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Discussing the use of animal models in biomedical research via role play simulation

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Abstract

Educational institutions have a responsibility not only to provide a solid theoretical background on scientific phenomena, but to also frame them within the wider social context and highlight their numerous ethical implications. It is fundamental that tomorrow's scientists be encouraged to develop an informed and critical approach towards scientific issues that, as in the case of animal experimentation, bring undeniable advantages to our society while carrying highly controversial moral implications. However, despite the considerable social and scientific relevance of the use of animal models in biomedical research, there is a scarcity of scholarly literature exploring the topic from a pedagogical standpoint. The case study presented in this paper aims to investigate the effectiveness of role play simulation in promoting critical understanding of the use of animal models in biomedical research and its ethical implications. A simulation was set up in which first year undergraduate students took the role of delegates to a conference purportedly organised by the United Nations Ethics Office. The simulation included two electronic voting sessions, an open debate, and a keynote lecture. Post-session feedback indicated that most students found the simulation more engaging than a conventional lecture. A comparison of self-assessment questionnaires compiled at the start and at the end of the session indicated that students' understanding of, and confidence in, the topic of animal experimentation had considerably increased after taking part in the simulation.

Keywords Animal experimentation · Role play simulation · Bioethics pedagogy · Animal models · Animal testing · Biomedical research

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"Shall I refuse my dinner because I do not fully understand the process of digestion?"

- Oliver Heaviside, Electromagnetic Theory, 1899

Introduction

Social role of scientific progress

Over the course of history, scientific research has played a fundamental role towards improving the welfare of the population as well as its social, economic, and intellectual prosperity. While it is widely acknowledged that advances in our understanding of the natural world have brought countless benefits to individuals and society as a whole, the scientific process is by no means exempt from profound ethical implications (Shrader-Frechette 1994). As Bertrand Russell poignantly remarked in The Impact of Science on Society, "we are in the middle of a race between human skill as a means and human folly as an end" (Russell 1976). As the tragic events of the last century have clearly indicated, scientific progress should not be seen as beneficial per se, but rather in the light of its impact on society (Brumfiel 2012). Hence, the academic and professional formation of future scientists cannot prescind from a thorough and informed understanding of the ethical implications of the scientific process.

The social role of scientists and science itself has recently hit the limelight in media headlines and political discussion. The last decade has witnessed an increased feeling of scepticism towards science, often fuelled by political agendas and amplified by online "echo chambers". While it would be tempting to brush aside movements such as "flat earthers", "anti-vaxxers", and "climate change denialists" as nothing more than "tin-foil-hat conspiracy theorists", the affirmation of such beliefs in popular culture is a symptom of a much wider issue affecting the public perception of science and its communication to lay audiences (Lewandowsky et al. 2013). While pinpointing the causes of this phenomenon is a challenging undertaking due to its multifactorial nature, it is reasonable to suggest that the infamous proliferation and diffusion of "fake news" cast a shadow on the objectivity of scientific facts (Lazer et al. 2018). Moreover, with the affirmation of populist movements across the international political panorama, scientists are often identified as scapegoats to blame for the current uncertain economic climate, and as allied to the "powers that be", scheming at the detriment of the common folk (Hartleb 2011).

The debate is particularly heated with regard to scientific topics such as (to cite a few) human cloning, compulsory vaccination, genetic modification, climate change, and animal testing, where the perception of the scientific fact is often filtered through pre-existing ideological and religious values (Nisbet and Goidel 2007). A common leitmotif among controversial science topics is that they tend to elicit "knee-jerk" emotional reactions within the general population and have therefore a highly polarising effect, whereby detractors and backers of a certain thesis progressively entrench into less compliant positions, often ignoring any evidence that does not support their own stance (Kaptchuk 2003). Recent events such as the emergence of

measles outbreaks caused by the (now widely disproved) popular belief of a causative link between childhood vaccination and autism further highlight the dramatic importance of promoting scientific literacy amongst the general population (Liu 2009; Mavragani and Ochoa 2018). In that respect, it is fundamental that scientists and scholars fully understand the wider implications of their research and ensure that it is communicated to non-specialised audiences in a transparent and accessible fashion.

Animal experimentation and its ethical implications

The use of animals as experimental models for the study of anatomy and physiology dates as far back as the study of natural sciences. The structural and functional similarities between the human body and that of other vertebrates were well acknowledged by physicians in ancient Greece, where the practice of vivisection and dissection of animals (and, notably, convicted criminals) were commonplace in medical science (Franco 2013).

Due to the prevalence of a fundamentally anthropocentric view of nature, there is no evidence of any moral concerns linked to the use of animals as test subjects in ancient Greek and Roman literature. The idea of a hierarchically ordered natural world where humans held a privileged position due to their physical and intellectual likeness to the gods, filtered in the light of Plotinus' metaphysics, contributed to shaping the Judeo-Christian view of humanity as the centre of all creation (Prioreschi 1994). Although cruelty towards animals was occasionally condemned in the work of Thomas Aquinas, this was not due to consideration of animals as sentient beings, but rather on account of their belonging to God's creation or being another human being's property (Aquinas 1955). After a centuries-long hiatus, arguably ascribable to the affirmation of Scholasticism in Western philosophy and consequent dogmatisation of the study of natural sciences, animal experimentation resurfaced in the Renaissance period. Early empiricists such as Leonardo da Vinci and Francis Bacon showed a renewed interest in the use of vertebrates as models of human anatomy and physiology. Interestingly, da Vinci challenged in a few occasions the dominant view of animals as intrinsically inferior to human beings, further demonstrating a breadth of views arguably ahead of his time (Jones 2011). The issue of the ethical treatment of animals did not fully emerge in scholarly discourse until the seventeenth century and the dawn of the Enlightenment period. In his 1677 philosophical treatise on ethics, Baruch Spinoza wrote: "Still I do not deny that beasts feel: what I deny is, that we may not consult our own advantage and use them as we please, treating them in the way which best suits us; for their nature is not like ours, and their emotions are naturally different from human emotions" (Spinoza 1997). The notion of the ethical treatment of animals was formalised in its modern acceptation by Jean Jacques Rousseau, who stated in his Discourse on Inequality: "mankind is subjected to a kind of obligation even toward the brutes. It appears, in fact, that if I am bound to do no injury to my fellow-creatures, this is less because they are rational than because they are sentient beings and this quality, being common both to men and beasts, ought to entitle the latter at least to the privilege of not being wantonly ill-treated by the former" (Rousseau 1984).

The concepts laid out by Enlightenment philosophers constitute the foundation of modern discourse and legislation on animal rights, which remains to this day a highly controversial topic amongst scholars and policymakers alike. The last century has also

seen the widespread diffusion of the controversy on the ethical use of animals, and the emergence of animal right activism among the general population. While the popularisation of the discourse on this topic should not bear negative connotations per se, there are significant concerns linked to the rise of extremist fringes within animal rights activist movements. As described in a 2011 Nature editorial, up to one third of researchers report having "been negatively affected by animal-rights activists", and witnessing "fire bombings, physical attacks, destruction of personal property and campaigns of harassment" related to their line of work (Animal rights and wrongs 2011).

The Nature editorial underlines the key role of scientific outreach and clear communication in order to dispel misconceptions and promote a less emotionally burdened, more rational view of the use of animals in research. Moreover, research institutions should implement and uphold strict and transparent standards in terms of animal experimentation (Gauthier and Griffin 2005), and strive whenever possible to "replace animals with more sophisticated research tools, refine research practice and reduce the overall number of animals used", an approach typically referred to as "the three Rs" (Animal rights and wrongs 2011).

It is widely acknowledged that the academic formation of future scientists should provide them with an extensive understanding of the use of animal models in biomedical research and its ethical implications (Festing and Wilkinson 2007). A deep knowledge of the biological phenomena related to the use of model organisms is fundamental towards the design and implementation of new strategies to reduce, replace, and refine the use of animals for biomedical research (Tannenbaum and Bennett 2015). However, knowledge of scientific phenomena should not be the sole focus of bioscientists' academic formation; it is essential that their training include a thorough evaluation of the social and moral implications of scientific research, as well as appropriate instruments to effectively communicate scientific findings and foster scientific literacy among the general population (Hurd 1998; Liu 2009).

Use of role play simulations in higher education

The pedagogic effectiveness of active learning techniques is widely established across all subjects and age groups (Silberman 1996). It has been argued that, while traditional lecture-based university teaching is an effective mean for students to assimilate key notions, it "encourages student to concentrate on superficial indicators rather than on fundamental underlying principles, thus neglecting deep (active) learning" (McCarthy and Anderson 2000).

Role play simulations have been extensively used as active learning tools to promote higher forms of thinking and learning in an academic context. Within the pedagogical context, role play has been defined as "a drama in which each participant is assigned a character to portray, but no lines are learned. The individuals portraying specific roles improvise their responses in a situation – a situation that presents a problem or conflict" (McKeachie and Svinicki 2013). There is large overlap between the expressions "role play" and "simulation", which are often used interchangeably in pedagogical literature; it has been

suggested that the two are conceptually akin, but different in duration, with "simulation" generally referring to longer and more structured activities (Bonwell and Eison 1991). The learning episode described in the present study contains elements of both role play and simulation, in the sense that students were assigned a role and asked to respond to a situation (which in McKeachie's definition constitutes role play) within the context of a simulated, semi-structured environment. Kristina DeNeve previously described a similar approach as "role play simulation" and extensively evaluated its effectiveness in comparison with traditional teaching strategies, reporting that students tended to "remember more information from the role play simulations than from the lectures" (DeNeve and Heppner 1997).

Over the last decade, several studies have reported the successful use of role playing in science education (Howes and Cruz 2009). Pedagogic strategies based on role playing and simulations are ideally suited to the teaching and learning of natural sciences in that they foster critical thinking and promote teamwork, both of which are critical aspects of the academic and professional formation in those disciplines. While the importance of frontal lectures in the accurate delivery of theoretical concepts within all scientific subjects is undeniable, role playing and simulations can be used to contextualise those concepts and promote a deeper understanding of their practical and ethical implications. This is especially important in "practice-oriented" subjects such as pharmacy or nursing, where knowledge of scientific phenomena generally represents the theoretical scaffold underpinning their application in professional practice (Vyas et al. 2012); in that sense, role playing and simulations allow students to contextualise theoretical learning and strengthen practical skills in a safe environment (Broussard 2008).

To date, scholarly literature on the use of role play and simulation in the teaching of bioethics is relatively scarce, and mostly focused on their application in medical practice (e.g. doctor-patient interaction) rather than "pure" biomedical research (Mitchell 1998). Despite its high scientific, ethical, and social relevance, very little research has been published on the issue of teaching animal experimentation, and an even smaller number of sources describe the use of role playing as a pedagogical tool in this context (Agell et al. 2015).

Case study design

The teaching episode described in this study took place in the context of the level 4 unit "Introduction to Cell Biology and Biochemistry", part of the Biology, Biochemistry, and Marine Biology degree courses at the University of Portsmouth (UK). This core unit is designed to provide first year students with a wide background on key biomolecules and on their structure and function within the cellular context. The unit culminates with a tightly-knit sequence of three lectures designed to combine the notions acquired earlier on towards the understanding of more complex biological topics, namely stem cells, cell differentiation, and use of animal models in biomedical research.

A simulation was set up in which students took the role of delegates taking part in the "Conference on the use of animals in biomedical research",

purportedly organised by the United Nations Ethics Office. The session involved a first round of votes, where students were asked to answer the question "Do you think animals should be used as test subjects in biomedical research?" and justify their answer. At this stage, students were also asked to self-assess their confidence on the topic of animal experimentation using a Likert-type scale.

Following the first round of votes, students were invited to take part in an open debate using roles they were assigned by the lecturer. Regardless of their personal stance on the matter, students sitting on one side of the lecture theatre were assigned the role of delegates in favour of animal testing, and students sitting on the other side were assigned the role of delegates against animal testing. Asking students to defend a stance that might not correspond with their views on the issue was a deliberate pedagogical choice aimed at encouraging students to consider the multifaceted nature of the topic, and evaluate the rationale behind a standpoint they did not necessarily agree with.

The debate was followed by a "keynote lecture", in which the conference chairperson (played by the lecturer) gave a detailed account of the scientific aspects of the choice and use of animal models in biomedical research and presented an impartial overview of its ethical implications. During the lecture, particular emphasis was given to the description and evaluation of the logical arguments underpinning both sides of the controversy.

The last activity of the session was a second round of votes, where the students were asked to answer again the same questions presented in the first round. At this stage, students were also asked to evaluate the effectiveness of the learning episode by indicating which part of the session they found more useful (debate, lecture, both of them, none of them) and justifying their answers.

As was described in a previous paper, "bring your own device" (BYOD) strategies are deeply embedded in the teaching, learning, and assessment of this unit (Siani 2017). For the present study, the Nearpod software was used as both a "voting system" during the simulation and a mean to collect anonymous answers and opinions from the students. Out of the 173 students enrolled in the unit, 100 chose to take part in the study by answering the questions via Nearpod.

Results

As described in the previous section, students' answers and opinions were collected at the start and at the end of the teaching episode to allow an evaluation of its didactic effectiveness.

At the start of the session, the majority of participants (57%) expressed a favourable opinion on the use of animal experimentation in biomedical research, 35% expressed an unfavourable opinion, and 8% chose to abstain (Fig. 1). A similar, albeit more pronounced, trend was observed in the second round of votes, where the share of favourable opinions rose to 73%, unfavourable opinions decreased to 23%, and abstention dropped to 4%. Table 1 shows representative examples of students' justification of their pro- or against animal

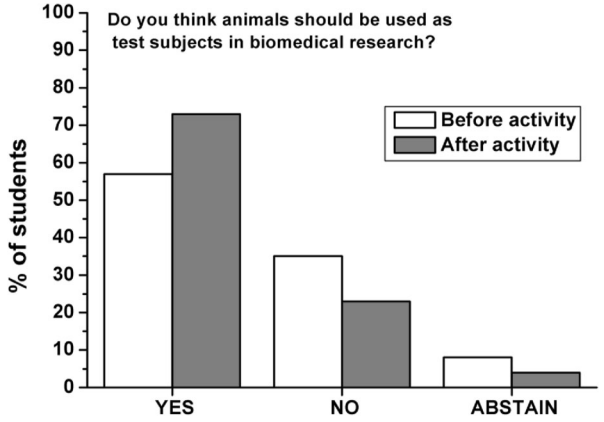

Fig. 1 Quantitative representation of students' answers to the question "Do you think animals should be used as test subjects in biomedical research?" Students' answers were collected at the start ("before activity") and at the end ("after activity") of the session

experimentation stance. The most frequently adduced explanation in favour of animal testing involved references to animal experimentation as a "necessary evil" towards the improvement of human condition. Several students who expressed an unfavourable opinion on the use of animal models were very vocal on the issue of consent, whereby animals "haven't got a choice whether or not they are tested on". Some students also raised the issue of the relevance (or lack thereof) of experimental results obtained from animal studies and their applicability to human physiology. These key points in favour and against animal testing also constituted the core of the discussion in the open debate, and were further articulated by students as part of the argument in defence of their assigned positions.

Students were asked to quantitatively self-assess their confidence on the topic of animal testing using a 7-points Likert scale; Fig. 2 shows the distribution of students' answers obtained during the two rounds of votes. At the start of the session, 52% of the students' answers were in the 1–3 range (indicating poor confidence in the topic), and only 24% in the 5–7 range (good confidence). A clear distribution shift could be observed in the second round of votes, with only 10% of students in the 1–3 range, and 74% in the 5–7 range.

Before leaving the lecture theatre, students were asked to evaluate the effectiveness of the session both quantitatively and qualitatively. As shown in Fig. 3, the vast majority (76%) of participants declared that "it is a good idea to have both the debate and the lecture; 22% answered that they would "rather just have the lecture", and a much smaller percentage (1% in both cases) "would rather just have the debate" or "did not find the activities useful". Most students expressed positive opinions (Table 2) on the session and particularly appreciated the synergy between the lecture, useful to "learn the hard facts about the topic", and the debate, which "allows you to hear

Table 1 representative answers to the questions "Do you think animals should be used as test subjects in biomedical research?" (answers shown in bold) and "Justify your choice". Students' answers were collected at the start ("before activity") and at the end ("after activity") of the session

	Before activity	After activity
Student A	**NO.** Because they shouldn't be used for human benefit.	**NO.** Still causes them unnecessary harm and distress and many animals don't have a body plan or a metabolism similar to humans so results obtained aren't viable or representative of humans.
Student B	**YES.** To make as much progress as possible.	**YES.** Because some animals are closely related to humans and conducting certain experiments on them could be beneficial to, for example drug development.
Student C	**NO.** Human beings do not have the right to cause prolonged suffering to animals who have no opportunity to deny experimentation.	**YES.** While not ethical, and sometimes horrific, animal testing is crucial for the development of many lifesaving medicines that cannot be tested or analysed in any other way.
Student D	**NO.** There are ways to grow tissues/organs for research use.	**YES.** For now it seems to be the most reasonable and most informative way of testing. Human volunteering, however, should definitely be an option before deciding to experiment on animals because animals can't choose whether or not to become a test subject, while humans are able to make that decision.
Student E	**NO.** I just don't think they should go through the pain, they haven't got a choice whether or not they are tested on	**NO.** Even though they may be useful in biomedical research, I am an animal lover and I don't agree with causing any kind of pain on animals.
Student F	**YES.** Humans > Animals	**YES.** At this moment in time animal testing is still our only truly viable option. When a better alternative is available and viable we should switch immediately.
Student G	**YES.** Without animal testing, you can't test the safety of medication. This should be done before human testing.	**YES.** They should be used as a last resort for medical testing. Other methods should be used before. Make sure animal living conditions are good and try and reduce pain.

both sides of an argument and challenge your own point of view on the subject". Unsurprisingly, students expressed contrasting opinions on the pedagogical use of debates: while some participants praised the role of debate in

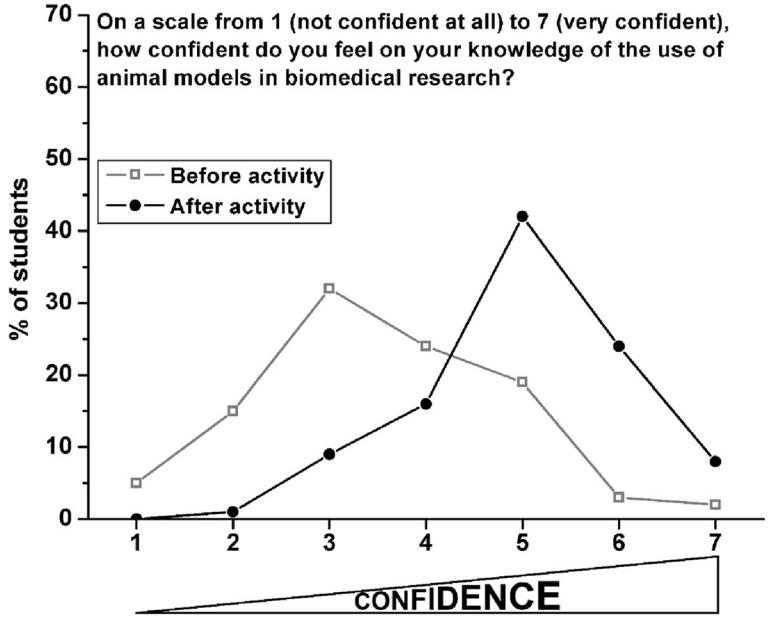

Fig. 2 students' self-assessment of confidence on the topic of animal experimentation. The graph shows the distribution of students' answers to the Likert-type question before and after the teaching episode

boosting confidence and promoting engagement, others expressed a preference for a more frontal teaching style ("I'm not a good public speaker so I wouldn't want to participate hence would prefer the lecture where I can make notes").

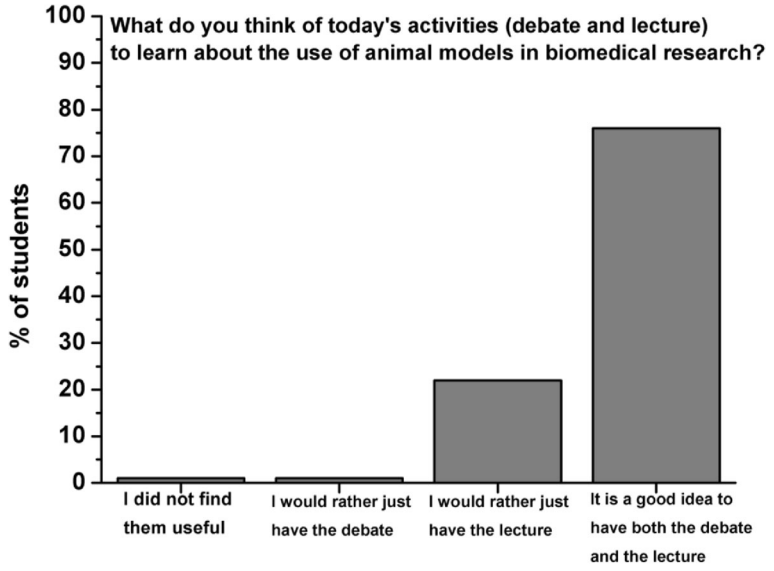

Fig. 3 quantitative representation of students' evaluation of the didactic effectiveness of the teaching episode. The answers to this question were collected at the end of the session

Table 2 representative statements showing students' opinions on the teaching session

The lecture is important to understand the subject being discussed, but the debate is good as you can hear other people's opinions that may not be considered in the lecture.
The debate allows you to hear both sides of an argument and challenge your own point of view on the subject in question. The lecture allows you to develop a deeper understanding on the subject in question and you can then use this knowledge to further question your standpoint.
I'm not a good public speaker so I wouldn't want to participate hence would prefer the lecture where I can make notes.
Getting people to engage in science is important. Many students lack confidence - this style breeds debate which is good.
Other people shared ideas that I'd never thought of before which almost changed my original opinion.
Better than just sitting and listening because that gets boring. Varied activities keep me more engaged.
Engaging in conversation kept your mind focused on the subject and it was somehow easier to take in the information.
The debate is very interactive and it stimulates your arguing capacity. It also stimulates your thinking and makes you understand who you are as a person, in the way you always have a side you fall into. It enriches you as a communicative scientist. However, the lecture should not be skipped because it brings knowledge and information one might not be aware of. It is always necessary to know about a topic if one is going to discuss it.
The debate shows us what different people think of the topic, but there should also be a lecture so we can learn the hard facts about the topic.

Discussion and conclusions

The present study sought to investigate three key hypotheses: 1) whether role playing simulation could be used to increase students' engagement with the topic of animal experimentation, 2) whether increased engagement would result in improved understanding of its scientific and ethical implications, 3) whether this teaching strategy would ultimately reinforce students' confidence with regard to the topic.

The session evaluation carried out at the end of the episode indicated that students were well engaged with the teaching activities described in this study and expressed overwhelmingly positive opinions on them, therefore confirming the first hypothesis of the study. Notably, several participants recognised the metacognitive value of the activities, and reported that the combination of frontal (lecture) and interactive (debate) teaching allowed them to reflect on their own learning and make connections between different concepts that had been taught. These findings are consistent with previous observations that role playing and simulations "promote working in groups, usually generate high levels of motivation and enthusiasm, provide credit for personal initiative, and can run parallel to lectures that explicate the material and issues under consideration" (Bonwell and Eison 1991).

In a recent Ipsos MORI survey, 71% of participants agreed with the statement "I can accept the use of animals in scientific research as long as there is no unnecessary suffering to the animals and there is no alternative" (Attitudes to animal research in 2016). In the present study, a considerably lower share of participants (57%) gave a positive reply to the question "Do you think animals should be used as test subjects in biomedical research?" in the first round of votes. While the discrepancy might be attributable to the smaller sample size used for this study, it is worth mentioning that the Ipsos MORI question clearly described the conditions

under which animal testing would take place by specifying "as long as there is no unnecessary suffering to the animals and there is no alternative". Interestingly, the results of the second round of votes in the present study returned a strikingly close fig. (73%) to the national average. A tentative explanation could be that the information delivered during the lecture might have dispelled the original ambiguity of the question by clearly describing the standards under which laboratory animals are maintained and used, resulting in more participants willing to express a favourable opinion on animal experimentation.

Regardless of the initial stance of the students, and whether their opinion changed after the session, open answers collected in the second round of votes showed clear evidence of increased awareness of the scientific and ethical complexity of the topic compared to the first round, thereby supporting the second hypothesis of this study. For some students (e.g. Table 1, students A and B) the increased understanding of the topic was reflected in a more articulate argumentation of the same position; for others (e.g. Table 1, students C and D) it resulted in a change of stance, whereby students remarked that, if conducted appropriately, the benefits of animal experimentation might outdo its disadvantages. The opposite phenomenon (i.e. students voting in favour of animal testing in the first round, and against in the second round) was not observed amongst the participants in this study.

At the start of the session, the majority of participants self-assessed as having poor or very poor confidence on the topic of animal experimentation. This should not be seen as an unexpected outcome: while the matter of ethical treatment of animals is often discussed in schools within the context of Religious Education, Citizenship, or PSHE (personal, social, health and economic) classes, the topic is not part of the UK secondary science curriculum (Reiss 2011). By the end of the session described in the present study, the vast majority of students self-assessed as being confident or highly confident on their knowledge of the use of animal models in biomedical research; these results confirm the third hypothesis, indicating that role playing simulation can be an effective pedagogical tool to bolster students' confidence towards this complex biological topic and its ethical implications.

While debates are nowadays frequently used as pedagogical tools in primary and secondary education, they usually imply the argumentation of each student's own point of view on a certain topic. In order to avoid ideological entrenchment and promote a more objective analysis of the matter, participants in the present study were assigned a stance that did not necessarily match their own. This strategy allowed the integration of a role reversal element in the session, whereby students might have to abandon their own personal viewpoint and defend an argument they disagree with, being thereby pressed to explore the wider complexity of the topic. Student feedback on the session indicated that the debate was perceived as engaging and stimulating by the majority of participants, however it is important to be aware that students with a more intrapersonal/solitary learning style might not fully benefit from this teaching strategy (Bromley 2013). The latter observation further reinforces the idea that a pedagogically effective approach should involve a variety of teaching strategies suited to cater for a wide spectrum of active and passive learning styles.

It was previously observed that "active learning techniques are more effective for achieving some goals, while lectures are more effective for achieving other goals. […] Lectures address the goal of helping students gain a body of knowledge which

can then be integrated with other material and applied to new situations. In this way, perhaps lectures provide basic information that active learning techniques then utilize in a more critical fashion" (DeNeve and Heppner 1997). The results of our study indicate that active and passive learning strategies can be integrated in a pedagogically coherent fashion within the context of a role play simulation; this approach showed a very promising potential from both a cognitive and metacognitive standpoint, and its implementation had a clear positive impact on students' engagement with, understanding of, and confidence in, the scientific and ethical aspects of animal experimentation.

Compliance with ethical standards The study was conducted in accordance with the University of Portsmouth research ethics regulations. All students were informed that participation in the study was voluntary, that answers would be collected anonymously, and that participants had the right to withdraw from the study if they wished to. Students were also informed that participation in the study would have no impact on the regular teaching and assessment of the unit, as they could anonymously opt out from the study and still take part in the whole didactic activity.

Conflict of interest statement The author states that there is no conflict of interest.

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