Lights, Camera, Action: Using Wearable Camera and Interactive Video Technologies for the Teaching & Assessment of Lab Experiments

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Abstract

In laboratory practicals, demonstrating laboratory techniques and equipment handling to students require frequent repetition. Also, it is difficult to identify whether students understand the relationship between theoretical concepts and their practical execution. Furthermore, for exclusively online courses, students' physical presence in the laboratory is not possible so appropriate teaching and assessment alternatives need to be employed. While the medium of video offers potential for addressing these issues, creating video can require specific production expertise and equipment. This study explores how relatively inexpensive wearable camera technology may provide an alternative approach for the rapid production of lab-based videos. It describes how this technology was used by an academic to video laboratory experiments relating to biomedical diagnostics. It also explains how an interactive question was embedded within the video to assess students' understanding of the concepts demonstrated. Data was drawn from student and demonstrator feedback surveys, and the experiences of the lecturer involved in this project are discussed. A number of distinct benefits of this approach were identified, including its preparatory potential akin to a flipped classroom, its rapid production time, the non-intrusive nature of the recording, the advantages over text descriptions, and the relatively low cost. The advantages and limitations of the embedded question format are also discussed. The study includes practical recommendations for other academics considering this technology and suggests further applications for potential use in laboratory learning.

Introduction

We live in a multimedia age. From the very young to the very old, people have devices in their pockets capable of filming anything from a baby's first moment on earth to a full-length feature film. Increasingly, video technology is being used in an educational context, with student-generated content and flipped classroom approaches becoming more common in teaching practice (Johnson, Adams Becker, Estrada, & Freeman, 2015; Kearney & Schuck, 2005). However, the teaching and assessment of laboratory experiments at university remains more traditional, frequently involving 'stand and deliver' style demonstrations by lecturers with assessment via lab reports. This is not without its disadvantages as the literature amply illustrates. As far back as 1958, Kruglak (cited in Hofstein & Lunetta, 1982, p. 32) wrote that "It is impossible to measure certain neuro-muscular laboratory skills by means of paper-andpencil tests. A student might get a perfect score on written tests but not be able to handle apparatus in the laboratory."

More recently, an Australian investigation of first year students attending lab-based classes suggested that students, especially those without prior lab experience, do not always receive "adequate introduction" to the equipment and practice of the lab (Rice, Thomas, & O'Toole, 2009, p. 46). Johnstone (1997) has written about the dangers of overwhelming students with information in the laboratory context, describing the lengthy list of items that a student has to perform, observe, and recall in order to make sense of a set of experiment instructions. Abraham (2011), reviewing 32 years of research in the field, writes that laboratory skills in particular are best taught by direct instruction strategies that inform and demonstrate but that lecturers do not always choose the method that is best suited to what they want to teach.

The use of video offers the ability to demonstrate lab-based experiments with distinct educational benefits. This medium has grown enormously in recent years (Harrison, 2015; Kaufman & Mohan, 2009) with increasing recognition of its potential for enhancing pedagogy and reducing cognitive overload. For example, recent implementations of the flipped classroom approach, where students are asked to review videos and other types of learning material in advance of class time, have highlighted the value of video-based learning as a preparatory learning aid (Lancaster & Read, 2013). However, recording video in a laboratory setting is not necessarily a straightforward endeavour: academics may not have access to the production expertise to set up and position the camera correctly, tripods and other equipment may be disruptive to a busy lab, and there are health and safety risks to consider. If an external production team is engaged, there are also significant costs involved, an issue which is all too frequently ignored in the literature (Winslett, 2014). This is where wearable technology may play a role.

The potential of wearables

Wearable technology describes any form of computer device that can be worn by users. It is used to track health-related behaviours, provide real-time access to data, and enable virtual reality experiences. According to the Horizon report, demand for wearable technology is likely to increase significantly by 35% globally over the next five years, as college students continue to experiment and engage with the technology (Johnson et al., 2015). One of the most high-profile wearable devices is Google Glass, which as well as enabling users to view web-based information about their surroundings, allows for hands-free, voice activated recording of video. Despite reported consumer issues with price, privacy and appearance (Kalinauckas, 2015), this product is experiencing growth in the field of medical education. Google Glass is increasingly being used to educate surgeons (Cuthbertson, 2014) and encourage a more empathic manner by making it easier to capture and later review patient reaction in a non-intrusive way. Another less sophisticated but significantly less expensive wearable device that may be more accessible to universities is the wearable camera. Recording video with a head-mounted camera of the type developed originally for recording sporting activities also enables hands-free non-intrusive recording of activities and a first-person perspective (Chalfen, 2014). Until recently, little published research was available on the use of head-mounted cameras in a laboratory teaching environment. However recent trials by Fung (2015) seem to support the potential for this technology in a laboratory context. After using this type of camera to record a first-person shooter (FPS) perspective for a chemistry lab demonstration, he wrote that

> This new element where a student can observe a scientific experiment through the demonstrators' eyes is both interesting and captivating. Instructors and students who have participated in the GoPro FPS learning activity found this new technique to be a useful tool in enhancing their knowledge and understanding of scientific experiments. (p. 1520)

Furthermore, another study on the use of flipped teaching in chemistry laboratory learning found that instructor-narrated videos of practicals together with pre-lab questions helped students to reorganise the information so that practical procedures and theory became clearer to them (Teo, Tan, Yan, Teo, & Yeo, 2014).

Whatever method of filming is used, sound pedagogical practice suggests that efforts need to be made to ensure that videos do not replicate or encourage a passive learning experience. The importance of active learning has been long recognised (Biggs & Tang, 2007). Among their seven principles of good practice for undergraduate education, Chickering and Gamson (1987) reinforce that when teaching undergraduate students, it is important to promote active forms of learning, provide prompt feedback, and respect diverse ways of learning. In popular culture, interactive techniques are increasingly being added to video (Grossman, 2014) in an attempt to engage viewers more deeply. In addition there is some evidence to suggest that instructional video is most effective when it requires students to complete learning activities such as multiple choice questions before continuing (Vural, 2013). He suggests that a video should encourage and motivate learners to attend to their learning by performing activities such as answering questions to continue to the next part of the video. He also found that students who experienced a question-embedded approach also tended to spend more time with the learning materials because "they might think that similar questions would be asked in the final exam" (p. 1322).

The purpose of this pilot study was to explore whether a point-of-view video recorded by a lecturer using a wearable camera and featuring interactive video techniques could potentially assist with the teaching and assessment of laboratory experiments. In addition, this study investigates how the inclusion of interactivity and feedback within such a video was perceived by students.

Methodology

The research was conducted over five months (November 2014 - March 2015) and predominantly focused on gathering feedback from two separate groups of students and one group of lab demonstrators.

- **Group 1**: 9 full-time postgraduate (PG) students taking a taught Master of Science (MSc) degree course in Biomedical Diagnostics
- **Group 2**: 29 undergraduate (UG) students enrolled in the third year of a Genetics and Cell Biology full-time Bachelor of Science (BSc) degree course
- **Group 3**: 4 lab demonstrators responsible for demonstrating laboratory techniques to students, monitoring students' activities in the laboratory, overseeing practical performance and providing guidance to students during the session. The demonstrators are postgraduate PhD candidates in year 2 or 3 of their research project.

The research was carried out using a case study approach that focuses on what Hitchcock and Hughes (1995) refer to as "the specific, the clearly bounded and unique" (p. 319). The case here is a specific group of students who have reviewed a specific learning intervention at a specific point in time. The research was undertaken as an exploratory study to identify whether this type of learning intervention may be worthy of further development and integration into future courses.

How and what was filmed

The process of performing an indirect enzyme-linked immunosorbent assay (ELISA) was filmed by an academic using a *Panasonic HX-A100* camera. The Panasonic HX-A100 is a lifestyle or action head-mounted camera. It is a light (167 g) and portable camera that consists of two connected components: the lens and the recording unit. The recording unit is similar in size to a pack of cards and can be easily placed in a shirt pocket or placed in the supplied strap. The lens is connected to the recording unit by a 70cm long lead. The design allows the lens to be attached to a supplied headband to enable a point-of-view (POV) camera angle. The user can start and stop recording using buttons on the recording unit but to access further settings, an app called the *Image App* needs to be downloaded to a smartphone. The app, in this case *Image App version 1.9.1*, connects to the camera via a wireless hotspot and once connected the user can use their smartphone to straighten and adjust the camera angle, select different resolutions (720p, 1080p), and select slow motion. Most importantly the app acts as a monitor so that the lecturer doing the recording can check if the appropriate shots are being captured.

The goal of the lecturer who created the video was to provide a clear demonstration and explanation of each experimental step. The filming was carried out in one of the research laboratories of Dublin City University on a bench near the window so that natural day light provided sufficient lighting for filming. The video began with introduction to the laboratory and an overview of the objectives of this assay. This was followed by filming those steps of the procedure that are performed on the bench, such as addition of the reagents and using the automated plate washer. Any time-consuming periods of incubation were not filmed, but explained in detail at the beginning of each of the periods. Overall, the actual filming time of the 8-hour experiment was approximately 3 hours. Some post-production techniques were employed after the video was created, which added approximately 5 more hours to the process. Repetitive and prolonged aspects, such as multiple washing steps or periods of incubation were fast-forwarded or cut out altogether, reducing the experiment to 10 minutes 42 seconds in total video duration. Figure 1 shows a screenshot from the video.

Figure 1. Screenshot from the ELISA video.

The main purpose of the video was to demonstrate the immunoassay technique to students. To enable active listening and to encourage students to refer to the content of the theoretical material, an interactive exercise in the form of a question appeared automatically at 6 minutes 57 seconds. This question appeared at the same time as a verbal prompt from the academic. The learner was required to answer the question correctly in order to proceed with watching the video. This interactive element of the video was created using *Articulate Storyline* software. The multiple choice question asked learners to identify what type of ELISA was being performed and offered four options as shown in Figure 2. When students clicked the (correct) **Indirect Elisa** option, the video continued and the audio narration confirmed the right answer.

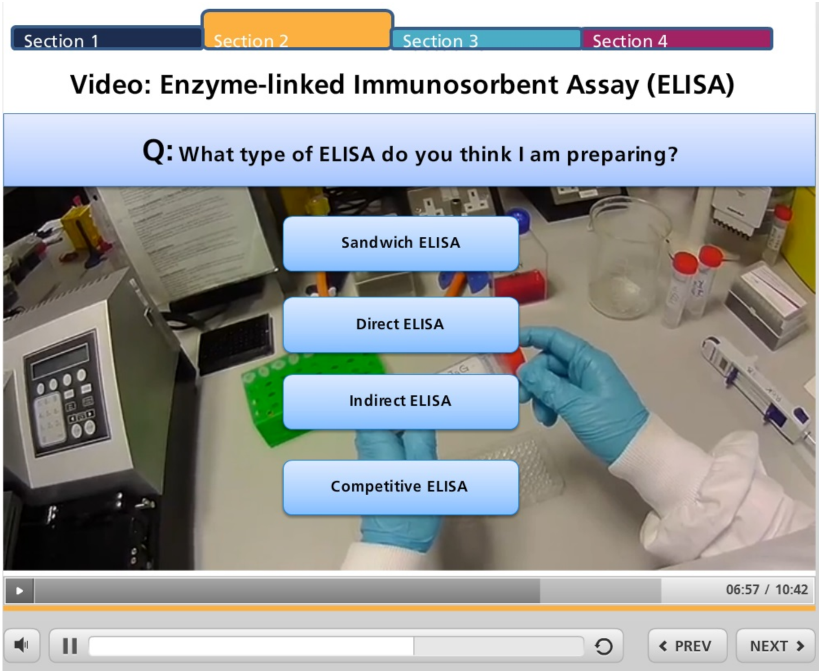

Figure 2. Embedded interactive question within video.

When students clicked any of the other three (incorrect) options, they were given feedback on their chosen answer and directed to an accompanying PDF document where they could read brief feedback and learn for themselves which option was correct (Figure 3). Both the video and the interactive exercise were presented within a learning object on the learning management system alongside other content on the topic of immunoanalysis.

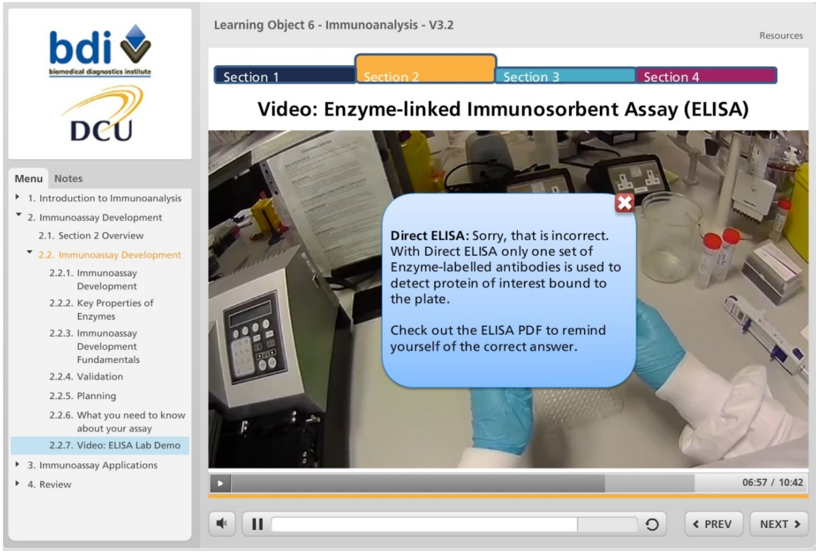

Figure 3. Sample of feedback provided upon selecting an incorrect option.

Survey design

In order to evaluate the potential of this format, we surveyed 38 full-time students who were taking practical lab-based courses within two groups. These students could compare the learning experience from watching the video to their physical laboratory session. The two groups of students were asked to watch the video and complete a 10 question survey (provided as Appendix 1) that asked them to express their opinions on this format of lab-based video and embedded interactive exercise. 26 out of 29 undergraduate and all 9 postgraduate students participated in the survey.

Since this research was exploratory in nature, we asked predominantly open-ended questions to capture as many perspectives as possible. Draft survey questions were reviewed by a critical friend and were subsequently revised. The two groups of students were asked to view the video of the ELISA technique in advance of their laboratory-based practical session during which they would be performing this immunoassay technique. Both the video and the survey were distributed to the students via the learning management system Moodle 2.6 one week before the practical session.

Four demonstrators, who had previous experience with delivering the laboratory-based practical training of this technique to students, were also asked to fill in a short survey (see Appendix 2). The demonstrators were asked to take a note of the changes in performance and overall understanding of the technique by the students who watched the video in comparison to the previous cohorts of students who did not watch the video.

All responses were anonymised. However, it should be stated that there is a recognised potential for bias from students who, by virtue of the fact that their lecturer has asked them to complete the survey, may feel reluctant to return negative viewpoints in case it impacts on grades. Although students were requested to be honest in their feedback, this tendency towards positivity should be acknowledged. Furthermore, because this particular video was published within a learning object, we only know whether students opened the learning object, not how long they spent on the video itself or if they stopped watching it before completion. Notwithstanding these limitations, the following section describes our findings to date.

Results

Student response to the video

All the respondents reported that they found the 10 minute video of the technique useful for understanding the technique and 34 out of 35 stated that they would like to have such videos available to them before each practical session. Students commented that it was useful to view the steps involved and hear the explanations as to why various components were being added while the technique was being performed. The consensus amongst the students was that this type of virtual demonstration of a practical technique possesses advantages over a text manual or verbal explanation by the lecturer. The removal of the waiting time typical of laboratory experiments, and the relative ease and speed at which individual steps could be viewed were noted. In addition, over 40% of the respondents (15 out of 35) volunteered comments about the point-of-view that the video was shot from. These students particularly liked that having the camera at eye-level gave them a clear view of what was being done at every stage of the experiment.

Student response to the interactive exercise

The interactive exercise embedded within the video was also broadly welcomed by both cohorts of students. 33 out of 35 respondents found its presence useful and motivating. In their responses the majority of the students commented that the interactive question significantly enhanced their attention to the video and encouraged learning. In fact, over a third of respondents (12 out of 35) expressed a wish for more interactive exercises to be included in such videos to encourage learning and understanding. Students who responded positively commented that the interactive question made them think about the steps in the video more closely when considering how to answer.

However, it should be stated that not everyone valued the mid-video question design and one of the negative comments made about the exercise referred to the position of the question itself. The student stated that they would have preferred the question to be at the end of the video as they found it disconcerting to have a question mid-way through without having full knowledge of the procedure.

Lab demonstrator response

In an effort to triangulate our data, we investigated the impact of the video and the interactive exercise on students' performance as assessed by the lab demonstrators. All four demonstrators had demonstrated the ELISA technique previously and therefore were in a position to compare the students' performance and overall understanding of the technique after viewing the video with students who had not watched the video. Three out of four demonstrators agreed that watching the video in advance of the laboratory practical session did improve understanding of the techniques amongst students, and all four agreed that it also improved their practical performance compared with previous cohorts of students. As one demonstrator commented, time in the lab is limited and students were able to work through the experiment more quickly, competently, and independently than if they did not have access to this video.

Discussion

The use of pre-recorded video of a scientific experiment as a mode of student preparation for practical sessions has been previously described for secondary school science in a flipped class approach by Bergmann and Sams (2012). In higher education, a variation of the flipped classroom approach is traditionally used as a means of preparation for all practical sessions, because students are usually asked to read their practical manual before attending laboratory sessions. From the results of our anonymous survey, students favoured the pre-recorded video of the technique to the laboratory manual as means of preparation. This was also echoed by the demonstrators, who agreed that watching the video better prepared the students for the practical session because their technical performance in the lab was noticeably improved.

However, before reading too much into these results a note of caution should be sounded. In addition to the study limitations described earlier, it is important to beware of the "everything works" syndrome described by Winslett (2014). In the literature to date, video usage is being reported on favourably when comparing the value of having some video materials with having no video at all. As Winslett describes, this overwhelming positivity towards inclusion of video in teaching does not take account of particular production styles and how they might influence the success or failure of video as a teaching tool. With all 35 students seeing this type of video used in this context for the first time, there may be an element of the novel versus the norm that is skewing our results.

Several respondents mentioned that they would like to see all the lab equipment and reagents clearly labelled and it was suggested that text subtitles could be used to aid deeper comprehension of the experiment. Such additional information can be incorporated using video editing software. Another level of detail could be afforded by inserting images, graphs and drawings to illustrate the theoretical concepts that are discussed. This could significantly add to the teaching value of the video, by providing an opportunity to demonstrate the material previously presented to the students in the lecture or textbook in direct association with the practical application. There are also opportunities for students to annotate the video, thereby promoting further levels of interactivity and active learning. Freely available software such as *Thinglink* (available from www.thinglink.com) could be employed to do this. However the extra time required to annotate videos should not be underestimated and should be carefully considered.

Another technique to potentially promote deeper engagement is the use of branching scenarios that allow students to experiment with different decisions, make mistakes, fail, and repeat what they have learned within a safe but realistic learning environment. Realistic scenarios can provide an excellent "hook" for students to reconnect with the steps, the process, and the point of the content itself (Bean, 2012). For example, students could be asked to choose the concentration of a reagent such as an enzyme from a list of options e.g., very low, correct, and very high. Each of the options could then lead to a different outcome of the experiment, such as no detection of the product is possible due to incorrect choice of the enzyme concentration. The students could then be further challenged to identify the reason for the unsuccessful experiment from a list of possible reasons including the wrong enzyme concentration. Providing the opportunity to make mistakes and learn from those mistakes is not generally possible given the limited time constraints of most lab sessions, but it provides a unique selling-point for video. Begg (2008) points out that incorporating what he refers to as “game-informed approaches” allows students to take highly individualised pathways through content, take consequences for their actions, and revisit routes and procedures as they wish. Branching video scenarios can encompass all of these elements. From a production perspective, one challenge of the wearable camera that should be noted is that the person recording must be aware of any habitual unconscious head movements, such as shaking or nodding while talking. Unintentional head movement can potentially introduce unsteadiness that can be distracting for viewers. This issue can be challenging to avoid, particularly for those new to video production and requires some practice. However, the time spent on preparation for filming and post-production processing was relatively low. In addition to the three hours required for recording, the video took approximately three hours to edit and it took approximately two more hours to create the interactive question, leading to eight hours in total. It should be acknowledged that the lecturer in this case was assisted by a multimedia specialist and a learning technologist and additional time would be required without access to this type of expertise.

Furthermore, in our study, the majority of students apparently relied solely on the video for all information and failed to do any other preparatory work, such as reading the lab manual or the associated text. Therefore this should be taken into account when creating such videos: as much information as possible should be included within the video or indeed several videos may need to be created to cover every desired learning outcome of the practical session.

Potential for assessment

We also investigated the use and application of the interactive exercise embedded within the video as means of assessing understanding of the theory behind the assay. Although we experienced some technical issues in creating and timing this exercise, in our opinion it improved the learning outcomes because it required students to demonstrate knowledge of the previously studied material and directed them to that information as required. This type of interactive exercise was praised by the students and the majority expressed a wish for more interactive questions to be available within any such video. The embedded exercise not only adds an element of interactivity to the video, but can also be used for assessment of understanding of the topic or concept by the individual student or by the class in general. While not used in this particular case, the *Articulate Storyline* software facilitates the inclusion of scores so that students could be graded on the basis of their ability to answer specific questions on a specific topic. In other words, the interactive video could potentially be used for summative (not purely formative) assessment.

However, there are limitations of the interactive video format that should be considered. When asked whether the interactive question embedded within the video was a useful assessment tool in their view, all lab demonstrators agreed that such exercises are important to stimulate analytical thinking and to understand the methodological differences between various types of the assay. However, three out of four demonstrators commented that once the students were asked to perform a different type of ELISA assay (the competitive ELISA as opposed to indirect ELISA shown in the video) there was little evidence of any deep understanding of that type of assay. In our opinion this signifies that the students solely relied on the video and failed to read the manual or any additional information related to the assay. If only surface learning is occurring, this could potentially signal a lack of understanding.

Low cost, non-intrusive approach

Use of the wearable camera allowed recording and demonstration of the scientific experiment in the teaching laboratory, without need for any extra space, highly-specialised equipment or personnel. Costs are thereby kept to a minimum. It is a scalable teaching strategy in that other educators can adopt a similar process to rapidly produce videos of their own.

While the wearable camera itself is relatively inexpensive (approximately €270 from one online retailer), there are some further costs that should be mentioned. *Articulate Storyline* is not freeware and at the time of writing, a licence cost approximately €640 after an academic discount is applied. In addition to this, the *Adobe Premiere Pro* video editing software was used which costs approximately €240 a year for students and teachers. If this software is beyond budget, there are other options for editing this type of video that could be considered. The edits made in this case study involved simple cuts, inserting title plates, and some 'speeding up' of clips. These types of edits can be implemented using freely available tools such as Microsoft's *Windows Movie Maker* and Apple's *iMovie*. Furthermore, the number of free tools for creating quizzes continues to grow as an online search will confirm. While such tools may not incorporate the ability to progress a video based on correct answer as the *Articulate Storyline*-created interaction does, they do offer possibilities for incorporating various question types within or alongside a video.

When discussing costs, it should also be noted that in a climate of growing population and increasing student numbers, the issue of funds and space at universities is becoming more and more acute. Ireland has undergone a period of population growth and in fact experienced the highest population growth in the European Union in 2014 (Holland, 2015). As a consequence, some universities are resorting to literature review-based assessment items as opposed to research-based projects and reducing the hours of practical sessions in the teaching laboratories for first and second year students. While published evidence of this is difficult to source, a recent audit of practical work undertaken by undergraduate bioscience students in the UK reiterated the perceived barriers to the delivery of laboratory-based practical education. In that report, university teachers almost unanimously agreed that increasing student numbers and limited resources regarding laboratory space, equipment, staffing and funding limited their provision of laboratory-based practical education (Coward & Gray, 2014). Of course no video can substitute the experience of physically performing an experiment, but it certainly can provide a valuable insight into the laboratory setting, correct use of equipment, and accurate performance of techniques. Such videos could potentially substitute the crowded practical sessions during the junior years of the degree programme, freeing funds, staffing and laboratory space for senior students, while providing detailed demonstration of the techniques, correct use of laboratory equipment and experimental application of the theory. Filmed from the eye-level of the lecturer and accompanied by an audio explanation, such video comes very close to the experiment being demonstrated to the students on the bench but with a better point of view.

Conclusion

On the basis of the described student and lab demonstrator reaction, the videoing of lab experiments using a wearable camera potentially offers a range of pedagogical benefits, and there are considerable financial advantages to this approach. This makes it a promising tool for those who have little or no experience with video production and who are prepared to engage in some experimentation of their own as to what works best for their students. There also appears to be value in making efforts to build in interactivity and our findings support Vural's (2013) assertion that a video-based learning tool should be designed to incorporate learners in the learning process.

Although our findings were promising, due to the small sample size and the limited level of interactivity incorporated, they cannot be considered generalisable. Rather, it is intended that they offer a starting point for further development and investigation. Given the lessons learned by the lecturer and learning technologists during this project, the authors suggest that further research should be done to formulate more detailed guidelines for academics who wish to employ this technology and replicate this approach. Furthermore, the data referring to the value of the POV angle employed is worthy of further research, especially because it may contribute to the literature on the most appropriate way to align video production approaches with desired learning outcomes. These topics will be the subject of future study by the authors.

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