

An Evaluation of the Use of Video Tutorials as Supporting Tools for Teaching Laboratory Skills in Biology

Manuela Truebano*
School of Marine Science and Engineering,
Plymouth University, UK
manuela.truebanogarcia@plymouth.ac.uk

Colin Munn
School of Marine Science and Engineering
Plymouth University, UK
C.Munn@plymouth.ac.uk

Abstract

The recent developments in digital media and availability of portable digital devices have opened many possibilities for educational use. A potential application arises when teaching a particular skill relies on the accurate description of the procedure involved. Teaching molecular biology falls within this description, as it requires highly specific skills with well-defined protocols, for which small errors can lead to failure of the process. This study aimed to evaluate the use of a video tutorial during an active learning laboratory-based session on students' competence and confidence. The study group comprised undergraduate students with minimal experience in a laboratory environment, previously identified as lacking confidence when first facing the procedures alone. Students were allocated to one of three groups which either (a) received face-to-face training and were asked to repeat the procedure alone at a later date; (b) received training and were asked to repeat the procedure alone at a later date with access to the video; or (c) did not receive training but were asked to carry out the procedure alone relying on the video. Comparisons were made between the groups in terms of their behaviour, the end result of the procedure, and their answers to a questionnaire assessing their confidence. Results suggest that a blended approach yielded the greatest success when performing the procedure alone. Moreover, the

* Corresponding Author

availability of the video tutorial increased students' confidence in their own ability. Video tutorials are proposed as excellent tools as part of a blended approach to teach practical skills.

Keywords: Blended approach; video tutorials; technology enhanced learning

Introduction

Teaching molecular biology in Higher Education (HE) includes a combination of lectures, workshops and laboratory practical sessions. A hands-on practical component mediates technical understanding of specialized laboratory techniques, enhances lecture material, and teaches problem-solving skills (Flowers, 2011). Practical work also promotes active learning, which has often been shown to enhance student performance (Yoder & Hochevar, 2005). However, students who have never performed a specific procedure need guidance through the process before they perform it for the first time. This is typically achieved by a visual demonstration of laboratory procedures, a key element in teaching pedagogy (Maldarelli et al., 2009).

In recent years, undergraduate biology education has undergone radical changes and many biology courses are not delivered fully face-to-face anymore because of the reported advantages of blended instruction (Valverde, 2012). This is in line with the recent shift from teacher- to student-centred approaches in teaching and learning in HE in the UK (Laurillard, 2002). E-learning, the use of web-based activities, is not exclusive to distance education (Light, Cox and Calkins, 2009). Indeed, it is widely used as part of a blended approach to teaching and learning, to support traditional face-to face interactions, whether tutorials, lectures or laboratory practical sessions (Davies, Ramsey, Lindfield & Couperthwaite, 2005; Ellis, Marcus & Taylor, 2005; Dantas & Kemm, 2008; Valverde, 2012).

Molecular biology tools are becoming extensively used in all areas of biology, leading to students from all biological disciplines now beginning to be trained in molecular biology concepts and techniques. For example, at Plymouth University, molecular biology has recently been incorporated into the Marine Biology curriculum. Previous observations of student learning suggest that students lack confidence when performing a procedure

alone for the first time, even after initial face-to-face training. This can lead to mistakes, and the need to approach an experienced researcher on a regular basis to “double check” that the protocol is being followed correctly. These observations prompted the idea to develop a blended approach that includes a combination of face-to-face training and multimedia tools which students can use when following the procedures on their own in the laboratory. Accordingly, a video tutorial demonstrating a widely used laboratory procedure was produced to supplement face-to-face training. When considering different learning styles, video tutorials incorporate visual and auditory aspects, thus are suitable for the majority of learners (Fortino & Zhao, 2012), particularly when adding a kinaesthetic element by using them as guidance in a laboratory environment.

The aim of this pilot study was to test the suitability of video tutorials to support face-to-face training in basic molecular laboratory techniques. Specifically, the investigation focused on students with no background knowledge of molecular biology. This was done by dividing students into groups and exposing them to different teaching methods, i.e. face-to-face training, use of video tutorials or a combination of both approaches only. Different teaching tools were evaluated by assessing both students' performance and perception (i.e. confidence when repeating the technique alone). It was hypothesised that students exposed to a blended approach would perform better and be more confident than those in the other two groups. Pedagogical principles underpinning this pilot study were derived from the concept of experiential learning (Kolb, 1984) and underlined by constructivism, thus the basic premise that learners who are active in learning, as opposed to passive recipients of knowledge, construct understanding through their experiences (Bruner, 1960, 1966; Vygotsky, 1962, 1978).

Materials and Methods

This study is framed within the concept of Action Research (reviewed by Hammersley, 2004), which draws on the intimate relationship between research and some form of practical activity. The research questions focused on students' competence and perceptions of their own ability to follow a procedure on their own for the first time. Accordingly, the methodology was developed around three main aspects: (a) the

production of a custom-made tutorial based on previous observations of students' learning, (b) the evaluation of the students' competence when performing the technique alone and (c) the evaluation of the student's perception of their own ability.

Participants

This pilot study was carried out in March 2014 at Plymouth University. Participants were second year students from the Marine Biology undergraduate programmes. An email requesting volunteers was sent to the second year cohort, in which the pedagogic nature of the study, the time commitment and the benefits of their involvement were highlighted. The first 14 students to respond were selected and these were sent information about the project and a consent form.

Ethical approval for this project was granted by the departmental Ethics Committee, according to the ethical principles of Plymouth University and British Educational Research Association.

Production of video tutorial

A custom-made video tutorial was produced for the widely used basic molecular laboratory technique of agarose gel electrophoresis. The final outcome of this technique allows visualization of a DNA sample on a gel using imaging software, which makes it possible to evaluate the ultimate success of the technique by the appearance of a distinct band on a gel image. The tutorial was based on a standard operating procedure (SOP) developed by the author, used when training undergraduate students, and subsequently for consultation while carrying out the procedure. Outlines of the different steps in the procedure were written and scripts were prepared to guide in the filming process. The vocabulary, reagents and materials used in the video were consistent with those used in the protocol and during the training sessions. Techniques were filmed in the molecular ecology laboratory at Plymouth University, the same in which students are trained and carry out the procedure thereafter. Filming was carried out using iMovie on an iPad. Raw footage was edited with iMovie; narrative voiceovers were recorded within the same programme and added to the footage; titles were added to break the different sections; and written comments were included to highlight critical steps. The edited video was uploaded to the video hosting site Vimeo (<http://vimeo.com/88402969>).

Experimental design

Participants were divided into three treatment groups: (a) a training only group (control), (b) a training and video group and (c) a video only group. Students in the training only group received a face-to-face training session by a qualified instructor. During a second session, they were asked to perform the technique following the same SOP used during their training, as well as their own notes. Students in the training and video group received the same training, and were asked to repeat the procedure alone, referring to the video tutorial during a second session. The video only group was asked to perform the procedure during a single session, with no previous training, while encouraged to watch the video as they performed the task. Both groups that received the video were asked to watch it before starting the session.

In all cases, participants received background information on the techniques and a safety briefing. During the session when they carried out the procedure alone, guidance was limited in order to minimise interference. Only information necessary to ensure their own safety and the protection of reagents and equipment was provided. Students were observed while carrying out the procedure, and were not told about the nature of the experiment until after they had completed the questionnaire.

Data collection

In order to increase standardisation, a quantitative approach was used throughout the study (see Malterud, 2001; Miles & Huberman, 1994). Several methods were used with the intention of triangulating data, including observations, questionnaires and end-point assessment.

For the analysis of student performance, both evaluation of the end product and observations of the students' behaviour during the procedure were performed, during which a series of parameters were recorded (i.e. number of questions they asked the researcher, number of times they approached each other and number of errors). The benefits of performing observations as part of descriptive research are clear, as these allow the researcher to get an indication of the student behaviour (Knupfer & McLellan, 1996). However, since observations might be influenced by the perspective of the

observer, potential subjective conclusions must be accounted for. With this in mind, an end-point assessment of the students' techniques results was carried out by an unbiased visualization of a successful end-product for the electrophoresis technique used in this study. Observed errors were classified as minor if they nevertheless resulted in a positive result from visualisation of a DNA band. Major errors were classified as those that prevented or significantly compromised the successful completion of the procedure, because the bands could not be visualised. All students were given the same samples and protocol, and were asked to load the samples onto the gel in the same order. The intensity and arrangement of the bands (end-product) provides an indication of closely the students followed the protocol. In the absence of deviations from the protocol, all gels are expected to look approximately equal. For the evaluation of student perception, a questionnaire was developed consisting of ten questions, each with three possible closed answers. Answers were not mutually exclusive, thus students were asked to select the option that best described their experience. Questions were constructed to be able to evaluate students' perceptions of their own abilities (i.e. confidence), by asking them to predict their future performance and current levels of mastery. The number of students who selected each of the answers was computed.

Results

Evaluation of student performance

Student performance was evaluated by observing their behaviour during the development of the procedure, noting the number of questions addressed to the instructor and deviations from the protocol (Table 1), as well as by assessment of the end results (Figure 1).

Table 1. Results from observations of student behaviour during the development of the procedure for gel electrophoresis of DNA.

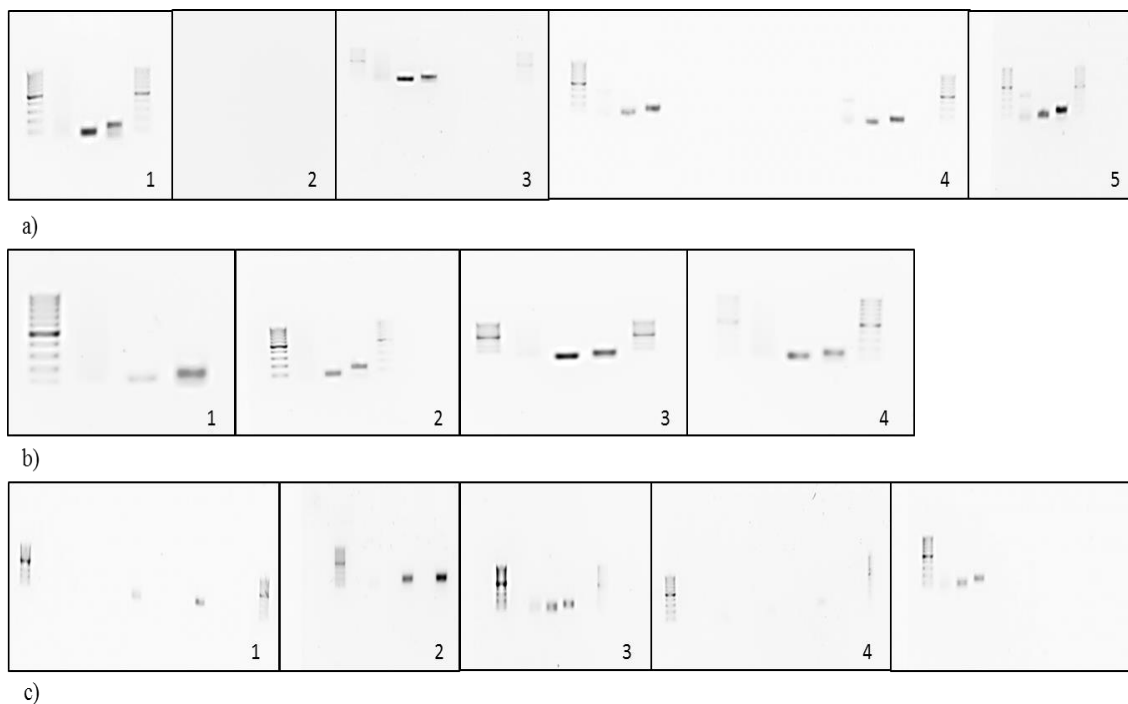
Observation	Treatment group		
	Training only (n=5)	Training plus Video (n=4)	Video only (n=5)
Total number of questions	2	3	17
Number of students asking questions	2	2	5
Number of errors	1*	3	6 (1*)

The total number of questions asked to the supervisor, the number of students who asked questions, and the number of observed errors (major errors are indicated with an asterisk) are shown for each treatment group.

All students in the video only group asked questions (n=5), compared to $\leq 50\%$ in the other two groups. Moreover, the video only group was the one that asked the most questions across all participants. The number of errors observed in the video only group was also the highest of all treatment groups (Table 1).

The nature of the errors observed in gel images representing the end-point result of the procedure for each participant and treatment group (N=14) (Figure 1). Major errors are indicated by absence of dark bands on the gel as in participant two in the training only group (a), and participant four in the video only group (c). Although not all minor errors observed by the instructor can be visualised, some led to visible differences (participants three and four in the treatment only group (a); and participants one and five in the video only group (c)). All students completed the procedure, with one student in each of the training only and the video only group making a major error. In both cases, this prevented visualization of the results (participants two and four respectively). No major errors were made in the training plus video group (b). Moreover, results across participants in this group (b) showed the greatest consistency in terms of band intensity and arrangement, both of which reflect rigour when following the protocol (i.e. differences would arise from deviations from the protocol). More variations amongst participants can be observed for the other two groups (participants two and four in the training only group (a); and participants one, two and five in the video only group (c)).

Figure 1. Agarose gels showing the final product of the procedure for each participant



In a) the training only group ($n=5$), b) the training plus video tutorial group ($n=4$) and c) the video tutorial only group ($n=5$). Results for each participant are shown in each box and indicated by a number. In each case, the first and last bands correspond with a standard (control) and the two dark bands in the middle show the desired DNA products.

Evaluation of student perception

Results from the questionnaire are given in Table 2. Only questions relating to assessing student confidence are shown. While the small sample size does not allow for statistically supported conclusions to be made, some trends can be observed in the data. Students that received initial training (i.e. training only and training plus video groups) were asked whether they would have attempted the procedure alone without training. The majority of students in the training only group felt they would not have been confident enough to try (80%), whereas the majority of students that had also used the video felt they would have felt confident enough to try if they had had the video (75%), suggesting that having gone through the procedure using the video increases students' confidence that they can confront the procedure alone. When asked if they would have performed the procedure successfully with no training, all students in the training only group believed they would have made mistakes, whereas the majority of students in the training plus video group (75%) felt they could have completed the

procedure successfully if they had had the video, suggesting that having gone through the procedure using the video increases students' confidence in their own abilities, assessed as likelihood to succeed.

Table 2. Questionnaire results for the key questions relating to assessment of student confidence.

Question	Answer	Treatment group		
		Training only (n=5)	Training plus Video (n=4)	Video only (n=5)
Would you have tried to do the procedure alone if you had not received any training?	Yes, with the protocol	0	0	n/a
	Yes, with the video	1	3	n/a
	Not confident enough	4	1	n/a
Could you have done the procedure <i>successfully</i> alone without the training?	Yes, with the protocol	0	0	n/a
	Yes, with the video	0	3	n/a
	I would have made mistakes	5	1	n/a
Could you repeat the procedure alone relying on your notes and written protocol?	Yes, but with mistakes.	1	2	3
	Yes, I would do a good job.	4	2	2
	No, I would need someone to be around.	0	0	0
Could repeat the procedure alone if you had the video tutorial?	Yes, but with mistakes.	1	1	1
	Yes, I would do a good job.	2	3	4
	No, I would need someone to be around.	2	0	0

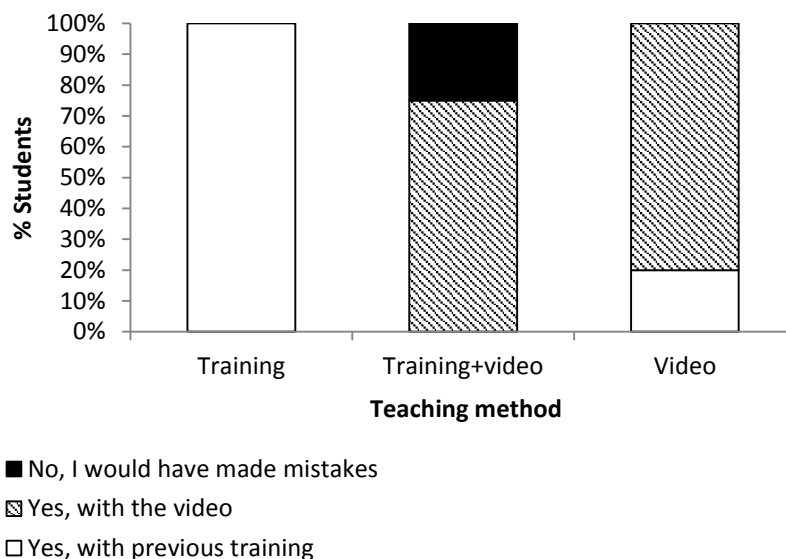
Questions, potential answers and number of participants that selected each answer are shown for all treatment groups.

When asked about their confidence in performing the procedure in the future, the trends were less clear. Students that received training and then repeated the procedure using the same protocol and their own notes had the greatest confidence that they would be able to do a good job if they could repeat it using the same tools (80%). For the other two groups, availability of the video increased confidence in their ability to repeat the procedure alone; 50% of students in the training plus video group, and 40% in the video

only group felt they would do a good job with the protocol only. This percentage increased to 75 and 80% respectively if they had the video.

In order to assess whether the presence of the instructor was necessary after the initial training session, students were asked whether they could have carried out the procedure successfully alone if the instructor had not been present. All students in the training only group felt they would have not needed supervision to repeat the procedure. The majority of students in the other two groups felt they would have been able to repeat the procedure without supervision if they had had the video (75 and 80%) (Figure 2).

Figure 2. Evaluation of students' own ability to perform the procedure successfully alone.



Discussion

This study aimed to evaluate the effects of the availability of a video tutorial during an active learning laboratory-based session on students' competence and confidence. Results suggest that a blended approach, including face-to-face training and a video tutorial, yielded the greatest success when students performed the procedure alone for the first time. In terms of confidence, having gone through the procedure using the video increases students' confidence that they can confront the procedure alone; as well as confidence in their own abilities, assessed as likelihood to succeed.

Evaluation of student performance

Although the video tutorial was not meant as a substitute for face-to-face training, results from this pilot study suggest that student performance (i.e. in terms of end-point results) using the video tutorial alone was similar to that using the face-to-face training session alone. Our results support the conclusions of Maldarelli et al. (2009), who demonstrated the use of video tutorials alone, when teaching biology laboratory skills, showed as strong an effect as performance of the lab technique alone. Nonetheless, this study indicates that the combination of training and availability of a video tutorial is best in terms of performance.

The greatest success in students exposed to both methods confirms the predictions that motivated this pilot study regarding improved performance. A blended approach to active learning in the laboratory, using e-learning tools to support face-to-face interactions, has been previously shown to enhance student learning (Dantas & Kemm, 2007). There is evidence that teaching approaches that combine face-to-face and virtual sessions can improve students' attitude, foster social interaction, address diverse learning styles and enhance learning outcomes (Lim & Morris, 2009; Movahedzadeh, 2011).

Analysis of social interaction was attempted by observing students and asking how much they relied on their peers. It has been proposed that students progress significantly more when working cooperatively than in isolation (Vygotsky, 1978), thus attempts were made to test what method encouraged cooperation. While there was some indication that the video only group relied less on each other (results not shown), the sample size used in this pilot prevented definitive conclusions.

Evaluation of student perception

Results from the questionnaire suggest that having gone through the procedure using the video increases students' confidence that they can confront the procedure alone, as well as confidence in their own abilities (i.e. successful completion).

The availability of a range of e-learning materials as preparative tools before attending the lab session, has been shown to significantly increase the students' success and/or confidence (Maldarelli et al., 2009; Fortino & Zhao, 2012; Valverde, 2012). While the present study was not designed to test the effect of "pre-exposure" to the video tutorial, it is possible that allowing the students to watch the procedure in their own time yielded greater confidence than teaching them to use it face-to-face, where the pace is dictated by the instructor.

When asked about their confidence in performing the procedure in the future, students who received training and then repeated the procedure with the same protocol had the greatest confidence in their abilities. For the other two groups, the availability of the video clearly increased confidence in those students who tried it. However, it cannot be excluded that the higher level of confidence observed in the training only group may be simply related to the fact that students in this group carried out the procedure twice, using the same method (i.e. during the training session, and again when asked to repeat the procedure alone).

An interesting point is that all students in the training only group felt they would have not needed supervision to repeat the procedure had they had initial training. On the one hand, it is possible that verbalising their doubts during the face-to-face session enhanced the active learning process. Modell et al. (2000) compared the success of different levels of instructor intervention in "predict and wrap up" laboratory practical session in physiology. The "instructor intervention" treatment, where students verbally presented their prediction before starting the procedure, and further discussed the outcomes with the instructor, yielded higher success rates than the other two, where students' either followed a written protocol on their own, or showed their predictions to an instructor before starting the procedure. In all cases, the instructor neither confirmed nor refuted the students' predictions. In a later study (Modell et al., 2004) the authors attributed the increased success in the "instructor intervention" group to the increased thought given to the predictions when having to verbalise them. On the other hand, the students' response contrasts with previous observations, as students typically have to approach the instructor before or during the time they repeat the procedure alone for the first time, even when a similar dialogue has been maintained during the sessions. When evaluating whether e-learning motivates students to learn, Colosimo & Casuto (2012) showed that around 30% of students (equivalent to a few hundred in their study) with

access to tutorials tailored to an assignment for a chemistry course, did not watch the video. The authors attributed this students' response to an overestimation of their own abilities. It is not possible to determine whether students overestimate their abilities, and then struggle when facing the procedure alone; or whether increased confidence in this case is a result of having already performed the procedure alone (albeit in the presence of an instructor) at the time of answering the questionnaire.

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