Teaching scientific inquiry in human reproductive biology through use of animal models: *In vivo* vs video

Category: Refereed Research

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Scientific inquiry (SI) refers to the process practiced by researchers to develop scientific knowledge. A sound understanding of SI is considered essential to achieve scientific literacy. In biomedical professions, it is also important to develop an appreciation for the necessity and value of animal-based research. This study describes the introduction of a laboratory-associated assignment to encourage undergraduate students studying 'Human Reproduction' to develop a deeper understanding of SI, and enhance their awareness of animal-based research. We also investigated the effectiveness of online video resources to deliver part of the laboratory content, thereby introducing a blended learning experience. An assignment was designed in 2011 to complement a pre-existing pregnant rat dissection laboratory, and online video resources were introduced in 2013. Both student cohorts achieved similar grades for the assignment overall. Interestingly, students achieved significantly lower grades for the 'Results' section of the assignment compared to all other criterion (both cohorts $P < 0.05$) which may reflect difficulty in the data analysis component of SI. Student perception data, gathered by questionnaire, demonstrated that the students found the assignment interesting (2011: 95% in agreement; 2013: 94%), and intellectually stimulating (89 and 100% respectively). 62% of students revisited the videos to revise laboratory content. Overall, this study suggests that introducing the laboratory-associated assignment led to a deeper understanding of SI, and enhanced student awareness of animal-based research. Furthermore, delivering part of the laboratory content by online videos did not compromise student achievement or engagement, and provided students with a useful revision tool.

Introduction

Scientific inquiry (SI) refers to the utilisation of methods and activities through which scientific knowledge is developed. SI is a continuous process, although it is often categorised into distinct stages for ease of understanding, such as: project design, data collection, data analysis, data interpretation and communication, usually via written publication. Authentic SI, that is, the realistic practice of SI in its entirety, is an effective pedagogical tool that encourages deeper understanding of routine scientific practice (Schwartz, 2004). Indeed, embedding scientific research into the undergraduate curriculum is widely acknowledged as an effective pedagogical tool to enhance the overall undergraduate experience (Lopatto, 2004). Authentic research experience is believed to encourage students to feel more connected to their educational experience (Kinkead, 2003), is associated with increased interest in a career in the science, technology, engineering and mathematics (STEM) workforce (Lopatto, 2004; Zhan, 2014), enhanced retention rate, deeper learning of research skills, a readiness for more challenging obstacles, and learning of transferrable skills such as teamwork, acquiring information, as well as communication and presentation skills (Hunter, Laursen, & Seymour, 2007; Nagda, Gregerman, Jonides, Hippel, & Lerner, 1998; Seymour, Hunter, Laursen, & DeAntoni, 2004; Zhan, 2014)

Although many aspects of SI are practiced over the course of an undergraduate degree, these are often exercised in a dissociated manner. Academic teaching staff at The University of Western Australia (UWA) frequently express concerns that students nearing the completion of their undergraduate degree often do not fully understand the process of scientific discovery. Of equal concern, students of a biomedical discipline seem to have little awareness of the necessity and value of animal-based research to scientists in the biomedical professions, a concern also raised elsewhere (Metzger, 2014).

Advantages of performing animal-based research includes the ability to conduct biological experiments under controlled environmental and genetic conditions, animal studies provide unique insights into the pathophysiology of disease, and allows for testing of treatments for toxicity and safety (Hackam, 2007).

The importance of animal models for understanding human health and disease is emphasised in *Human Reproduction*, a final-year undergraduate unit in the Anatomy and Human Biology major at UWA. A particular emphasis in this unit is placed on using the rat to understand major reproductive parameters; maternal adaptations to pregnancy, fetal and placental growth and development, puberty and the long-term consequences of early life insults. The ability to define questions, acquire skills to address these questions, and critically assimilate, analyse and discuss information are key learning outcomes for this unit. Integral to this, is a laboratory where students dissect pregnant rats at two developmental stages of pregnancy. This laboratory experience is considered important because it facilitates skill acquisition and provides a realistic insight into animal-based reproductive biology research. As originally applied, however, the laboratory only addressed one component of SI; data collection. Students' understanding of the importance of attaining such data were not evaluated, nor were they expected to analyse or present this data once it had been collected. Therefore, in 2011, the aim of the laboratory was revised to provide students with an authentic scientific research experience by prompting students to follow the process of SI. To this effect, an assignment relating to data obtained from the associated laboratory was designed such that students practiced each component of SI. The effectiveness of the newly implemented assignment was evaluated with regard to student perception and achievement.

In 2013, a blended teaching approach was introduced where parts of the laboratory session were converted to an online video. Students watched the initial dissection of a pregnant rat via a high quality video production, and then continued the dissection of fetal-placental pairs in small groups of two or three. Dissemination of content via a digital format is becoming increasingly popular because it offers several benefits to the student learning experience; learners have control over their learning sequence, pace of learning and time allocation, which allows them to tailor their experience to meet personal learning objectives and promotes accountability (Ruiz, Mintzer, & Leipzig, 2006). The introduction of online video resources was also logistically and financially beneficial. In their pre-existing format, the laboratory sessions were associated with costly use of staff, animals, and reagents. By 2013 enrolment in the unit had risen from approximately 40 students per year to 86 with a further doubling in 2014 to a cohort size of 216; consequently it was neither feasible nor ethically justifiable to continue the laboratories in the small-group format. Introducing online resources meant the valuable laboratory experience would continue for future cohorts despite resourcing pressures; class sizes could be increased, staff supervision decreased, and the number of animals sacrificed kept to a minimum.

This paper describes the effectiveness of introducing a laboratory-associated assignment task to a) promote a deep understanding of the SI process and b) promote student awareness of the value of animal-based research. We also evaluate the introduction of online video resources to aid these objectives.

Method

Laboratory activities

Two laboratory sessions were conducted: *Oestrous Cycle and Pregnancy Determination* and *Pregnant Rat Dissection*. The first laboratory is essential to the authenticity of the student experience; data collection for the associated assignment was obtained during the subsequent *Pregnant Rat Dissection* laboratory. In 2011 students attended the laboratory sessions in three separate rotations, and in 2013 in two rotations.

The *Oestrous Cycle and Pregnancy Determination* laboratory allows students to witness how researchers in the field of reproductive biology use the vaginal smearing technique to a) identify oestrous cycle stage and optimal mating period of a female Wistar rat, and b) confirm pregnancy by identification of spermatozoa in the smear. Students are provided vaginal smear slides, and set the task of determining oestrous cycle stage and/or pregnancy status by visual examination of vaginal cells through a microscope.

The *Pregnant Rat Dissection* laboratory demonstrates the dissection of the abdominal cavity of the pregnant Wistar rat at two developmental time-points: mid-gestation (day 16; term = day 23), and late gestation (day 21). These two time-points are chosen because they span the period of maximal fetal growth and placental nutrient exchange function, and as such are commonly used in research relating to placental function and fetal development (Jones, Mark, & Waddell, 2013). The average rat litter consists of 6 to 9 pups, although this varies greatly with stock, strain and maternal age (Suckow, 2005). In 2011, the pregnant dams were dissected and all fetal-placental pairs were removed by an experienced researcher in view of small student groups (12-15 students). From 2013 the students instead watched the dissections via a high quality video production during class which was also made available online (see section Online Video Resources below). The pregnant dams were dissected in a separate laboratory facility and then all feto-placental units delivered to the classroom. For both years, fetal-placental pairs were distributed to student pairs for further dissection and data collection. The forms of data collected included: litter size, fetal weight, placental weight, weight of the two morphologically and functionally-distinct rodent placental zones (labyrinth and junctional zones), fetal length and structural abnormalities. Due to practical and ethical reasons, students were provided part of the required data, and collected remaining data themselves to create a complete data set. All procedures involving animals were conducted under approval by the Animal Ethics Committee of The University of Western Australia.

Toward the end of the laboratory, time was allocated to an interactive discussion regarding how students could analyse the data they had obtained. Discussion amongst peers was encouraged; the tutor played no didactic role.

Online video resources

In 2013, two videos were designed and scripted by UWA staff, and then recorded and produced by Blue Forest Media (Victoria Park, WA, Australia). The first video corresponds with the *Oestrous Cycle and Pregnancy Determination* laboratory activity. This video clearly demonstrates techniques used to determine puberty onset (manual retraction of the prepuce for male and vaginal opening for female), and determination of oestrous cycle stage and pregnancy status in females by vaginal smearing technique. Students watched this video after a brief introduction to the associated laboratory, and were advised that they could access this video via the UWA lecture capture system for the remainder of the semester.

The second video corresponds with the *Pregnant Rat Dissection* laboratory activity. This video demonstrates dissection of the rat abdominal cavity, and compares the uterus of a non-pregnant rat, a pregnant rat at day 16 of gestation, and a pregnant rat at day 21 of gestation. Students watched this video after a brief introduction to the associated laboratory, and were advised that they could access this video via the UWA lecture capture system for the remainder of the semester. Students then dissected fetal-placental pairs, collected data, and received guidance relating to data analysis as described previously.

The assignment

Each component of SI is reflected in scientific journal publications as ‘Introduction’ which reflects the rationale, hypothesis development and project design, ‘Materials and Methods’ which describes data collection, ‘Results’ which reports data analysis, and ‘Discussion’ which reflects data interpretation. Therefore, the assignment was designed such that students were required to collect, present, analyse, and interpret data, and present this in a format suitable for submission to a peer-reviewed journal.

Marks were allocated to each of these defined components (20% per criterion), and for presentation and referencing (10% each).

Assignment submission was due two weeks following the laboratory, and occurred electronically via the UWA learning management system. Feedback was given in the form of in-text comments to students' submitted Microsoft Word documents.

Evaluation

Student achievement was evaluated using the marks awarded for the associated laboratory assignment. Marks for each component of the assignment (Introduction, Methods, Results and Discussion) align with a stage of the SI process, and as such the grades achieved for each component of the assignment acts as a marker for how fluently the students progressed through the SI process required to complete the assignment.

Student perception was evaluated by questionnaire responses. Students for both year groups (2011 and 2013) were administered hard-copy questionnaires during a scheduled class one week after receiving feedback for the assignment. For the 2013 cohort, while all students in the unit (n = 86) completed the laboratory, they then had a choice to complete the subsequent assignment regarding either the pregnant rat dissection laboratory or an alternative laboratory experience regarding endocrinology. All 86 students were administered a questionnaire addressing the laboratory experience. Those students who chose to complete the associated assignment (n = 50) were administered a second questionnaire targeting the assignment experience. Each questionnaire consisted of a series of initial questions to identify potential confounding factors, such as age, laboratory rotation, and prior experience having completed a similar research-based assignment. This was followed by 4-point likert scale questions, with room for 'additional comments.' Written comments were reviewed to provide greater insight into the likert-scale responses, and are described where appropriate. Overall, the questionnaires targeted perceived engagement of the assignment, consequential understanding of the research process and the use of animals, and motivation to continue research after the completion of their degree (Table 1). For the 2013 cohort, additional questions were included that specifically targeted perception of the online video resources. These questions addressed perceived clarity of the videos, and whether they were used as a revision tool (Table 2).

Findings

Average age of the student cohort in 2011 was 20.8 ± 1.5, and in 2013 was 20.5 ± 1.2. Student age did not influence any measured outcomes. The outcomes of this project were considered with regard to student achievement and student perception.

Student achievement

All students enrolled in the unit (n = 33) completed the laboratory and associated assignment in 2011. In 2013, all students enrolled in the unit (n = 86) completed the laboratory; 50 students chose to write their assignment about this pregnant rat dissection laboratory. The average marks for the associated laboratory assignment did not differ significantly between 2011 and 2013 cohorts (73% ± 15% and 66% ± 14% respectively). Marks also did not differ by laboratory rotation in either year group suggesting consistency was maintained between laboratory rotations. Both year groups received significantly lower marks for the 'Results' section compared with all other criterion ($P < 0.05$ for each year group; Figure 1), with the marks in 2013 being lower still than the 2011 cohort (20% lower; $P < 0.05$). This may reflect a difficulty in the data analysis component of SI. Accordingly, student written comments reflected an appreciation for the data analysis discussion conducted during the laboratory, or a request for even more guidance (4 of 8 written responses to the assignment-experience questionnaire).

I found the short info session on stats at the end of the lab really helpful too. It made the data analysis much less stressful than previous reports.

More guidance on the hypothesis/stats that we were supposed to run.

I thought the research report was a good assessment. The only problem I had was writing the results I wasn't really sure what to do/write so unsurprisingly I didn't do well in that section so maybe a bit more direction in that area but otherwise I thought it was good.

I had trouble with the stats so a video helping with that would be good. Otherwise the lab report was good.

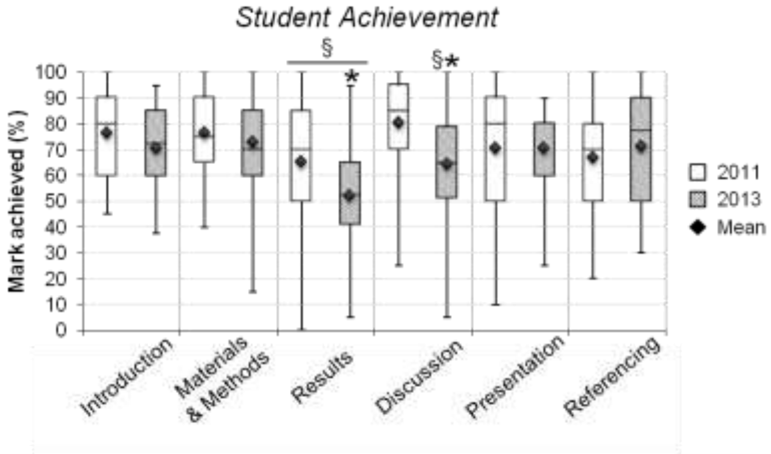

Figure 1: Marks achieved for each component of the assignment for the 2011 and 2013 cohorts
(pooled laboratory rotations; n = 33 for 2011, n = 50 for 2013)
* $P < 0.05$ compared to 2011 value for same criterion; § $P < 0.05$ compared to all other criteria
(One-way ANOVA blocking for 'student,' *post poc* LSD test)

The 2013 cohort also received lower marks for the 'Discussion' criterion compared to the 2011 cohort (20% lower; $P < 0.05$), which may suggest this cohort of students experienced difficulty in the data interpretation component of SI.

Student perception

In 2011, 19 students responded to the student perception questionnaire (58% response rate). In 2013, 62 students responded to the questionnaire regarding the laboratory experience (70% response rate), and all 50 students who completed the associated assignment responded to the questionnaire regarding the assignment (100% response rate). A majority of students (84% and 81%, 2011 and 2013 cohorts respectively) indicated they had done a similar type of assignment previously. This suggests that the process of SI is being practised within science disciplines, although does not discern whether these experiences are authentic.

Student engagement and perceived learning
Students from the 2011 cohort found the assignment engaging, with 95% of students in agreement that the assignment was interesting, and 89% in agreement that the assignment was intellectually stimulating (Table 1). In 2013, students equally found the associated assignment interesting (94%) and intellectually stimulating (100%). Importantly, this suggests that introducing the online video format did not compromise student engagement with the laboratory or associated assignment, and indeed may suggest student engagement was enhanced. Despite this, fewer students in the 2013 cohort found the assignment and associated tasks to be delivered in a logical manner (20% fewer students in agreement compared to 2011; Table 1). It is unclear why this perception arose in 2013, although it is possible that introducing the online video resources may have caused some students confusion and discomfort if they had not experienced a blended-teaching approach previously.

Notably, both year groups felt they had a greater understanding of the research process from having completed the assignment (73 to 84%) suggesting that its introduction promoted a greater depth of understanding about the SI process. Given this response it is perhaps surprising that when queried as to whether the laboratory session had motivated students to consider a future in scientific research responses were more varied, with only 33% of students in 2011 and 56% in 2013 in agreement with this statement (Table 1). It is important to note, however, that the purpose of embedding a research-based project within the curriculum extends beyond encouraging students to continue down a research pathway. Indeed, undergraduate research experience is acknowledged as a way to make students feel more connected to their educational experience (Kinkead, 2003).

The large majority of students also found the organisation and delivery of the laboratory and assignment appropriate, agreeing that the assignment and associated tasks were delivered in a logical manner (80 to 100%), the weight of the assignment was appropriate (75 to 84%), and that the feedback received was adequate and helpful (95 to 100%; Table 1).

Table 1: Student response (percentage) to questionnaire statements regarding the assignment
These statements were asked of students in both the 2011 (n=19) and 2013 (n = 50) cohorts.
SD = Strongly Disagree; D = Disagree; A = Agree; SA = Strongly Agree

	2011				2013			
	SD	D	A	SA	SD	D	A	SA
I found the assignment interesting	0	5	74	21	0	6	75	19
I found the assignment was intellectually stimulating	0	11	73	16	0	0	88	12
The assignment and associated tasks were delivered in a logical manner	0	0	68	32	7	13	73	7
The weight of the assignment was appropriate	0	16	63	21	0	25	63	12
I have a greater understanding of the ‘research process’ as a result of this assignment	0	16	74	10	0	27	67	7
I found the feedback provided on my ‘Research Report’ adequate and helpful	5	0	53	42	0	0	81	19
Completing this assignment has motivated me to consider research when I finish my degree	0	67	33	0	6	37	56	0

Student perception of the use of animals

For both student cohorts, the large majority of students (92% to 95%) believed the sacrifice of animals to be a useful aid to their learning (Figure 2). Moreover, all students felt that the use of animals during the laboratory was conducted in an ethical manner. This suggests that students recognised that animal-based research is valuable, and justifies the use of animals for this authentic scientific learning experience. Importantly, student responses were similar for 2011 and 2013, which suggests that the implementation of the online video resources did not compromise students’ understanding of animal-based research. Written comments from students commended the use of video resources to reduce the sacrifice of animals.

> I think the use of video is well worth the benefits of not killing more animals unnecessarily.
> I think it’s good that we don’t have to sacrifice too many animals. The video was good.
> Personally we could have learnt more doing the dissection ourselves BUT for the number of rats we’d be required to use to do each one would be unethical when we can do it via videos. I think this is the best way to do it.

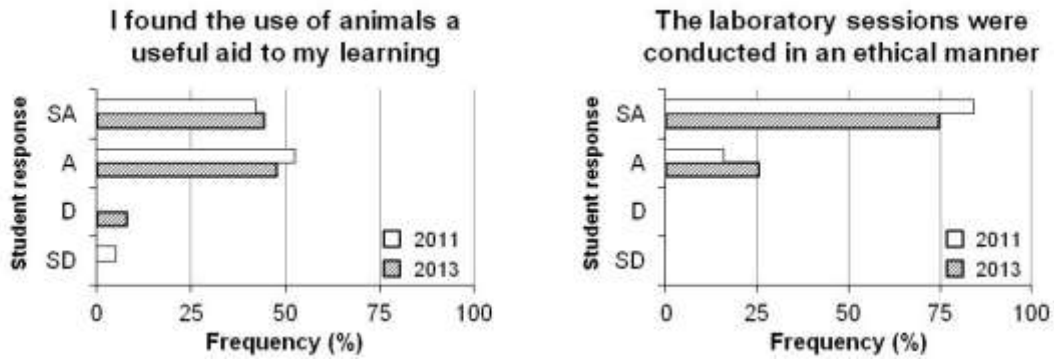

Figure 2: Student response to the statements 'I found the use of animals in the laboratory a useful aid to my learning' (left) and 'The laboratory sessions were conducted in an ethical manner, with due regard paid to ethical issues' (right)
Pooled laboratory rotations; n = 19 for 2011, and n = 62 for 2013
SD = Strongly Disagree; D = Disagree; A = Agree; SA = Strongly Agree

Student perception of the online video resources
Student comments reflected an understanding of the benefits of having the video resources in a large class size, for example;

> Everyone had a clear view of the dissection on the video which would have been impaired if rat dissection was demonstrated in person.
> Really liked the videos. Everyone could see the dissection which was really good.
> Videos were both very informative and simplified key ideas. Everyone had a clear view of the dissection on the video, which would have been impacted if rat dissection was demonstrated in person.
> The dissection video was well put together – I think that this allowed the whole class to view the dissection process clearly.

62% of students claimed they had revisited the videos after the laboratory, indicating the video resources were a useful revision tool (Table 2). All students felt both videos were presented in a logical manner, and the large majority agreed that both videos presented important techniques clearly (95-97%; Table 2). Indeed the video allowed inclusion of other techniques and features (determining puberty onset and comparison of non-pregnant and pregnant states) that were not able to be demonstrated in the original laboratory format because this would require sacrifice of additional animals for each laboratory rotation. Written comments also emphasised this perceived clarity and detail of information disseminated by the videos.

> The videos were really clear, logical and easy to understand.
> I like that the videos were very explanatory. I think I learnt more from them than I would if just doing dissection (with no clue what I was doing).
> I thought the videos were very clear and concise in explaining rat pregnancy and puberty.
> The video was extremely helpful in my understanding of the lab.
> Videos are very easy to follow and provide clear information, but a hands on experience is always welcome.
> I think the videos are very informative.
> I believe the video was so informative that there was no room to learn more during the lab.

Introduction of the online video resources was deemed successful, as demonstrated by comparable student learning (marks achieved), and perceived student engagement parameters. Despite this, 47% of students believed they would have learnt more from the laboratory session should they have observed a live rat dissection, and 71% felt that they would have benefited from performing the rat dissection themselves (Figure 3). Although students of this cohort received comparable grades for their assignment, it seems they perceived their 2011 counterparts who witnessed a live pregnant rat dissection to have received a more valuable learning experience.

Table 2: Student response (percentage) to questionnaire statements regarding the online video resources (2013 cohort only; n = 62)
SD = Strongly Disagree; D = Disagree; A = Agree; SA = Strongly Agree

	SD	D	A	SA
The video used to demonstrate rat *Puberty, Oestrous Cycles and Pregnancy Determination* was delivered in a logical manner	0	0	30	70
The video used to demonstrate rat *Puberty, Oestrous Cycles and Pregnancy Determination* demonstrated techniques clearly	0	5	33	62
The video used to demonstrate the *Pregnant Rat Dissection* was delivered in a logical manner	0	0	38	62
The video used to demonstrate the *Pregnant Rat Dissection* demonstrated techniques clearly	0	3	41	56

	No	**Yes** (total = 62)		
		Both videos	**'Puberty' video only**	**'Dissection' video only**
Did you re-watch either of the videos outside of doing the associated laboratories?	37	25	12	25

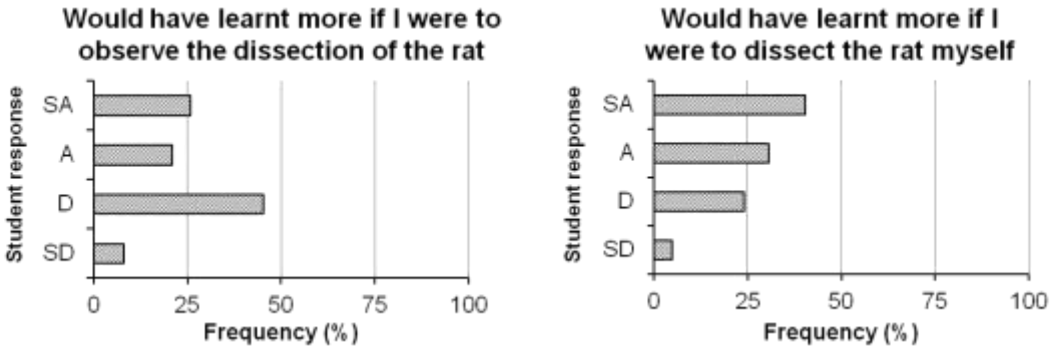

Figure 3: Student response to the statements 'I feel I would have learnt more from the laboratory if I were to observe the dissection of the rat, rather than watching it on a video' (left) and 'I feel I would have learnt more from the laboratory if I were to dissect the rat myself, rather than watching it on a video' (right) Pooled laboratory rotations; n = 62

Conclusion

This study described the introduction of an assignment that utilises data collected by students during an animal-based laboratory session. The assignment was structured such that students practiced all elements of SI, which is considered an essential characteristic of scientific literacy. This exercise successfully prompted students towards a better understanding of the scientific process, and also encouraged students to consider the necessity of animal-based research in biomedical practices. Indeed, students expressed recognition that using animals in this context was a useful aid to their learning, and as such the use of animals is justifiable in certain situations. They also acknowledged that animal-based research can be, and indeed was, conducted in an ethical manner.

This study also described the introduction of online video resources to replace part of the associated laboratory session. This introduced a blended laboratory experience, and also served to alleviate some of the logistical, financial and ethical burden of the laboratory. It was expected that the introduction of these videos would enhance the student experience by enabling students to prepare for the laboratory session and revise what they had learnt outside of class time. Indeed, the majority of students claimed they took advantage of these video resources to use as revision tool. Student learning (measured by assignment grades) and perceived student engagement parameters were comparable between those students who witnessed an animal dissection first-hand and those who viewed this via video resources. This suggests that the videos maintained student achievement and engagement, while also introducing a learning resource that will be of value to all future cohorts.

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