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BRINGING ETHICS INTO BIOLOGY EDUCATION: A BEST PRACTICE EXAMPLE ON ANIMAL ETHICS

INTRODUZIR A ÉTICA NO ENSINO DA BIOLOGIA: UM EXEMPLO DE BOAS PRÁTICAS SOBRE ÉTICA ANIMAL

INTRODUCIR LA ÉTICA EN LA ENSEÑANZA DE LA BIOLOGÍA: UN EJEMPLO DE BUENAS PRÁCTICAS SOBRE ÉTICA ANIMAL

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ABSTRACT | Ethical considerations play an essential role in science education, particularly in addressing socioscientific issues (SSI) that require students to evaluate scientific innovations within social, political, and moral contexts. However, these aspects are often underrepresented in the science classroom, limiting students' ability to critically engage with ethical dilemmas. This paper presents an educational approach integrating ethical discussions into biology education, focusing on animal ethics and animal experimentation. The objectives are to familiarise students with fundamental ethical concepts, encourage reflection on human-animal relationships, and develop skills in structured ethical discussions and reasoned decision-making. Students and teachers have positively evaluated the teaching concept. The approach developed is well-suited for integrating ethics into biology lessons even if the students have no prior knowledge.
KEYWORDS: Ethical inquiry, Socioscientific issues, Biology teaching, Moral education, Animal experimentation.

RESUMO | As considerações éticas desempenham um papel essencial no ensino das ciências, particularmente na abordagem de questões sociocientíficas (SSI) que exigem que os alunos avaliem as inovações científicas em contextos sociais, políticos e morais. Um desafio fundamental é a insuficiente preparação dos professores durante os seus estudos. Este documento apresenta uma abordagem educativa que integra discussões éticas no ensino da biologia, centrando-se na ética animal e na experimentação animal. Os objetivos são familiarizar os alunos com conceitos éticos fundamentais, incentivar a reflexão sobre as relações humano-animal e desenvolver competências em discussões éticas estruturadas e tomadas de decisão fundamentadas. Os alunos e os professores avaliaram positivamente o conceito de ensino. A abordagem desenvolvida é adequada para integrar a ética nas aulas de biologia, mesmo que os alunos não tenham conhecimentos prévios.
PALAVRAS-CHAVE: Investigação ética, Questões sociocientíficas, Ensino da biologia, Educação moral, Experimentação animal.

RESUMEN | Las consideraciones éticas desempeñan un papel esencial en la enseñanza de las ciencias, sobre todo a la hora de abordar cuestiones sociocientíficas (SSI) que exigen que los estudiantes evalúen las innovaciones científicas dentro de contextos sociales, políticos y morales. Sin embargo, estos aspectos suelen estar infrarrepresentados en las aulas de ciencias. Este artículo presenta un enfoque educativo que integra debates éticos en la enseñanza de la biología. Los objetivos son familiarizar a los alumnos con los conceptos éticos fundamentales, fomentar la reflexión sobre las relaciones entre los seres humanos y los animales, y desarrollar habilidades para los debates éticos y las decisiones razonadas. Los alumnos y los profesores han evaluado positivamente el concepto de enseñanza. El enfoque desarrollado es muy adecuado para integrar la ética en las clases de biología, incluso si los alumnos no tienen conocimientos previos.
PALABRAS CLAVE: Investigación ética, Cuestiones sociocientíficas, Enseñanza de la biología, Educación moral, Experimentación con animales.

1. INTRODUCTION

Ethics plays an increasingly important role in science education, particularly in addressing socioscientific issues (SSI) that require students to evaluate scientific innovations within social, political, and moral contexts. Regardless of its importance, ethical considerations are often underrepresented in science curricula, leading to a gap in students' ability to critically engage with ethical dilemmas related to scientific and technological developments.

This paper introduces an approach to integrating animal ethics into biology education. The practice was developed within the Austrian school system, where formal ethics education is limited to the upper secondary level. Given that many students lack prior exposure to ethical reasoning, the instructional design incorporates structured approaches to animal ethics. The main objectives of this educational intervention are to familiarise students with fundamental ethical concepts; encourage reflection on the human-animal relationship and the ethical considerations of animal experimentation; and develop students' ability to engage in structured ethical discussions and reasoned decision-making. The educational practice presented employs a structured pedagogical model (Saunders & Rennie, 2013) that guides students through ethical exploration using case-based learning. The implementation was conducted in various stages, including student focus groups and teacher training workshops to refine the approach. The results from student workshops and teacher evaluations highlight the effectiveness of this approach, demonstrating its potential for broader application in science education.

2. RATIONAL AND CONTEXT

Socioscientific issues (SSI) are an important area of research in science education. SSIs are science-related societal issues without clear solutions. This is mainly due to the different perspectives involved, for example from politics, business, science and society, but also because of the ethical issues raised (Sadler & Zeidler, 2004). Science education should enable students to apply their knowledge in social decision-making situations (Dawson & Venville, 2010). When dealing with SSI they learn to evaluate problems on a social, political, and ethical level and to actively participate in solving the problems society faces (Garrecht et al., 2022; Mueller & Zeidler, 2010). Literature reviews show that SSI in science lessons foster various skills and attitudes. These include increased interest and motivation for the subject and the topics covered, deeper subject knowledge, a better understanding of science, enhanced reasoning, critical thinking, problem-solving, moral sensitivity, and local engagement (Sadler, 2009).

Many educators call for the integration of ethical topics into science lessons (Mueller & Zeidler, 2010; Owens et al., 2017). On the one hand, the hesitation to integrate ethics into science education is explained historically: science was formerly seen as “pure science”, independent of external influences (Iaccarino, 2001). Arguments against inclusion emphasise the different focus of science (facts) and ethics (norms) (Reiss, 1999). Teacher training prioritizes subject-specific content over ethics, raising concerns about teaching quality (Dittmer & Zabel, 2019; Garrecht et al., 2022; Reiss, 1999). On the other hand, there is an inseparable link between science and ethics, as scientific goals can be evaluated morally (Reiss, 1999). The rapid pace of scientific development requires ongoing ethical reflection (Iaccarino, 2001). The integration of ethical topics could enhance students' ethical sensitivity and understanding of moral and legal duties (Reiss, 1999) and increase interest in science by relating it to real societal problems (Garrecht et al., 2022; van

Griethuijsen et al., 2015). The current educational goals of many countries, such as Austria, support the integration of ethical issues into science lessons. Addressing of values, norms, and ethical responsibility is clearly required (Bundesministerium für Bildung, Wissenschaft und Forschung [BMBWF], 2025). However, teachers find it difficult to integrate ethical issues into science lessons. Besides lacking ethics training (Dittmer & Zabel, 2019; Garrecht et al., 2022; Reiss, 1999), teachers face additional obstacles: the significant preparation time required, and low confidence in content knowledge and leading discussions (Alfs et al., 2012; Garrecht et al., 2022; Tidemand & Nielsen, 2017). This paper therefore focuses on presenting a best practice example of how ethical issues can be integrated into biology lessons. The following section introduces relevant literature on animal ethics, the focus of the teaching units.

2.1 Connecting animal ethics to biology education

In general, it can be said that ethics deals with the evaluation of moral actions and animal ethics deals with how animals should be treated (Grimm & Wild, 2020). Animal ethics is an area of applied ethics that has gained immense popularity and broad social interest in recent decades. This is also demonstrated, for example, by the current Special Eurobarometer, in which three quarters of all Europeans claim that animal welfare should improve in their country (European Commission, 2023). There are many animal ethics topics that can be dealt with in biology lessons, as there are explicit links to the curriculum (BMBWF, 2025). These include, for example, the value of non-human life, animal welfare, animal husbandry, animal experiments, animal breeding and overarching topics on environmental ethics, such as species extinction or species protection (Dittmer & Gebhard, 2012). Although there are a multitude of possible links, textbook analyses show that (animal) ethics tasks are hardly present in biology textbooks (Garrecht et al., 2022; Mikelskis-Seifert et al., 2013). The fact that animals are primarily presented as a resource in school textbooks makes it more difficult to critically reflect on the existing human-animal relationships (Cho et al., 2022; Garrecht et al., 2022; Mikander et al., 2024). In addition, a value-based categorisation can be found, for example, in pets and farm animals. Pets are considered to have more intrinsic value and minds than farm animals (Folsche et al., 2024). The integration of animal welfare topics into education is recommended as it promotes animal-friendly attitudes (Binngießer et al., 2013) and has a positive influence on young people's understanding and attitude towards animals (Zhang & Li, 2022).

2.2 Students' attitudes toward animal ethics

Singer (2009) describes the majority of the (Western) population as speciesists, and studies have shown that people value different species differently (Bastian et al., 2012; Broad, 2020; Caviola et al., 2019; Caviola et al., 2021). Living beings are often categorised as pets, food (or animals for profit) and pests, and this categorisation determines the degree of protection they receive (Broad, 2020; Taylor & Signal, 2009). Pets and monkeys are generally rated higher than farm animals, unpopular mammals (e.g., mice), non-mammals or invertebrates (Batavia et al., 2020; Caviola et al., 2021; Enzinger, 2022; McGuire et al., 2022). In moral dilemma situations, children (5-9 years) show a lower tendency than adults to save humans and are more oriented towards the number of animals saved, while adults usually prefer a human, even over many non-human animals (Wilks et al., 2021). Children therefore show less speciesism compared to adults and tend to see farm animals as pets rather than food (McGuire et al., 2022). However, there is also a tendency to draw a distinction between humans and animals in children, which also leads

to inconsistent statements. For example, although fourth-grade children can describe humans and animals as mammals, they may deny that humans are animals (Leddon et al., 2012). The moral value of animals is strongly influenced by age (McGuire et al., 2022), with speciesism being a socially acquired construct that develops in late childhood (Wilks et al., 2021).

A conflict of interest between humans and animals is clear in animal testing. These are emphasised by scientists as essential for the development of new drugs (MacArthur Clark et al., 2019), and their importance was most recently demonstrated in the context of the Covid-19 pandemic (Genzel et al., 2020). The ethical dilemma is that the benefits of animal testing usually accrue to humans, while the animals must bear the suffering (Korsgaard, 2011). From a purely legal point of view, animal experiments are defined as follows: experiments carried out on vertebrates or cephalopods for experimental, scientific or educational purposes which cause suffering, stress or pain to animals (TVG 2012/1.10.2019, §2; European Commission, DIRECTIVE 2010/63/EU, 2010, Articles 1 and 3). Therefore, animal experiments that have to be officially applied for always involve stress or pain for the animals. This official definition is also used in this study when referring to animal experiments. Prior knowledge of animal experiments is generally low among the population (Ipsos MORI, 2018). Personal beliefs about the benefits of animal experimentation can influence how ethically or unethically animal experimentation is viewed (Saucier & Cain, 2006). In principle, however, even adolescents have no problems evaluating animal experiments based on their given level of knowledge (Garrecht et al., 2021; Lund et al., 2012). When evaluating animal experiments, laypeople mainly refer to the (subjectively) perceived benefits for humans and the resulting harm to the animal. In terms of attitudes, a distinction can be made between people who are generally in favour of animal experiments, generally opposed to them, or who vary in each situation (Lund et al., 2012).

However, the findings in the literature are inconsistent regarding young people's attitudes towards animal experiments. On the one hand, studies with young people have shown that participants feel better informed when given additional information about animal experiments, but their attitudes change only slightly (Agell et al., 2015; France & Birdsall, 2015). On the other hand, it seems to depend on the method used to what extent young people make general statements about animal experiments or specific assessments. The presentation of detailed animal experiments leads adolescents to adapt their assessments specifically to the situation and to use different criteria for their approval or rejection. In general, it can be stated that young people use the same criteria for evaluating animal experiments as adults, such as, for example the relevance of the research and the extent of animal suffering (Enzinger, 2022). The costs and benefits of animal experiments are known to be the most relevant criteria for the evaluation of animal experiments (Almeida & García Fernández, 2021; Laslo & Baram-Tsabari, 2021; Lund et al., 2012; Saucier & Cain, 2006). Previous research has shown that animal testing is a good topic to engage young people in ethical discussions as it presents a complex societal problem while linking scientific content (Garrecht et al., 2021).

3. DESCRIPTION OF THE EDUCATIONAL PRACTICE AND ITS IMPLEMENTATION

The Austrian school system is divided into 4 years of elementary school, 4 years of lower secondary school and 4-5 years of upper secondary school. Philosophy and ethics lessons only take place in the upper secondary school (grades 9-13). Philosophy lessons are only taught in grade 12 or 13. Since the school year 2021/22, ethics lessons have been introduced in the upper secondary school as a compulsory alternative for students who do not attend religion lessons. Below grade 12, science teachers must therefore assume that at least part of the class has no prior knowledge of ethics. An introduction to ethics is therefore essential for the implementation of ethical issues in biology lessons.

Saunders and Rennie (2013) developed a pedagogical model for dealing with ethical issues in the classroom, which was used to develop the series of lessons. Table 1 provides an overview on each step and the role of teachers and students. At the centre of their model is the joint exploration of ethical issues by teachers and students. The following steps should be taken:

1. The teacher must prepare the content regarding the scientific background, ethical aspects, and methodological implementation. The links to the curriculum should be considered.
2. In actual lessons, it is important for the students to establish a personal connection to the topic to make the relevance of the subject clear.
3. The teacher must address the relevant scientific background on the topic.
4. Then, the students should explore their own point of view and individually reflect on the problem.
5. Next, they discuss the problem in a group discussion, where they examine the most important arguments on the topic.
6. After that, they identify the ethical question inherent to the problem.
7. The teacher then provides various ethical or political frameworks (e.g., consequentialism, pluralism) for the students to examine the ethical question.
8. Finally, the students make a reasoned decision, justify which ethical framework they have used, and reflect on why they think this way and how other people might think.
9. The lesson ends with the students reflecting on any changes in their own thinking.

Table 1 *- Adapted overview of the Model of ethical inquiry (Saunders & Rennie, 2013), to demonstrate the role of teachers and students.*

Stage	Teacher's Role	Students' Role	Purpose
1. Content Preparation	Prepare scientific background, ethical aspects, and curricular links	—	Set academic foundations and align with curriculum
2. Topic Introduction	Present topic with relevance and context	Connect personally to the topic	Stimulate interest and perceived relevance
3. Scientific Exploration	Provide in-depth scientific content	Understand and engage with factual background	Build foundational understanding
4. Individual Reflection	Facilitate inquiry	Reflect personally on the problem	Encourage personal engagement with the topic
5. Group Discussion	Moderate group discourse	Discuss arguments and diverse perspectives	Develop critical and collaborative thinking
6. Ethical Question Identification	Support analysis of discussion outcomes	Identify central ethical question	Shift from general debate to ethical focus
7. Framework Application	Introduce ethical frameworks (e.g., consequentialism, pluralism)	Apply a selected framework to analyze the question	Deepen ethical reasoning
8. Justified Decision	Guide evaluation	Make a reasoned ethical decision and justify chosen framework	Develop moral judgment and metacognition
9. Final Reflection	Encourage metacognitive thinking	Reflect on their own thinking and consider others' perspectives	Foster personal growth and ethical awareness

The development and evaluation of the teaching concept followed a Design-Based Research (DBR) approach (Anderson & Shattuck, 2012; Brown, 1992; Collins, 1992; Design-Based Research Collective, 2003). DBR is particularly suited to educational settings where the aim is both to improve practice and to generate theoretical insights. It involves iterative cycles of design, implementation, analysis, and redesign, carried out in real-world contexts and in close collaboration with practitioners (Design-Based Research Collective, 2003; Scott et al., 2020). Typically, DBR begins by identifying an educational challenge. Researchers then design instructional tools informed by theory and prior research, which are tested in classroom settings. As implementation progresses, these tools are continuously evaluated and refined based on emerging evidence. Finally, outcomes are analysed to improve both the tools and the theoretical understanding of the learning process. These phases - design, implementation, evaluation, and reflection - often overlap and recur, forming a continuous cycle of improvement (Scott et al., 2020). The aim of the lessons developed and presented in this paper is to introduce norms, ethics and general animal ethical questions to grade 10 students. After this general introduction to (animal) ethics, the students get an introduction to animal experimentation and discuss different examples of experiments. The model of Saunders and Rennie (2013) guided the lesson conception but had to be adapted slightly: since developing their own ethical questions takes a lot of time (especially if the students are inexperienced in developing ethical questions), it was easier to provide the questions. The introduction to ethical thinking frameworks is also very time-consuming, so the discussion of the tasks was based on intuitive student ideas. The teacher can instead incorporate ethical frameworks into the class reflections following the students'

discussions or, if necessary, omit that part due to its high complexity. The development of the series of lessons was carried out in several stages based on the DBR approach.

Step 1. The tasks for the series of lessons were developed and tested in focus group interviews. Eight groups of 5-6 students (n=42) from grades 9 and 10 were interviewed at school. Based on their feedback on comprehensibility, the tasks were adapted, and timing processes were improved.

Step 2. The teaching concept was developed using the model of Saunders and Rennie (2013) and implemented as a 4-hour student workshop (with breaks) in three grade 10 classes (n=32). To facilitate more effective group discussions and ensure active participation, each class was split in half - one group attended the workshop on animal ethics, while the other participated in a separate workshop on environmental issues, allowing the sessions to be conducted in smaller, more manageable groups. The students gave feedback on the lesson conceptions. Results of the feedback are presented in this paper (see section 4).

Step 3. The lesson concept was presented in a teacher training course and feedback was received through two anonymous evaluation possibilities (n=12). An anonymous critical reflection on the topic and the teaching concept at the end of the training (paper and pencil) and an online evaluation regarding general feedback on the teacher training including the professional relevance of the training. The questions can be found in the appendix.

Step 4. The lesson conceptions, especially the tasks for the animal experiments, were revised based on feedback from steps 2 and 3. For example, teachers asked for examples of actual animal experimentation to connect students with actual research. Actual examples of animal experiments were developed which focused on topics which are easy to connect with the biology curriculum (cancer, vaccinations, and obesity). Missing information (that was not originally included) was integrated (e.g., number of animals used in the experiments).

Step 5. The updated teaching concept was tested in a further teacher training course (n=9). The participants gave feedback through the same two anonymous evaluation possibilities described in step 3. This finalised version of the teaching concept is presented in this paper.

The first lesson (Table 2) focuses on giving the students a general introduction to morals and ethics. The students are given the opportunity to reflect on their personal human-animal relationship and that of society. The students' intuitive ideas are put in relation to the current animal ethics approaches.

Table 2 *- Teaching lesson 1: Introduction to ethics and animal ethics*

Teaching step	Time	Content
1. Introduction to ethics	15-20 minutes	As no prior knowledge of ethics can be assumed, the lesson starts with an introduction. The students are asked to think about rules that are valid in our society (e.g., Respect others. Don't hurt anyone. Don't lie. Comply with the General Data Protection Regulation). They are then asked to rate how important they think each rule is. They are encouraged to reflect on the fact that some rules are anchored in law, while others are established in the norms of society.
2. Reflection on human-animal relationship	20-25 minutes	The students are asked to reflect individually on how they themselves would rank an exemplary moral community of eight living beings (adult, dog, ape, human baby, pig, fish, mice and beetle) and to find reasons for the structure they develop. The aim is to reflect on the personal human-animal relationship. This is followed by a discussion in small groups of 3–4 people on the same question, allowing students to engage with different perspectives.
3. Introduction to animal ethics	15-20 minutes	After the student activities, the teacher compares the students' reasons with different animal ethics orientations (e.g., anthropocentrism, pathocentrism). Additionally, the teacher gives a brief overview of central questions in animal ethics (e.g., How should we treat animals? To what extent should we take animals into moral consideration? What criteria are used to distinguish between species?).

In the second and third lessons (Table 3), the focus is on a specific example of animal ethics in the form of animal experiments. Since no prior knowledge of animal experiments can be expected, the students are initially given a theoretical introduction to animal experiments[1]. This introduction includes the general definition of animal experiments, different areas of application of animal experiments, frequently used animals, approval process, 3R principles (refine, reduce, replace), degrees of severity, cost-benefit analysis, and the moral dilemma.

[1] The students in the focus group interviews all stated that they had no prior knowledge of animal experiments (Step 1).

Table 3 *- Teaching lesson 2 and 3: Animal experimentation*

Teaching step	Time	Content
1. Introduction to animal experiments	35-40 minutes	Before beginning the theoretical input, the teacher conducts an anonymous opinion poll on whether students consider animal experiments acceptable. This activity serves to capture students' initial perspectives and to activate prior knowledge and intuitive attitudes toward the topic. Following the poll, the teacher provides a structured introduction to the topic of animal experimentation. The content includes the general definition of animal experiments, different areas of application of animal experiments, frequently used animals, approval process, 3R principles (refine, reduce, replace), degrees of severity, cost-benefit analysis and the moral dilemma. This input ensures that all students have a solid foundational understanding before engaging in ethical reflection.
2. Discussion on harm-benefit analysis (HBA)	15-20 minutes	Students reflect on the strengths and weaknesses of the harm-benefit analysis, which is a mandatory component of the Austrian approval procedure for animal experiments. While the HBA is intended to make approval processes more transparent and prioritize animal welfare, students are encouraged to critically consider its limitations. These include the difficulty of quantifying animal suffering, the unpredictability of research outcomes, and the delayed or uncertain realization of potential benefits.
3. Decision on the approval of different examples of animal experimentation	30-35 minutes	Students are then presented with three real-world examples of animal experiments. They first make an individual decision on whether each experiment should be approved, using the information provided (e.g., purpose, species used, number of animals, expected severity, predicted benefits and suffering). Following this, students form small groups (3–4 members) to discuss their evaluations. This structure allows them to compare perspectives and understand how different values or criteria may influence decision-making.
4. Reflection on decisions, criteria used and personal development process	20-25 minutes	In the final step, the teacher facilitates a plenary discussion in which students reflect on the various reasons given for approving or rejecting the experiments. The teacher connects these arguments to the animal ethics theories introduced in the first unit (e.g., anthropocentrism, pathocentrism). The discussion also includes a reflection on the challenges faced during the decision-making process and examines whether and how students' views have changed compared to their initial responses in the opinion poll (step 1).

Subsequently, three different examples of animal experiments (Figure 1) are analysed and a reasoned decision for their approval is made. It is important that the students evaluate several animal experiments, as it is very often the case that one and the same person evaluates one animal experiment as acceptable and another animal experiment as unacceptable. This makes the difficulty of the decision and the need to evaluate animal experiments based on their different circumstances apparent to the students. A double lesson is recommended, but if that is not possible, the second lesson should cover the theoretical introduction and the discussion of the required harm-benefit analysis. In the following third lesson, the analysis and discussion of different examples of animal experiments should take place.

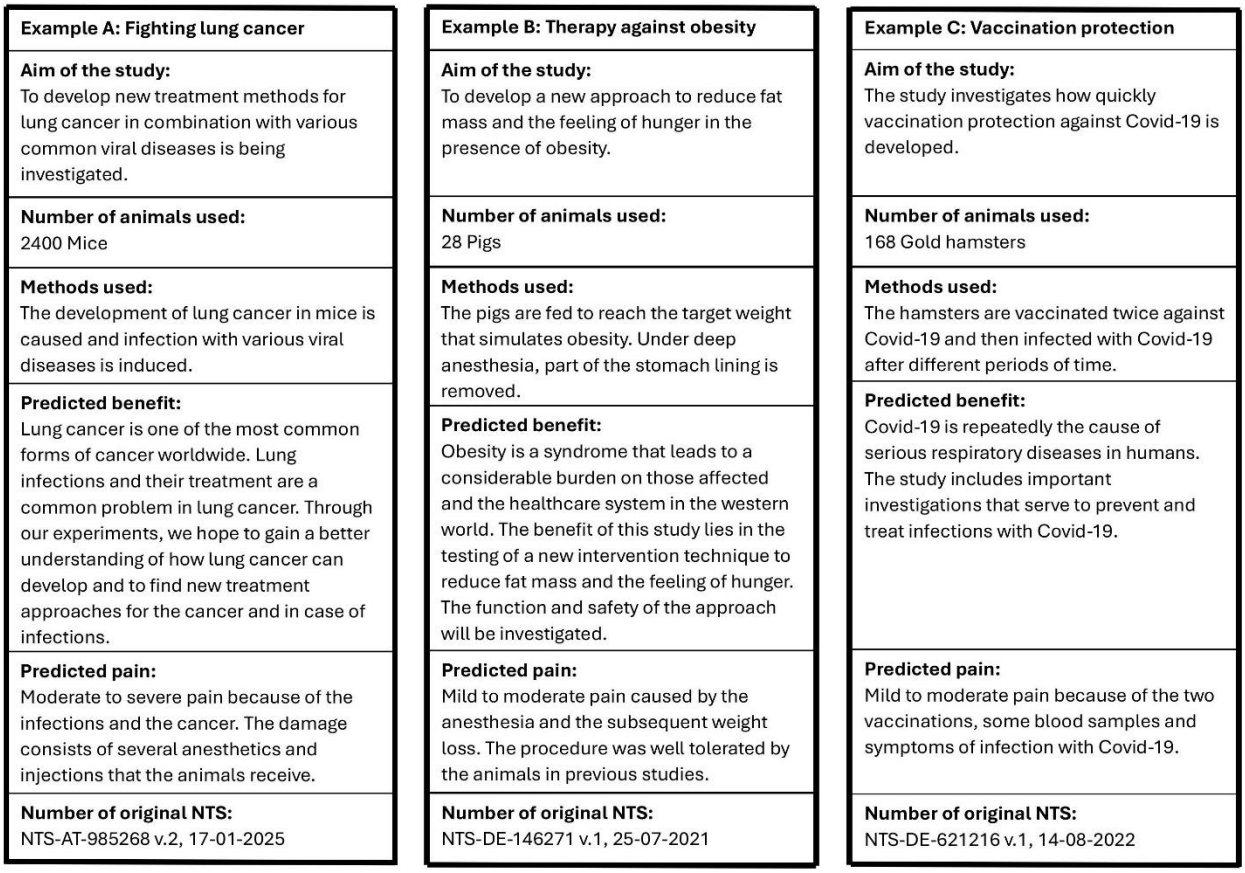

Figure 1 Three possible examples of animal experimentation which could be used for discussion with students.

Animal testing is uniformly regulated in the Directive 2010/63/EU. For the use of current animal experiments in the classroom, it is advisable for teachers to refer to the non-technical project summaries (NTS). Every animal experiment carried out in the EU must publish a non-technical project summary in which the animal experiment is presented in a way that is understandable to laypeople. Since January 1, 2021, there has been an EU database - ALURES - ANIMAL USE REPORTING - EU SYSTEM (European Commission, 2025) - for these non-technical project summaries in which you can search for suitable animal experiments based on the teaching topic (e.g., cancer, immune system, basic research, applied research). All relevant information on project objectives, implementation, animals used (including numbers), expected severity and information on expected costs and benefits are included. Three examples of suitable animal experiments are presented in Figure 1. The examples follow a structure by Lund et al. (2012) which contain the following information in the original version: title, aim, animal used, expected pain, methods. The following additional content was added to the examples as our own research with adolescents and teachers has shown that necessary adaptation: number of animals used, predicted benefit and predicted pain. In the original version of Lund et al. (2012), only the level of severity was present (named as expected pain) which was criticised to be not detailed enough. Additionally, the wording of the examples was made as clear as possible. The understandability of the examples was tested in a 10^{th} grade class.

4. EVALUATION OF THE IMPLEMENTATION OF THE PRATICE AND MAIN RESULTS

All students in the focus group interviews (Step 1) and workshops (Step 2) successfully completed the lesson tasks. They made reasoned decisions on moral community (Lesson 1) and animal experiments (Lesson 2). Some groups in Step 1 struggled with technical terms in animal experiments, leading to simpler language in Step 2. Both focus group discussions and completed worksheets were analysed using Mayring's (2014) qualitative content analysis. The data was transcribed, and two researchers (author and a research colleague) coded the data material. Inductive category formation was used, where the categories are built out of the data material. This coding technic requires various feedback loops between the researchers to develop coding rules and to discuss the built categories. An interrater reliability (IRR) analysis using Krippendorffs Alpha (Hayes & Krippendorff, 2007; Krippendorff, 1970) was conducted to ensure objectivity across raters (Mayring, 2014). It verifies that the evaluation criteria were applied uniformly, minimizing subjective bias and enhancing the reliability of the findings (Krippendorff, 2004). Table 4 shows an overview of the built subcategories of arguments students used to assess animal experimentation and how they were structured into main categories.

All participants in step 1 stated during the interviews that they have no prior knowledge on animal experimentation. Most participants found animal experiments both acceptable and unacceptable, emphasizing that decisions depend on specific details. Exemplary student answer: "*Cancer is simply a strong disease in our society. So that is widespread, and I think something should be done about it. And even if it's not so good for the animals, but I just think it should be done*." (Reference to [FI28B1]'s transcript, Enzinger & Dürnberger, 2022). The analysis of students' arguments regarding animal experimentation revealed three dominant main categories: the relevance of research (34.4% of total arguments), the extent of animal suffering or death (31.3% of total arguments), and the existence of alternative methods (13.7% of total arguments) (Enzinger & Dürnberger, 2022). In another study (Step 2), analysis of the assessments of 32 students on two examples of animal experimentation reproduced this result. Specifically, 53.1% of the students used the main category relevance of research, 59.4% used extent of animal suffering or death, and 15.6% used existence of alternative methods (Enzinger, 2022). More data on the arguments provided by the students in this activity and the developed category system can be found at Enzinger & Dürnberger, 2022 and Enzinger, 2022.

Step 2 workshop students (n=32) evaluated the lesson concept and group discussions positively, particularly praising the interactive design. Reflection on the human-animal relationship (Lesson 1, Part 2) was favoured by 93.9%, the theoretical input on animal experiments by 87.9%, and the evaluation of different experiments by 90.9%. All students enjoyed the tasks and group interactions. However, 12.5% noticed dominant voices in discussions. It is therefore relevant that teachers point out to the students before they start working on the tasks that all opinions are important for group decisions. If consensus cannot be reached, recording differing viewpoints can be a useful alternative. Reflecting on the causes of different perspectives (e.g., personal closeness to different animals and assessments based on this) can be a valuable experience for the students.

Half of the teachers at the first teacher training course (Step 3, n=12) gave feedback that some aspects of the animal experiment examples could be supplemented, e.g. the number of animals used or specific information on the costs and benefits of individual animal experiments. Some also asked for actual examples of animal experimentation and where to find actual

information on animal experimentation. All teachers at the second teacher training course (Step 5, n=9) rated the newly developed examples positively. The good comprehensibility and the fact that they provide a good stimulus for discussion were particularly emphasized. Most of the teachers stated that the topic and the examples are only suitable for upper secondary school (grade 9-13 in Austria). Exemplary teacher statement: *"Very good basis for discussion in class. Very easy to understand. The content is very exciting, certainly also for the students. Suitable for upper secondary school, not for lower secondary school."* For most teachers, the description of the content was sufficiently detailed. A few teachers wanted more information on the individual animal experiments in the examples, especially details on the methods used on the animals. All teachers (n=21) in the teacher training course (Steps 3 & 5) affirmed the high relevance of the topic to professional practice and its practical applicability in the evaluation. Some provided additional feedback:

Teacher 1: "*Excellent, great examples for the classroom."*

Teacher 2: "*Interesting, well organised, well thought out, well structured, varied.*"

Teacher 3: "*I have a really good feeling now about how I can work on animal ethics with the students."*

The analysis of student and teacher evaluations shows that the lesson concept developed is a beneficial method of integrating ethical topics into biology lessons. Previous knowledge of philosophy and ethics is not necessary for the students. The teacher must prepare the content in relation to animal ethics, and animal experiments in particular, to be able to implement the lesson plan efficiently.

5. CONCLUSIONS AND IMPLICATIONS

The implementation of the lesson series demonstrates that students can engage meaningfully with complex ethical issues such as animal experimentation, even without prior instruction in ethics. Using a structured pedagogical framework adapted from Saunders and Rennie (2013), students were guided through personal reflection, group discussion, and reasoned decision-making. This scaffolded approach enabled them to critically assess moral dilemmas while simultaneously building understanding of biological and ethical content. Feedback from students and teachers highlights the educational value and practical applicability of the concept. Students particularly appreciated the interactive and reflective components of the lessons. Teachers reported that the materials were well-structured, and highly relevant to professional practice. These findings align with previous research demonstrating the value of socioscientific issues (SSI) in enhancing students' moral sensitivity, scientific literacy, and interest in science (Sadler, 2009; Dawson & Venville, 2010; Garrecht et al., 2022). The ability of students to distinguish between acceptable and unacceptable animal experiments based on harm-benefit analyses supports earlier work by Lund et al. (2012) and Agell et al. (2015).

Nevertheless, several limitations should be acknowledged. The evaluation relied on qualitative feedback and content analysis, without longitudinal or quantitative measures of ethical reasoning development. While interrater reliability was ensured through Krippendorff's Alpha, the small student sample size limits generalizability. Group dynamics occasionally led to imbalanced participation, highlighting the need for facilitation strategies that promote equitable

dialogue. Additionally, the ethical frameworks were simplified during classroom instruction due to time constraints - an adaptation that, while practical, limits deeper theoretical engagement. The design-based research (DBR) approach, although well-suited to the iterative development process, means that students and teachers encountered different versions of the lesson sequence, complicating comparative evaluation.

Despite these constraints, the study contributes both practical and theoretical insights into science education. The teaching concept presents a structured, replicable model for integrating ethical issues into biology classrooms. It encourages interdisciplinary learning and helps students critically evaluate scientific practices in their broader social and ethical context. The iterative design and multiple rounds of implementation (focus groups, student workshops, teacher training) demonstrate the concept's robustness and adaptability to different settings.

Students showed an ability to formulate nuanced ethical judgments based on real-world dilemmas, such as animal experimentation. The lessons promote not only ethical reflection but also have the potential to promote a deeper understanding of scientific processes and their societal relevance. According to the literature (Sadler, 2009), educational activities with similar features also foster critical thinking, empathy, and ethical awareness - skills which are increasingly essential in contemporary science education. However, successful implementation requires sufficient preparation time and teacher confidence in handling ethical discourse. Teachers must also manage classroom dynamics to ensure all voices are heard. Professional development opportunities focused on ethics in science teaching could improve teacher readiness, and greater inclusion of ethical content in science textbooks would support wider adoption. Structured lesson plans, like those presented in this study, represent a practical first step toward supporting teachers in integrating ethics more systematically into biology education.

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Appendix

Evaluation sheet students used to evaluate the workshop in Step 2

1.) What did you like about the workshop?	2.) What did you not like about the workshop?

3.) Do you have any suggestions for improving the workshop?

4.) How did you perceive the atmosphere in the workshop?

5.) How did you like the individual parts of the workshop?

	Did not like it at all	Rather did not like it	Rather liked it	Liked it very much
A) Sorting different living beings based on how much moral consideration they should receive.				
B) Group discussion on animal husbandry and tips for improving discussions.				
C) Theoretical input on animal experimentation.				
D) Task to evaluate two animal experiments and perform a harm-benefit analysis.				
E) Searching for questions on the human-animal relationship followed by a discussion.				

6.) To what extent do you agree with the following statements about working in your small group?

	Strongly disagree	Rather disagree	Rather agree	Strongly agree
A) In my group, everyone's opinion counted in making decisions.				
B) We had fun working on the tasks.				
C) We treated each other kindly in our group.				
D) The discussion in our group was dominated by a few individuals.				
E) I felt that my opinion was not welcome in the group.				
F) The mood in my group was negative.				

7.) Where does your knowledge about animal experimentation come from? (Multiple answers possible)

O exclusively from this workshop O from this workshop and the following sources:

O Television O Radio O Newspaper O Organizations informing on the street

O Internet O Family O Friends O School lessons

Evaluation teachers used to evaluate the teacher training program on teaching animal ethics in Step 3 and 5

Paper and pencil: Anonymous critical reflection on the topic and the teaching concept at the end of the training (paper and pencil)

1). What did you like about the workshop?

2.) What did you not like about the workshop?

3.) To what extent was the teaching material understandable and appealing?

4.) Do you have any suggestions for improvement of the lesson conception?

Online evaluation: Participants were asked to rate the questions on a 4-point Likert scale (strongly agree, rather agree, rather disagree, strongly disagree)

1. Practical Relevance

1.1) The topics covered had high relevance to professional practice.

1.2) The workshop helps me apply the topic in my professional context.

2. Preexisting Interest

2.1) I was interested in the topic before registering.

3 Open Question

3.1) Additional comments about the workshop: