Computers & Education 66 (2013) 64–73

Contents lists available at SciVerse ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Application of linear mixed-effect models for the analysis of exam scores: Online video associated with higher scores for undergraduate students with lower grades

Josée Dupuis [a], Josée Coutu [b], Odette Laneuville [c,*]

[a] Department of Biostatistics, Boston University School of Public Health, 801 Massachusetts Ave., Boston, MA 02118, USA
[b] Department of Biochemistry, Faculty of Science, University of Ottawa, 30 Marie Curie, Ottawa, ON K1N 6N5, Canada
[c] Department of Biochemistry, Microbiology and Immunology, Faculty of Medicine, University of Ottawa, 451 Smyth Rd., Ottawa, ON K1H 8M5, Canada

ARTICLE INFO

Article history:
Received 15 October 2012
Received in revised form
11 February 2013
Accepted 15 February 2013

Keywords:
Molecular biology
Online videos
Undergraduate
Exam scores
Linear mixed-effect models

ABSTRACT

In higher education, many of the new teaching interventions are introduced in the format of audio-visual files distributed through the Internet. A pedagogical tool consisting of questions listed as learning objectives and answers presented using online videos was designed as a supplement for a molecular biology course and made available to a large class of upper-level undergraduate students. The aim of the current study was to evaluate the impact of online videos on test scores. For this, linear mixed-effect models were fitted to the data and used to jointly estimate the effect on exam scores of video access and a set other variables including gender, academic year, course segment and cumulative grade point average (CGPA) of students. On average, scores for the segment of the course corresponding to the introduction of the online videos increased by 2%. Interestingly, students with lower CGPAs benefited the most from access to online videos; if CGPA = 4.0/10, then average score increase was 6.2%. For students with a higher CGPA of 8.0/10.0, the average increase of scores was 1.0%. The measure of exam performance represents a preliminary evaluation of the educational intervention described. Overall, the availability of videos demonstrating the application of concepts to solve problems in molecular biology was associated with statistically significantly higher scores on the exams.

1. Introduction

New teaching approaches often use audio-visual files distributed through the Internet to stimulate learning and promote academic success. Science courses offered in higher education taught as traditional lectures are often supplemented with audio-visual files containing educational material and accessed by students from personal computers outside the classroom. The evaluation of the effectiveness of new interventions is critical to establish a causal link between the intervention and the outcome measured. In the field of educational research, the majority of studies aiming at measuring the impact of the new interventions including, electronic tools, include a qualitative rather than quantitative analysis of the data collected (Cook, 2002). Using qualitative analyses researchers have identified key benefits to learning and studies indicate that students used the electronic products frequently (Heilesen, 2010) and describe those as useful, effective and helpful (Bennett & Glover, 2008; Holbrook & Dupont, 2010; Pilarski, Johnstone, Pettepher, & Osheroff, 2008). Access and use of videos is described by students as easy and convenient (Chester, Buntine, Hammond, & Atkinson, 2011; Hill & Nelson, 2011), improves learning (Bennett & Glover, 2008; Holbrook & Dupont, 2010) and intellectually stimulating (Fernandez, Simo, & Grinfeder, 2009). Overall, studies report comments collected from users of educational video support a positive impact on academic performance (Kay & Kletskin, 2012).

A limited number of studies in the field of educational research include a quantitative analysis of the impact of the intervention on students' academic success. The rarity of quantitative analyses in the field of educational research could be attributed to the use of a common design generating observational rather than experimental data (Cook, 2002). The analysis of observational data must include a

Abbreviations: BSc, Bachelor of Science; CGPA, cumulative grade point average; LME, linear mixed effect; NMP, nucleotide monophosphate; NTP, nucleotide triphosphate; PPi, pyrophosphate.

* Corresponding author. Tel.: +1 613 562 5800x8402.
E-mail address: olaneuvi@uottawa.ca (O. Laneuville).

0360-1315/$ – see front matter
http://dx.doi.org/10.1016/j.compedu.2013.02.011

provision to ensure that the groups being compared are similar enough to establish valid conclusions and studies rarely adequately address the impact of nonrandom assignment on results (Graham & Kurlaender, 2011). An additional challenge to the application of quantitative analyses is to measure the impact of covariates potentially influencing the outcome measured. For this, the analysis of variance or regression analysis with the inclusion of relevant covariates provides the investigators with a strategy to quantitatively and statistically measure the impact of an intervention on the measured outcome (Graham & Kurlaender, 2011).

2. Literature review

2.1. Failure to convey understanding of fundamental concepts

Science education has been the subject of many criticisms and research, particularly from the mid-80s on, and the need to improve the quality of science education in post-secondary institutions has been documented (National Science Foundation, 1996; Villafane, Bailey, Loertscher, Minderhout, & Lewis, 2011). One common finding of these studies is that failure to convey understanding of fundamental concepts often results in students underperforming or even abandoning the field of science (Michael, 2007; Popper, 1979; Rowland, Smith, Gillam, & Wright, 2011; Tobias, 1990). This fact can potentially be explained by the theory of Popper stating that individuals acquire knowledge by formulating hypotheses (concepts) and subjecting them to critical reasoning to eliminate false hypotheses (or false conceptual understanding) and retaining the ones that best explain factual observations (Ruiz-Primo, Briggs, Iverson, Talbot, & Shepard, 2011). A corollary of this theory is that every individual will acquire knowledge (or concepts) differently and at a different rate because individuals all have a different amount of knowledge to start with and acquire knowledge at a different rate. Following this logic, it is not surprising to observe that the pedagogical conveying of complex scientific concepts can be difficult and is likely to leave behind many students (Wright, 1996).

2.2. Teaching large classes

The challenge of teaching the application of concepts is especially acute when faculty are confronted by large groups of students and have a limited amount of time at their disposal to convey a large amount of material. In fact, analysis of the teaching methods practiced in large undergraduate science classes revealed that traditional lectures often promote the acquisition of facts rather than understanding of scientific concepts (Armbruster, Patel, Johnson, & Weiss, 2009; Tanner & Allen, 2005). Students' opinions corroborate this observation and surveys indicated that science courses are often presented as a collection of facts to be memorized with little emphasis placed on understanding (Bransford, Brown, & Cocking, 2000; Hake, 1998; Uekert, Adams, & Lock, 2011; Weimer, 2002). Rather than memorizing facts, successful students apply core concepts to solve complex problems and experience better academic success and higher satisfaction (Cox, 2011; Dean & Nielsen, 2007; Wright, 1996).

In general, students registered in science programs complete introductory courses in mathematics, physics, genetics, chemistry, etc. before registering in more specialized courses. Although students registered in specialized courses have successfully completed courses in basic science and have accumulated two years of university-level education, they still face many learning challenges. Perhaps the most difficult challenge for many students is to apply concepts taught in introductory courses to the more specialized courses (Wright, 1996). Furthermore, the more specialized courses often supplement the basic material with emerging scientific knowledge thereby increasing the difficulty for students to distill essential concepts. The subject of molecular biology is especially challenging in this respect.

2.3. Web-based methods in science education

Student-centered teaching methods were developed to improve the quality of science education and aimed at stimulating interest and promoting students' participation in their education (Armbruster et al., 2009). Among the new approaches developed, the availability of online videos is rapidly increasing and provides students with additional learning material to stimulate learning and interest in science (Heilesen, 2010; McGarr, 2009). The use of online material with educational content seems prevalent in higher education and often used by students as an efficient strategy for test preparation. Many studies described the benefits of videos to viewers, however, a limited number of studies have included in their experimental design, the quantification of the impact of online material on test scores and grades (Traphagan, Kusera, & Kishi, 2010). Yet, a quantitative evaluation of the intervention is essential to establish a link between the availability and use of online material and the outcome measured; test scores.

2.4. Purpose

The main purpose of our study was to quantitate the impact of online videos on test scores. For this, we exploited the advantages of linear mixed-effects models and measured the contribution of covariates potentially influencing the outcome measured. Our analysis took into consideration the existing structure of the Molecular Biology course offered to third year undergraduate students at the University of Ottawa, which includes three segments, one test at the end of each segment and a different faculty associated to each segment. Data were collected over a period of three consecutive academic years and videos available only for the second segment of the third year.

3. Methods

3.1. Course format

The Molecular Biology course in the Faculty of Sciences at the University of Ottawa is a requirement for the Bachelor of Science (BSc) degrees in Biochemistry or Biology. It is offered once per year and is usually taken during the third year of those programs. The 13-week course is taught in 2–80 min sessions per week in a large lecture hall and is worth 3 of the 90 credits required for completion of the BSc