown that extraneous cognitive load is imposed by splitting attention between text and diagrams within complex instruction documents, which results in fewer cognitive resources being available for learning. They have also demonstrated that this can be overcome using multimedia presentations in which diagrams are presented visually and instructions aurally (Kalyuga, Chandler, & Sweller, 1999).

Mayer and colleagues proposed a Cognitive Theory of Multimedia Learning (Mayer, 2005) and this theory provides a useful framework to understand the use of vodcasts in teaching statistics. The theory is based on the dual-channel (visual and aural) understanding of human cognition and memory (Clark & Paivio, 1991) and it leads to recommendations for designing multimedia resources (Mayer, 2009; Mayer & Moreno, 2003). Their constant theme is to minimise cognitive load imposed by the method of communication and thereby maximise the cognitive resources available to learn from the content being delivered. To reduce cognitive load in multimedia vodcasts, teachers should eliminate redundant or irrelevant content (e.g., text which duplicates narration, interesting but irrelevant pictures), organise material to limit visual search, guide attention throughout the presentation, and segment the content across multiple short coherent presentations (Mayer, 2009).

One teaching method that is particularly useful in statistics subjects and which vodcasts are well suited is the presentation of worked examples. Paas (1992) compared learning outcomes for students who practiced traditional problem-solving exercises, students who were given vodcasts of fully worked examples to study, and students who completed partly worked examples. The results showed greater skill transfer from the worked and partly worked examples conditions than for the traditional practice exercise condition. Worked examples have been argued to impose less cognitive load and allow students to construct meaning and form schemas (Atkinson, Derry, Renkl, & Wortham, 2000). In contrast, novices tend to focus on superficial characteristics and they lack the schemas to make sense of the problem they need to solve (Chi, Feltovich, & Glaser, 1981). Worked examples which guide students to identify underlying patterns and reduce cognitive load have been shown to result in greater schema acquisition (Quilici & Mayer, 2002; Tuovinen & Sweller, 1999). For instance, a teacher can provide worked examples via vodcasts to demonstrate a statistical technique (e.g., using statistical software or work through the interpretation of statistical output). This approach allows students to see the statistical technique through the eyes of an expert by directing their visual attention to the relevant statistical elements which are further explained by the voice-over narration.

Online tutorials

As either a substitute for or an addition to f2f tutorials, on-line tutorials can address many of the pedagogical objectives in Picciano's (2009) multimodal model. On-line tutorials can be used for content delivery, to develop collaborative learning among students and the teacher, and to provide dialectic/questioning opportunities. On-line tutorials can be delivered via software applications such as Blackboard Collaborate. The software applications typically provide a joint whiteboard, allow the sharing of the teacher's or student's computer desktop in real-time, sharing of presentation slides, and support interactions through chat facilities, audio, and web cams.

The success of on-line tutorials has changed substantially as technology has advanced (Mills & Raju, 2011). In statistics subjects, some studies have found more positive attitudes among students to blended learning subjects than for purely f2f subjects (Ward, 2004). Other studies have found less positive attitudes to a blended learning subject (e.g., Utts, Sommer, Acredolo, Maher, & Matthews, 2003). A subsequent meta-analysis conducted by the United States Department of Education (Means et al., 2010) found that learning outcomes were improved in subjects that combined on-line tutorials and f2f delivery when compared to f2f alone.

Two particular roles can be suggested for on-line tutorials in a blended statistics subject. One is based on Tallmadge and Chitester (2010) who found that an additional optional on-line tutorial in a first year chemistry subject allowed students with a limited prior understanding of chemistry principles to keep up with the subject. Therefore, additional on-line tutorials may help students with low self-efficacy towards statistics in the same way as an optional f2f workshop reduced poor self-efficacy and statistics anxiety in first year statistics students (Hood & Neumann, 2013). Another role for on-line tutorials in a blended statistics subject is as a means of providing a worked example. Unlike vodcasts, the on-line tutorial format allows for interaction between the student and teacher during the worked example. Research is required to establish whether the interactivity of on-line tutorials enhances the understanding of a worked example by allowing students to ask questions, or if the visual complexity of on-line tutorials (with chat windows and other extraneous elements) increases cognitive load and detracts from learning.

Dynamic Collation of Responses through Audience Response Technology

Engagement by students in educationally purposeful activities will foster a positive learning environment, increase motivation, and is associated with better academic performance (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008). Engagement is particularly important for a statistics subject due to the low interest and motivation towards the subject shown by many students (Onwuegbuzie & Wilson, 2003). In small class teaching of statistics, a teacher can draw students to the topic and monitor understanding through asking questions of individuals. However, it is difficult to ask questions to individual students in a large f2f lecture. As a result, questions tend to be less complex so that they can be answered by a show of hands. Audience Response Technology (ART, or sometimes called “clickers”) is a technology that can overcome this problem. ART allows large audiences to answer questions posed by the teacher, and see summary data of their responses in real time. Early versions of this technology required specially designed hand-held units linked by radio or other technology. Today, applications exist (e.g. Pinnion, Socrative) which can be installed on tablets, laptops and smartphones, which has increased the availability of the technology without the financial and logistical constraints of the earlier versions. The use of ART has been shown to promote a positive attitude and an active atmosphere in the classroom (Caldwell, 2007) with some studies showing improved learning outcomes (Stowell & Nelson, 2007), although there are exceptions (Anthis, 2011).

Although ART has yet to be extensively evaluated when used in statistics subjects, there are good reasons to suggest that it could benefit a blended learning curriculum. It can be particularly useful in achieving the pedagogical objectives described by Picciano (2009) of dialectic/questioning and collaboration/student generated content. The study of statistics is an incremental and sequential learning experience. Questions posed using ART allow the teacher to determine if the foundational concepts have been understood and to correct student errors prior to proceeding to the next concept. Students are able to answer anonymously and independently, and there is evidence to suggest that students answer more honestly with ART than when raising a hand or using response cards (Stowell & Nelson, 2007). Anonymity might also reduce the anxiety faced by students when giving answers about which they are unsure. ART provides reassurance for those who answer correctly that they are on track, and for those who are incorrect the reassurance from knowing they are not alone.

Some ART applications (e.g. Pinnion, Survey Monkey) can be used to administer a questionnaire to students and collect data in real-time. Compiled responses can be downloaded immediately as a spreadsheet to create a data file. In a statistics subject, this is an excellent feature as it allows the teacher to quickly and easily create a data set from the students themselves. Prior research has shown that student generated data increases interest and improves learning in statistics subjects (Neumann, Neumann, & Hood, 2011). Thus, the teacher can use the students' ART data to demonstrate a statistical principle or application. Actively engaging students in the whole research process can improve the recall and understanding of statistics (Neumann et al., 2011). As the ubiquity of internet enabled devices increases among the student population, ART will become a more accessible and promising tool for teachers of statistics.

Social media

A significant challenge in teaching statistics is to enable students to integrate content and apply statistics in novel situations. In this respect, the pedagogical objective of synthesis/evaluation (Picciano, 2009) can be facilitated in a statistics subject by using social media. In today's "information age" real-life examples of statistics are readily available through the internet. The use of real-life data and examples of statistics has several benefits for student learning (Neumann, Hood, & Neumann, 2013), and social media offers a platform for bringing these examples to the attention of students. Through a Facebook page or Twitter account, links can be provided and a conversation initiated that stimulates student's imagination and presents them with relevant examples of statistical data. Whether the example comes from a TED talk, YouTube clip, web site, or other on-line media, students can see how statistics are used in evidence-based debates to answer important questions.

Not only might social media be used to foster interest in statistics, it might also provide models to students of the kinds of values and behaviours they should be embracing. Social cognitive theory suggests that modelling behaviour is an effective means of teaching it (Bandura, 1988), and engaging relevant examples shared through social media can draw student's attention to appropriate models. It can also help students build a schema for how to approach questions by being exposed to a number of examples of using statistics to answer questions. In this way, the student not only learns statistics, but also embraces critical thinking and enquiry.

Discussion Boards, Blogs, and Journals

Discussion boards, blogs, and journals are blended learning technologies that can be a useful addition to the statistics curriculum. Discussion boards can serve the pedagogical objective of dialectic/questioning (Picciano, 2009). Most on-line delivery systems incorporate discussion boards (e.g., Blackboard). Alternatively, wikis have been created so that they promote discussion between students and the teacher in a statistics subject (Carter, 2009). Blogs and journals are different to discussion boards in that they are generally written as a stand-alone piece, rather than as a dialogue among students. However, many systems that support the writing of blogs typically include the functionality for others to make comments in response to the written piece. In some cases, conversations about the blog can emerge in the comment area. From a pedagogical perspective, blogs and journals can serve the objective of reflection (Picciano, 2009). For example, a blog could require students to reflect upon what statistics they encounter in their daily lives or their interpretation of statistics reported in the media.

There have been few descriptions and evaluations of the use of discussion boards, blogs, and journals in statistics education. Nevertheless, their ease of access and flexibility can allow them to be easily incorporated as part of a blended learning curriculum. Extending on Gomes' (2008) suggestions, students could use blogs in statistics subjects to develop a digital portfolio of their application of statistics, provide a digital space for debate and interchange of ideas about statistics, facilitate student collaboration in solving statistics problems, or to assist students to integrate statistical concepts. Blogs and discussion boards may also provide a way for teachers to make information available to students (Gomes, 2008). Brownstein and Klein (2006) provide further curriculum advice on how blogs can be used in an educational context.

Blended Learning as Part of an Integrated Statistics Curriculum

From the literature reviewed in the previous sections, it is apparent that the various blended learning approaches in statistics teaching have tended to be evaluated in isolation. Although evaluations of individual technologies are useful because they can isolate effects more precisely, they can prohibit the development of an integrated blended learning approach in a statistics curriculum. A broader perspective is particularly salient in light of the relationship between pedagogical objectives and technologies described by Picciano (2009). As noted by Picciano (2009), technologies tend to focus on one or two objectives only. For example, vodcasts are mainly focussed on the pedagogical objective to deliver content. In order to achieve multiple objectives, it is necessary for teachers to use a combination of blended learning approaches in a statistics curriculum.

Neumann et al. (2011) provided one of the few examples of a broad evaluation of multiple blended learning approaches in a statistics subject (for other examples, see Baharun & Porter, 2009; Ward, 2004). Neumann et al. (2011) described the case of an introductory first year statistics subject with an enrolment of approximately 200 psychology students. The subject was taught through f2f lectures and tutorials but incorporated various blended learning approaches during the classes and in associated resources. Students were given on-line access to lecture notes, in addition to a discussion board. Interactive exercises and simulations of statistical concepts could also be accessed on-line. During the lectures, there was extensive use of multimedia presentations, animations, and the use of statistical software. The tutorials made use of these same resources but allowed students to interact with them directly (e.g., conduct their own statistical analyses). In subsequent development of the subject, the curriculum has been enhanced through the availability of lecture recordings, vodcasts on selected statistical concepts, and a collaborative wiki that incorporates written content, a manual on conducting data analysis, and video.

In a qualitative evaluation of this blended learning approach, Neumann et al. (2011) identified several advantages. Most students reported that the use of technology as an adjunct to the f2f teaching helped them to understand statistics better and increased the link between statistical theory and application. In addition, a large percentage of students reported that the technology increased their interest, engagement, and motivation towards statistics. Students also appreciated the use of a different approach to teaching. The technology was reported to be beneficial because it gave a visual aid to learning. The incorporation of technology during f2f teaching also helped to break up the content into smaller, more manageable sized chunks. Finally, and importantly for statistics teaching, the incorporation of technology was reported by students to reduce their anxiety and stress towards the subject. Although a quantitative evaluation would be required to demonstrate that these student perceptions translate into actual improved learning outcomes, the results suggest that an integrated blended learning approach can have significant benefits in the statistics curriculum.

Recommendations for the use of Blended Learning Approaches in Statistics Teaching

The application of a blended learning approach in the statistics curriculum has shown promise to date, although further research and refinement of techniques will be required in the future. Moreover, as new technologies emerge, statistics teachers will find themselves in a continual process of curriculum development and renewal as part of the subject improvement process. Within the multimodal blended learning model proposed by Picciano (2009), various pedagogical objectives can be achieved within a statistics curriculum by using wikis, interactive exercises, vodcasts, on-line tutorials, ART, social media, discussion boards, and blogs, among other approaches. The choice of which approach to use will depend on the individual context in which the statistics subject is taught. Nevertheless, the most effective blended learning approaches will be those that take a student-centred approach, are integrated seamlessly into the curriculum, and make use of technologies that are readily available, reliable, and easy to use. As Hood (2013) demonstrated, it is also essential to take into account practical (e.g., competing work demands) and technological considerations (e.g., access to required statistical software), as well as student attitudinal and motivational characteristics (e.g., learning styles and preferences) when making decisions about the use of available tools.

Based on the foregoing discussions on blended learning approaches in general and in statistics (e.g., Neumann, 2012; Picciano, 2009), and the principles of constructive alignment in outcomes-based curriculum design (Biggs & Tang, 2007), several recommendations for using blended learning approaches in teaching statistics can be made. These recommendations are not intended to be prescriptive, nor are they intended to be complete. Rather, they aim to give guidance on the major issues that need to be considered by those who intend to take a blended learning approach in teaching statistics.

Recommendation 1: Select Approaches that Account for Student Individuality

Negative perceptions and anxiety towards statistics (Finney & Schraw, 2003; Onwuegbuzie & Wilson, 2003; Tremblay et al., 2000; Zeidner, 1991) are common among students, particularly those from social science backgrounds. However, not all students share this negativity. Students also have different learning styles and teachers should use an approach that complements their student's style (Felder & Silverman, 1988; Hood, 2013). There is also student individuality in their preparedness for a statistics subject and whether they have any special physical or psychological needs. Consequently, teachers should not assume that a given technology would necessarily suit every student. For example, interactive exercises tend to favour students with a visual or experiential learning style, and are less well suited for those with an auditory learning style. Therefore, the teacher could complement the interactive exercise with a vodcast in which they use the exercise themselves and talk through their interactions with it.

Recommendation 2: Ensure Adequate Scaffolding of Student Learning

Many technologies focus on students engaging with material individually (e.g., vodcasts, interactive exercises and simulations, blogs). However, the teacher should ensure that they appropriately scaffold (Wood, Bruner, & Ross, 1976) student interactions. For example, interactive exercises should be complemented by written or auditory instructions that describe the interactive exercise and guide the student through their interactions with it. Once the student can competently use the interactive exercise, the support should be reduced to facilitate independent student learning. Scaffolding is most commonly associated with the learning of content. However, additional scaffolding may be necessary to assist students with learning the technical features of the technology (e.g., how to access and download vodcasts, how to edit a wiki). In addition, it may also be necessary to scaffold the way students interact with each other. This will ensure that interactions occurring via wikis, on-line tutorials, or discussion boards will be collaborative and constructive.

Recommendation 3: Design Learning Tasks that Capture the Strength of the Technology

No blended learning technology will be effective if it is merely “made available” for students. Rather, teachers need to purposefully design learning tasks around the technology. The multimodal approach described by Picciano (2009) can be a useful tool in this design process. Importantly, the learning tasks should be designed so that they take full advantage of the strengths of the blended learning technology. For instance, a learning task based on using a wiki would be most effective if it requires students to be collaborative, particularly if that collaboration occurs asynchronously in time. Teachers should be prepared to change their learning activities to suit the technology that is used.

Recommendation 4: Use Constructive Alignment of Learning Outcomes, Learning Activities, and Assessment

The adjustment of the learning activities to suit the strength of the technology should also be considered more broadly. It is important that there is a constructive alignment between the intended learning outcomes, the learning activities used, and the assessment approaches employed (Biggs & Tang, 2007). The technology used should be selected so that it provides a continuous link between the learning outcomes and the assessment methods. As such, it is good practice to use the same technology in the assessment task. Neumann (2010) provides an example of this in which interactive exercises were used within classes and as part of an on-line assessment approach in an introductory statistics subject. This assessment approach was valued positively by students as a method that enhanced their learning about statistics (Neumann et al., 2012).

Recommendation 5: Make the Learning Experiences Authentic

Authentic learning experiences are those that are based around real-world problems and can make use of problem-based activities, debates and discussion, examination of case studies, and role-playing (Lombardi, 2007). Authenticity is important in statistics education and GAISE recommendations (Aliga et al., 2005) emphasise using real data and studying real-life problems. Social media can be used to show real-life examples of statistics in action and discussion boards, blogs, and journals can all facilitate authentic learning experiences in the statistics curriculum. The technology used, which can often be foreign to many students, should not interfere with delivering an authentic learning experience. Rather, it should enhance the application of statistics in real-world contexts.

The Future of Blended Learning in Statistics Teaching

The 2014 Technology Outlook for Australian Tertiary Education Report (Johnson et al., 2014) identified 12 emerging technologies that are likely to have a major impact on tertiary education, not only in Australia but globally. Some of these were relevant to blended learning (e.g., using vodcasts as part of a flipped classroom approach, using on-line tutorials as part of a virtual laboratory approach), while others were less relevant to blended learning (e.g., MOOCs, mobile learning). The report also identified barriers to wide-scale up-take of these technologies. Low digital fluency among academics was identified as the biggest barrier, requiring major investment in training by tertiary institutions to ensure full integration of the available and emerging technology and media applications.

Emerging trends in wearable technology offer exciting potential opportunities for student involvement in collecting real data (Johnson et al., 2014). Wearable technology that allows extraction of information about one's surroundings (e.g., Google glasses), quantified self-enabled devices such as fitness trackers (e.g., Fit Bit devices or iPhone apps), and wearable camera devices like Memoto that take a photo of the wearer's surrounding automatically at fixed time intervals already exist. Wearable technologies could be used by students to collect data on themselves for subsequent use in a statistics class to answer real-world research questions. For example, heart rate data collected using an iPhone app such as iRunXtreme could be used for lessons on descriptive statistics (what is the distribution of resting heart rate in the class?), association (is there a correlation between age and resting heart rate?), or experimental design and analysis (does heart rate change in response to a cognitive task?). It is likely that more of these wearable and data-enabled devices will emerge in the near future, offering exciting new opportunities for use in a blended learning statistics curriculum.

However, it would appear as though the development of new technologies and the innovative application for statistics teaching is outpacing a careful evaluation of their effectiveness in enhancing student learning outcomes. Pearl et al. (2012) concluded that research on the application of technology has been strongest at the primary and secondary school levels. In contrast, research in using technology in higher education has tended to be more simplistic. Future research is needed to go beyond descriptions of the approach, qualitative evaluations that rely on student reports, and even comparisons between a class that uses the technology versus the traditional approach (Pearl et al., 2012). As has been noted by Neumann et al. (2012), the use of technology is most effective if the task requires students to use it in a way that directly increases their engagement and learning of statistics. It is these types of issues that should be investigated further.

Future research is also needed to examine several important questions regarding the utility of a blended learning approach in teaching statistics. A more nuanced approach is required so that a greater resolution is achieved to better identify the important goals of the statistics curriculum. For example, evaluations of blended learning technologies need to be done separately for each specific learning outcome. In statistics education, it is important that students not only learn the theoretical basis of statistics, but also understand how the statistics are calculated, their interpretation in the context of the problem, and their application to everyday real-world problems. Specific blended learning approaches may be more beneficial to enhancing learning for some of these outcomes than for others. Consequently, a targeted approach is required in research if we are to produce a well-integrated blended learning statistics curriculum.

Conclusion

The teaching of statistics continues to be a challenge. While there are many teachers who are ready and willing to meet these challenges, they also need the pedagogical tools and relevant training to support them. The use of technology as part of a blended learning approach promises to play an increasingly significant role in the educational tools of statistics teachers. These teachers must be supported by sophisticated research that not only evaluates the effectiveness of the different approaches, but also assists in developing a coherent theoretical approach to blended learning in statistics teaching. Now more than ever the face of statistics education is undergoing rapid changes and teachers need to be creative, innovative, and evidence-based in their use of blended learning technologies. However, the end goal is a valuable one because improving statistical literacy will have many benefits for students in their personal and professional lives.

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