Antibiotics in livestock: introducing in-service teachers to the nature of contemporary socio-scientific controversies

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Abstract This article presents an experiential activity organised around a contemporary socio-scientific controversy about the use of antibiotics in livestock. Such controversies can help students develop skills to engage in evidence-based discussions about modern societal challenges. Even though the activity was initially set up and tested with in-service science teachers, it can be customised so that it is appropriate for use with secondary school students. The goal of the activity was to help teachers appreciate how different stakeholder opinions give rise to controversy, and for them to experience how students might engage in democratic dialogue with others, while respecting their right to hold differing viewpoints.

The importance of socio-scientific controversies in the science education curriculum

Citizenship education features in many curricula around the world, including those of the UK and the USA, and is considered important as a means to understand how society is governed and how to become politically empowered. As science and technology spearhead modern economic growth, understanding the complexities of socio-scientific topics, and being able to reason from evidence, are salient characteristics of a responsible citizen. This approach is also fundamental to the PARRISE (see *Acknowledgements*) socio-scientific inquiry-based learning (SSIBL) pedagogical framework (Levinson, 2018), as SSIBL is built on the synergistic operation of inquiry-based learning, socio-scientific decision-making and active citizenship. The inclusion of socio-scientific controversies in the science curriculum signifies a departure from traditional science teaching that usually avoids discussion of ill-structured, open-ended topics. Levinson (2006) suggests that a controversial issue cannot be easily resolved because of the existence of contradictory evidence and multiple stakeholders, who have differing points of views stemming from different beliefs, values, interests and interpretation of available evidence. In contemporary societies, ambivalent issues with the above characteristics are becoming increasingly common and, as such, students should be inducted in how to critically approach them.

Levinson (2006) presented an epistemological model on how to approach controversial issues in the science classroom. This model has three strands:

- a reasonable disagreement (or what we call in this article the controversial socio-scientific issue);
- nine characteristics of discourse when discussing such controversies, which Levinson calls '*communicative virtues*' (such as patience, tolerance, respect for differences, thoughtful listening, etc.);
- modes of thought (such as discourse based on scientific data).

The activity described in this article presents one example of how to introduce a controversial socio-scientific issue (the first strand of Levinson's tripartite model) to teachers who are new to the topic, to help them experience such an activity as learners themselves. The activity was used with in-service science teachers who taught at different levels (primary school science, and lower and upper secondary school level) and had different disciplinary backgrounds (primary school science, biology, chemistry). The goals of the activity were to illustrate how multiple viewpoints of a controversial socio-scientific issue can be raised and discussed in a democratic way in the science classroom, and how to reach evidence-based decisions in such contexts. The article begins by explaining the socio-scientific controversy at the core of this activity and then continues with a discussion of how the experiential activity was designed and implemented with in-service science teachers. The activity can also be adapted for use with secondary school students.

The socio-scientific controversy

The use of antibiotics in livestock is an example of a current socio-scientific controversial issue. In 2013, more than 131 000 tons of antibiotics were used in food animals worldwide and this trend is expected to exceed 200 000 tons by 2030 (Van Boeckel *et al.*, 2017). The use of antibiotics protects animals from diseases and hence influences public health. However, continuous use of antibiotics can increase the resistance of bacteria to antibiotics and lead to antibiotics becoming ineffective in treating bacterial diseases. For instance, Casey and colleagues (2013) showed that people living near pig farms, or crop fields fertilised with pig manure, were more likely to become infected with bacteria that were resistant to known treatments. As the resistance develops, the possibility of pathogens remaining on meat increases, thus posing risks to human health.

On the other hand, the use of antibiotics in livestock is found to be beneficial for accelerating the growth of the farm animals and thus increasing economic profit. According to some studies (e.g. Santman-Berends *et al.*, 2014; Philips *et al.*, 2004), administering a small dose of antibiotics on a daily basis can improve the average daily weight gain and feed efficiency in livestock; this is an important discovery in an industry where profits are measured according to the weight of the animal. A major controversy in this issue is the use of the same antibiotics for livestock that are also used for humans, thus potentially rendering the antibiotics for human use ineffective. In addition, antibiotics, but also resistant bacteria, can end up in the natural environment, leading to soil and groundwater contamination. The different sides of the debate are shown in Box 1, which also lists the main stakeholders.

An analysis of how the UK national newspapers and the farming press frame the use of antibiotics in livestock in relation to policy actions that also involve interpretation of scientific evidence suggests that much is at stake, and multiple stakeholders' interests depend on how the controversy is understood and argued for (Morris, Helliwell and Raman, 2016).

Activity overview and objectives

The 'Antibiotics in livestock' activity aimed to promote in-service science teachers' understanding about the

Box 1 The antibiotics in livestock debate

Arguments in support of the use of antibiotics	Arguments against the use of antibiotics
• Antibiotic use for the treatment, prevention and/or control of a particular disease in livestock follows strict guidelines provided by veterinarians and pharmaceutical companies. • Human antimicrobials, such as macrolides, are rarely used in livestock. • Antibiotics improve and maintain animal health, and therefore contribute to the protection of consumers from various food-borne infections. • Antibiotics are subject to a rigorous control procedure, and antibiotics approved by the Food and Drug Administration for use in livestock meet specific indicators regarding human and food safety. • The main cause of microbial resistance in humans is antibiotics inappropriately consumed for viral infections, against which antibiotics are completely ineffective. • Treating livestock with antibiotics is expensive so farmers only do so when it is necessary. • Antibiotics are beneficial for accelerating the growth of the farm animals, and thus increasing economic profit.	• Most antibiotics are used for non-therapeutic purposes (i.e., for fattening and accelerating the growth of animals). In fact, in the USA 70% of antibiotics is used by the meat industry for these purposes, instead of disease treatment. • The use of antibiotics for animal growth has been banned in the EU since 2006, but the precautionary use of antibiotics in livestock continues. • The increased use of antibiotics in livestock results in the animals' resistance to known treatments while the possibility of pathogens remaining on meat increases. • Many of the resistant bacteria in animals can be easily transferred to humans via the food chain, when working with animals (e.g. farm workers, meat industries, etc.), or through the natural environment (e.g. contamination of soil, groundwater, etc.). • The use of antibiotics in livestock results in human infection with bacteria that are resistant to known treatments. • The same antibiotics for livestock are often used for humans, and this potentially renders the antibiotics ineffective for human use. • Public health officials are alert to the danger and point to the need to reduce antibiotics in livestock, indicating episodes such as the deaths of patients.
Indicative stakeholders: Food-animal breeders and breeder associations, pharmaceutical industries and companies, governmental services	**Indicative stakeholders**: Public interest organisations against antibiotic use, consumer associations, environmental organisations, unions of concerned scientists, governmental services

nature of controversial socio-scientific issues. By the end of this activity, the science teachers were able to:

1 understand the complexity of contemporary socio-scientific controversies;
2 analyse a socio-scientific issue to identify the main stakeholders involved, and the controversial points of view;
3 recognise the pedagogical value of socio-scientific controversies;
4 reflect on how they would use the 'Antibiotics in livestock' learning environment with their students.

During the activity, which was part of a teacher professional development programme, 56 in-service science teachers assumed the roles of learners and reflective practitioners to investigate the controversial socio-scientific issue of antibiotics in livestock. The activity was structured in three stages and lasted approximately 120 minutes.

Stage 1: Adopting the perspective of a stakeholder

During the first stage (60 minutes), teachers assumed the role of learners, working in groups of six or seven members. Each group was assigned to one of the five stakeholder roles identified in this controversy:

- concerned scientists;
- farmers;
- medical industry representatives;
- government officials;
- public interest organisations that oppose antibiotics.

Teachers were given access to a website (Figure 1) that included information to support each stakeholder group in order to appreciate the position of the group they were assigned to, and to develop their arguments and counter-arguments for the debate.

This website was designed by the professional development mentors using a free web design service (*Google Sites*) and using resources that are available online, including *YouTube* videos and online articles on the topic. The structure and content of the website is shown in Table 1.

Teachers were asked to carefully study the relevant sources, aiming to:

1 learn more about the controversial socio-scientific topic 'Should antibiotics in livestock be banned?';
2 discuss the role and the position of the stakeholder that had been assigned to their group;
3 identify the main arguments of their stakeholder role in relation to the driving question.

Each group was advised to use *Google Docs* to document the main arguments of the stakeholder role they were assigned to and organise their stakeholder arguments, which would then be presented during a public debate.

Stage 2: Group debate

During the second stage of the activity (30 minutes), all stakeholder groups reconvened as a plenary. One member of each stakeholder group was assigned to represent the group during the debate, with all other teachers

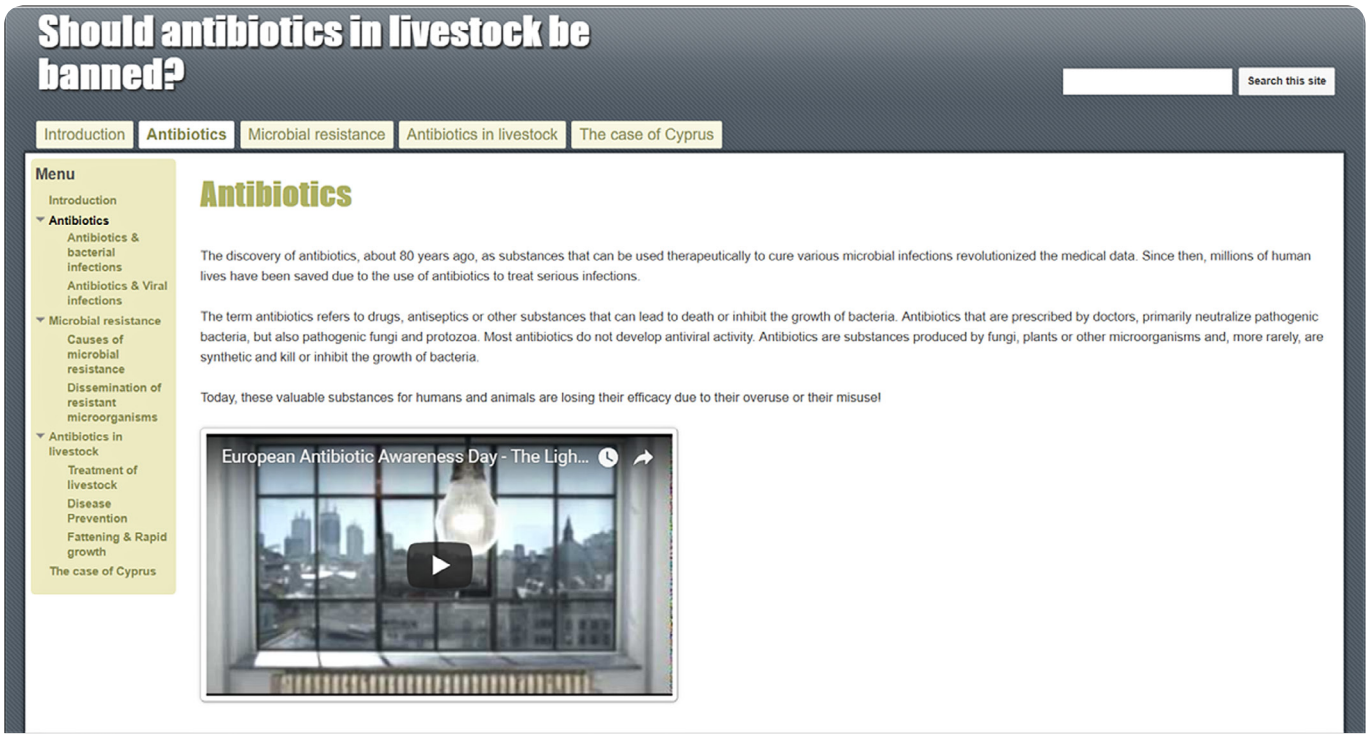

Figure 1 A screenshot of the website with information to support the stakeholder debate on the use of antibiotics in livestock (translated from Greek)

Table 1 The 'Antibiotics in livestock' website content

Webpage title	Content description	
Outlining the problem (homepage)	The problem is presented to the learner through textual information, images and a video. The following paragraph is a synopsis of the problem presented as an introduction to the controversial socio-scientific issue. '*Farmers have been giving antibiotics to their livestock for years, as they have found that the administration of antibiotics contributes to the fattening and rapid growth of the animals. Recently, several researchers have expressed concerns that, in combination with the general mass use of human antibiotics, the continued use of antibiotics in animals for fattening poses a serious risk to human health, such as microbial resistance to antibiotics. On the other hand, a ban on the use of antibiotic drugs would significantly reduce the productivity of the meat industry, while at the same time increasing the cost of meat. However, representatives of the livestock industry estimate that at this time there is no clear scientific evidence linking the use of low-dose antibiotics in animals for fattening with human-resistant diseases. As such, a ban on the use of antibiotics in livestock farming is not justified.*'	
The socio-scientific controversy	On this webpage the teachers can read information about the current situation of the problem in Cyprus, as presented through: (a) local newspaper articles; and (b) the results of the EU Special Eurobarometer 407 Survey on 'Antimicrobial resistance'.	
Sources of information	This webpage presents the sources of information that were available to each stakeholder group to study. Providing access to these pages supported each group in understanding and adopting the perspective of the stakeholder group they were assigned to. Providing access to the other stakeholders' information also allowed each stakeholder group to study their competitors' arguments and discuss how to strengthen their own arguments or how to refute other stakeholders' arguments during the debate that would ensue.	
	Stakeholder group	**Information was collected from the following sources**
	Concerned scientists	• Union of Concerned Scientists • Centre for Responsive Politics
	Farmers	• American Farm Bureau Federation • National Chicken Council • European Farmers' Union • Cyprus agricultural organisations
	Medical industry	• Animal Health Institute • International Federation for Animal Health – Europe
	Government agencies	• Veterinary Services of Cyprus • State General Laboratory • Cyprus Ministry of Health
	Public interest organisations that oppose antibiotics	• Friends of the Earth • Keep Antibiotics Working • The European Consumer Organisation • Consumers' Association 'Quality of Life'
The problem as covered by the Cyprus media	This webpage presents nine publications in national newspapers discussing the problem of antibiotics in meat. The publications cover a period of 5 years.	
Resources	This webpage lists all the sources used in the entire website as links, so that anyone who is interested can study the topic on their own, in more depth and at their own pace.	

participating as audience (Figure 2). Each representative had a few minutes to present his or her group's position towards the controversial socio-scientific topic. A group debate among the representatives followed after the presentation of each group's position. At this point, the audience could also contribute to the discussion and ask questions or clarifications of any of the representatives, request evidence and make suggestions. Teachers in the audience were also invited to change their point of view, if they were persuaded by the arguments presented by another stakeholder group.

Stage 3: Reviewing the process

The goal of the final stage of the activity was to engage teachers in reflection about their participation, to discuss what they had learned, and how this activity, or a similar one, might be implemented in their science classrooms with their students. An informal discussion followed the

Figure 2 Representatives of each of the stakeholder groups participate in a debate about the controversy of antibiotics in livestock

debate, which gave the opportunity to all participants to ask questions and express their arguments for or against the use of antibiotics in livestock.

Teachers as learners

Asking the teachers to assume the role of learners responds to calls for continuing professional development and creates opportunities for teacher learning and familiarisation with novel pedagogical approaches, such as the introduction of socio-scientific controversies in science education. Such learning activities can be more powerful and effective when coupled with teacher reflection. In this way, the professional development needs of the teachers can be acknowledged and met in context.

The SSIBL framework emphasises the role of inquiry in reaching evidence-based decisions about socio-scientific controversies. By asking teachers to assume the role of learners in the 'Antibiotics in livestock' activity, they were also asked to become inquirers and to examine, interpret and discuss secondary sources of data, in order to answer the driving question and suggest a solution to the 'Antibiotics in livestock' debate. This experiential activity can deepen teachers' understanding of how to approach these topics with their own students, as compared with an activity in which they are passive recipients of guidelines of how to engage students with inquiry in such contexts. The following excerpts are examples of the arguments created after the examination of the online information and were taken verbatim from the teachers' statements (as representatives of stakeholder groups) during the debate.

Farmers: *I would like to say that antibiotics are useful and harmless, as their use, according to the legislation, is terminated about 15 days before the slaughter of the animals. Therefore, by the time the meat is sold to the consumers, it is already clean!*

Public agencies: *We know that if antibiotics are banned, this would reduce the number of animals, and thus increase the price of the meat, which would be against the consumers' best interest. If antibiotics are used wisely, then animal diseases will be eliminated, and according to research results, there will be no further problems.*

Public interest organisations against antibiotics: *I will start with my first argument according to which there are studies indicating that 70% of the use of antibiotics is for commercial purposes, that is for fattening and growing the animals, rather than for therapeutic purposes or for preventing disease outbreaks.*

Pharmaceutical industry: *I would like to add that our primary goal is human health. Of course, humans need food, and, in turn, this needs to be safe. The pharmaceutical industry produces drugs under strict specifications in terms of quantity, quality and use. In this context, the blame should be placed on humans who misuse these drugs, as well as on the government agencies who are supposed to monitor this use.*

Concerned scientists: *We recommend that prescriptions should be mandatory for the use of antibiotics in animals. At the same time, the cost of the meat should be inversely proportional to the use of antibiotics. In cases where there is a detection of antibiotics at high levels, then the government could impose a penalty on these companies. There should be a government subsidy, in combination with other incentives, for those who do not use antibiotics, as well as a webpage informing citizens about how many antibiotics each company has used per month. In general, we should be given the right of choice. As in the case of organic products, we should be able to choose meat with or without antibiotics. I should, therefore, have this right.*

Overall, this three-stage experiential activity allowed teachers to conceptualise how inquiry-based science education (IBSE), socio-scientific controversies and citizenship education are interlinked and related to the idea of Responsible Research and Innovation (RRI), which seeks socially desirable, ethically acceptable and sustainable development of science and technology (Owen, Macnaghten and Stilgoe, 2012).

Teachers as reflective practitioners

The importance of reflection in professional learning, and the idea of the teacher as a reflective practitioner (Schön, 1987), has garnered wide acceptance worldwide. Reflective thinking considers problem situations and can critically examine how they fit into a teacher's professional schema, leading to a possible re-organisation of beliefs and practices. Following the experiential activity (stage 1), which culminated with the debate (stage 2), the 56 in-service science teachers who had participated in the professional development programme were asked to reflect on their experience. During this reflective discussion, the professional development facilitators helped participants make connections between the

SSIBL framework, the PARRISE project approach and RRI-related goals. All participating teachers had the opportunity to express questions and provide suggestions on how this learning activity, and the SSIBL framework, could be used with their students. Their conclusions were based on what they perceived they had learned during their activity as students: how to identify and evaluate stakeholder arguments, appreciating the complexity and plurality of arguments, and using arguments to convince others of one's position.

Conclusion

Modern societies witness a massive number of scientific and technological developments that affect all of us and raise socio-scientific controversies at a personal, social and global level. Addressing these controversies through an inquiry and active citizenship approach is of paramount importance and is at the core of the SSIBL pedagogical framework. By participating in the activity about antibiotics in livestock, teachers were provided with the opportunity to make sense of the SSIBL pedagogical framework in an experiential way and to conceptualise the notion of RRI, which is the backdrop to the SSIBL framework.

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