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ARTICLE

'Should We Be Doing It, Should We Not Be Doing It, Who Could Be Harmed?'

Addressing Ethical Issues in Science Education

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Abstract
Many science educators have argued in favour of including socioscientific issues (SSI) in general, and ethical issues in particular, in school science. However, there have been a number of objections to this proposal, and it is widely acknowledged that such teaching places additional demands on science teachers. This study examined the curricula, textbooks and views of both student teachers and established teachers in England and in Germany regarding the teaching of ethical issues in secondary school science, particularly the ethical issues surrounding animal tests. Analysis of the curriculum documents for secondary or upper secondary school science showed that in both countries, ethical considerations feature strongly. However, in both countries, the overall treatments in the school textbooks of the ethical issues of animal testing were generally 'thin', and little opportunity was given for students to consider different ethical frameworks. The teacher and student teacher interviews revealed that interviewees generally gave ethical issues less emphasis than fundamental science. A number of interviewees referred to a lack of appropriate teaching material, and many of them also had concerns that such teaching could give rise to classroom management issues or that they might be accused of indoctrinating their students. Given the increasing acknowledgement of the need for school science to address so-called wicked socioscientific problems, these findings are a concern. We end with recommendations for curricula, for textbooks and for teacher education.

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1 Introduction

Although most scientific developments, such as the production of new medical products, more efficient batteries and genetically modified crops, come with much potential to improve our lives, they also often open the door for new ethical challenges. For instance, to what extent do wild organisms have interests that we should take account of when planting new crops? Is it justifiable to accept non-human animal suffering when conducting research on a new drug that may ultimately help humans? Consideration of such questions should not only be undertaken by scientists working in the relevant fields but also by ethicists, regulators and the broader society since the public eventually has to live with the consequences. Yet, the question of how to prepare society to deal with ethically and factually complex science-related social issues remains largely unanswered. To provide a grounding, a substantial number of science educators have called for the incorporation of school students' ethical reasoning as part of their science learning (e.g. Owens et al., 2017; Zeidler, 2014).

While the use of ethical issues in the science classroom has been shown to enable students to acquire and practice the skills to reach well-informed decisions about their future and the future of others, the current literature also shows that there are several obstacles that need to be overcome by science teachers in this respect (e.g. Borgerding & Dagistan, 2018; Bossér et al., 2015). These concerns cover both the intended curriculum (as manifested in curriculum documents, textbook materials and teacher education) and the implemented curriculum (science classroom experiences; see Kara, 2012). This paper reveals novel insights by investigating different aspects of *both* the intended and implemented curriculum regarding the implementation of ethical issues in science education (here: biology education) in *two different* countries (England and Germany). Our aim is twofold: to better understand how the two countries approach such issues and to contribute to the production of practical guidelines to inform future steps for the inclusion of ethical aspects within science teaching.

2 Theoretical Background

2.1 Should Ethics Be a Part of the Science Classroom?

The debate about whether or not the science classroom should be a place for students to explore ethical consideration is not new (e.g. Iaccarino, 2001). Two opposing positions exist, each of which is the endpoint on a continuum.

Exclusion of Ethics from Science Education Arguments that support this position often start from the claim that ethical and scientific reasoning have very different traditions and must be distinguished on epistemological grounds. From the early beginnings of the modern 'Scientific Revolution' (during the sixteenth and seventeenth centuries), scientific inquiry has often been considered to be the search for definite answers and general laws that could be verified by empirical observations and experiments. The claim is therefore made that science is about inquiring how the world *is*, while ethics concerns itself with how the world *ought to be* (Reiss, 1999).

Ethics differs from science in many ways, including the fact that whereas established science generally operates at any one time within one framework for any particular topic—for example, Neo-Darwinism for evolutionary biology, the standard model for particle physics, and plate tectonics for a range of earth science phenomena—there is no single widely accepted ethical framework. Instead, there are three principal ones: deontology, consequentialism and virtue ethics (Wood, 2020). Deontology has a focus on rights and duties. In the Western tradition, it is particularly associated with the work of Immanuel Kant in his *Groundwork of the Metaphysic of Morals* (Kant, 1785), where he argued, among other things, that humans should never be treated only as means to ends and should obey certain categorical imperatives, for example, never to lie. In consequentialism (including utilitarianism, where the benefits and harms are pleasures and pains), associated in its origins especially with Jeremy Bentham and John Stuart Mill, the way to decide whether any proposed course of action is morally right or not is to weigh up all the anticipated benefits (i.e. positive consequences) against all the anticipated harms (i.e. negative consequences). If the benefits outweigh the harms, the action is right. Virtue ethics dates back to Aristotle and puts the emphasis on the character of the moral actor. A morally good person is someone who manifests the various virtues—such as compassion, courage and prudence.

From a more practical point of view, arguments at this end of the continuum target teachers' skills. If one wants to become a science teacher, broadly speaking, a major component of one's university education will be about learning the relevant scientific content (e.g. key concepts within a domain) and science-related pedagogical content knowledge (e.g. how to adapt these key concepts for learners; see Shulman, 1986). Expecting science teachers to have sufficient ethical and pedagogical content knowledge to teach aspects of moral philosophy is somewhat optimistic (Reiss, 1999).

Inclusion of Ethics in Science Education At the other end of the continuum, many science educators advocate the inclusion of ethical aspects into science learning. Some of the main arguments for this position are as follows. First, science is conducted by scientists who are also members of societies with values and ethical principles that are at least implicit in guiding their behaviours. Science can therefore be understood as a social practice which cannot be seen as independent from the values that are shaped by society (Osborne, 2007). This cultural embedding of science could furthermore explain why students' ideas about science and the goal of scientific practices differ substantially between countries (van Griethuijsen et al., 2015). Secondly, one of the core arguments as to why ethics should be included in science education is that it helps learners to be able to make subsequent decisions about science-related social issues, such as humanity's use of fuels, water supplies and biodiversity. Making such decisions and then acting on them require ethical decision-making as well as scientific knowledge.

If ethics is to be included within school science lessons, a number of intended aims can be envisaged (Reiss, 2001). For example, if we think of teaching about the use of animals in scientific procedures, we might hope that teaching the ethics of such animal use would result in students who show greater moral sensitivity. In addition, it might motivate some of them to learn more science, for example about the different sorts of nervous systems that animals have, in attempting to determine whether fish or insects can feel pain. More generally, we might hope that teaching ethics would enhance a person's scientific literacy and ability to analyse how science can be used in real-life situations. To give another example, teaching about environmental ethics might cause students to wonder about how humans relate to and use the natural environment. In some cases, such teaching might

cause students to become not only more scientifically literate but more politically aware and engaged in public society (see Kretz, 2014).

This links to a much more student-centred perspective with regard to arguments in favour of teaching ethical aspects in science, targeting the well-documented decline of student interest in science, especially among secondary school students (e.g. Osborne et al., 2003; van Griethuijsen et al., 2015). Several explanations for this decrease of interest can be found; however, the argument that is most striking within the context of this paper claims that students seem to perceive their science learning as too out-of-touch with their real lives (e.g. Lyons, 2006). With the intention to make science learning more relevant to students, so-called socioscientific issues have received increasing attention in the field of science education (Sadler & Zeidler, 2003; Zeidler, 2014).

2.2 The Use of Socioscientific Issues in Science Education

The term 'socioscientific issues' (SSI) describes authentic and controversial problems, which also manifest a process-related and/or conceptual reference to science (Fleming, 1986; Sadler, 2011). Since SSI are located at the interface between science and society, their negotiation requires both scientific knowledge *and* normative considerations (Sadler, 2004). This includes, for example, taking into account opposing interests and various value systems that can be found in our societies. Acknowledging this pluralistic view also means accepting the multiple perspectives that are interwoven into the problem as well as the lack of a simple and clear-cut solution (Kolstø, 2006). Foregrounding the humanistic part of science, the implementation of SSI aims to empower students to contemplate the ethical dimension of science and scientific inquiry to foster students' cognitive development while equally emphasising students' moral growth (Kolstø, 2001; Sadler & Zeidler, 2003; Zeidler, 2014; Zeidler & Sadler, 2008).

Over the past few decades, several studies have documented the educational benefits that can be linked to the use of SSI within the science classroom. Implementing SSI as part of students' science learning has been found, for example, to deepen students' content knowledge (e.g. Klosterman & Sadler, 2010), to promote their decision-making (e.g. Chung et al., 2016; Saunders & Rennie, 2013), to develop their epistemic understanding (e.g. Dawson & Venville, 2010; Eastwood et al., 2012) and to advance their skills for scientific inquiry (e.g. reasoning and argumentation; Dawson & Venville, 2010). Yet, even though there is a broad consensus about the importance and benefits of addressing SSI in the science classroom, recent literature also reports an insufficient realisation of this agreement (Aikenhead, 2006; Dunlop & Veneu, 2019). As a result, 'only a small percentage seems to be including SSI in their classes on a regular basis' (Lee & Witz, 2009, p. 932). In this paper, our particular focus is on ethical issues within SSI.

2.3 Teachers' Difficulties When Implementing SSI

With rising interest in the potential of SSI for science education, more and more studies have investigated teachers' experiences, hopes and perceived difficulties when it comes to their instructional use. A central piece of work was a study by Lee et al. (2006) with Korean secondary science teachers. One of the study's major findings revealed a severe discrepancy between the perceived necessity by teachers to address SSI within the science classroom and their actual instructional behaviour. Similar discrepancies between positive

intentions mentioned by teachers to implement SSI and a lack of actual classroom instruction has been found in other international research (e.g. Kara, 2012; Levinson, 2004; Pedersen & Totten, 2001; Reis & Galvao, 2004). Building upon these insights, a number of studies have explored the different factors that impede SSI being addressed in the science classroom.

On balance, the identified factors can be assigned to two groups: external and internal challenges for science teachers. Within the first group, the identified obstacles range from those operating at an institutional level, such as a lack of support by other teachers and the faculty (e.g. Pedersen & Totten, 2001), to ones at an instructional level, such as limited instruction time and inadequate teaching material and tools (e.g. Ekborg et al., 2013; Sadler et al., 2017). In a qualitative study with teachers from four universities in England and South Africa, the obstacle of insufficient instruction time was attributed to the densely packed curriculum which left teachers with little time to discuss ethically complex issues with their students (Chikoko et al., 2011). This observation leads to a more fundamental consideration when it comes to dealing with SSI. As described in Zeidler et al. (2011), the implementation of SSI requires a 'deep restructuring' (p. 279) of how science is traditionally taught in school. This transformation process concerns underlying structures (e.g. of an institutional or cultural nature) that maintain existing hierarchies of power within the science classroom. A prominent example describes the power relationship that prevails between the teacher and his or her students: in more traditional science classrooms, the teacher usually holds an authoritative position and pursues their task of transmitting robust and accurate science content knowledge. Students, in this exaggerated portrayal, are, on the contrary, understood as rather passive consumers of non-negotiable knowledge who merely respond to the teacher's prompts and demands (see Scott et al., 2006). Teaching SSI, however, requires the opportunity for a shared exploration of these ideas. To promote an SSI-friendly classroom culture, teachers' instructions should thus support dialogic and highly engaging practices among students (Zeidler et al., 2019). This restructuring of power might lead to unfamiliar or less predictable situations for science teachers which, in turn, introduces the second group of obstacles that impede the implementation of SSI, i.e. internal factors.

Since SSI are inherently controversial and therefore often emotionally charged, one of science teachers' main concerns with regard to their implementation is to do with their self-professed lack of skill to manage students' affective reactions (e.g Day & Bryce, 2011; Levinson, 2004). Besides these pedagogical demands, addressing these normative aspects of a classroom discussion can pose additional demands on science teachers whose training often does not include teaching ethical knowledge. Another challenge with regard to the negotiation of value-laden SSI is managing one's own views. The results of a questionnaire study with about one hundred pre-service teachers pointed out, for example, that science teachers are afraid of imposing their own values on students (Kara, 2012).

3 Research Interest

Although a considerable body of research has paid attention to science teachers' challenges with regard to the implementation of SSI, previous research has largely overlooked the importance to investigate both the intended *and* implemented curriculum. In this study, we set out to address this gap by applying a more holistic approach to clarify the boundaries and possibilities when implementing ethical issues in the science classroom with the

aim to inform future steps for the inclusion of ethical aspects within science teaching. This endeavour aspires to inform future steps for the inclusion of ethical aspects within science teaching. While this study draws on data from two countries, the primary goal is not particularly to compare the countries in terms of their performance, although sometimes we will draw out contrasts between them to highlight certain conclusions. Rather, we aim to use this richness of data to conclude what can be learned from a study undertaken in more than one country.

There are many topics that might be used when teaching ethics to school students in science lessons. The topic of animal testing seems potentially to be particularly suitable as the issues (principally, putative benefits to humans on the one hand and the harms caused to sentient non-human animals on the other) are easy to understand. Furthermore, this is a topic about which many students already feel strongly, and it constitutes an effective issue to engage them with the complexity of SSI using only their existing knowledge (Garrecht et al., 2021). Then there is the advantage that the topic is 'close to home'. Issues such as tropical rainforest conservation, threats to the polar ice sheets and ocean acidification might be more frequently covered issues in the science classroom, but for many students, these are issues that take place in other countries. Animal testing, on the contrary, is widespread.

4 Methodology

This study was carried out in England and in Germany aiming to explore the implementation of ethical issues in biology education (i.e. bioethical issues) in these two different countries, each of which has a long tradition both of school science and of ethical thinking (with, for example, Germany being the home of the deontologist Kant and England of the utilitarians Bentham and Mill). The data collection comprised three successive phases (curriculum documents, textbook materials and experiences of science student teachers and science teachers) to mirror a development from policy (intended curriculum) to practice (implemented curriculum).

4.1 Phase I—Curriculum Documents

In order to explore the extent to which science curricula in Germany and England take bioethical issues into account, we examined 16 curriculum documents across both countries. For Germany, the selection of curriculum documents included the national educational standards for science education (which include biology, chemistry and physics education) as well as four biology-related curriculum documents at the federal level (Schleswig–Holstein, Nordrhein-Westfalen, Berlin and Baden-Württemberg).[1] The selection aimed to represent a geographical spread throughout the country (north, east, south and west). Three of these federal states have high population densities; the other, Schleswig–Holstein, is more rural. For England, we examined the National Curriculum for science and the biology curriculum documents published by AQA, Edexcel and OCR, the three major awarding bodies in England, preparing students for examinations

[1] In Germany, education is primarily the responsibility of the 16 independent *Bundesländer* (federal states). For more information on the structure and development of educational policy across the *Bundesländer*, see Rürup (2007).

either at age 16 (GCSE) or at age 18 (A Level). All documents refer to either secondary or upper secondary school level and were examined in their most recent edition (see Appendix 1).

Each document was read carefully to identify all passages that potentially link to bioethical considerations. All relevant passages were documented thoroughly in a separate spreadsheet, and these spreadsheets were used inductively to develop five main categories for a better visualisation of analysis results (see Table 1). To reduce potential bias, all relevant passages were coded twice by two of the authors. Differences in coding were discussed in the larger group of authors until consensus was found.

4.2 Phase II—Textbooks

Textbooks can have a significant influence on the emphasis that is applied by teachers within their lessons (Gropengießer, 2020). Therefore, 14 English and 11 German biology textbooks were analysed to examine how ethical issues have been incorporated. All selected textbooks were designed for secondary or upper secondary school levels. In Germany, most federal states have explicit guidelines that regulate which books are allowed for teaching. For the present textbook analysis, the selection included four book series that are authorised in most of Germany: Linder, Markl, Natura and Prisma. The book series Prisma was written for comprehensive schools and therefore does not include a book for upper secondary school level. For England, books that have been published by the three major awarding bodies, AQA, Edexcel and OCR, were included in the analysis (see Appendix 2).

The selection of textbook passages, which solely focused on the issue of animal testing, followed a three-step process. First, an initial keyword list was generated to screen the textbooks' indices. For this, other articles that also carried out a textbook analysis focusing on bioethical topics were used as templates (e.g. Lazarowitz & Bloch, 2005; Peters et al., 1997). Secondly, the indices of the selected textbooks were screened for additional relevant keywords. German equivalents were used for German textbooks' indices.

> **Initial keyword list**: animal research, animal testing, animal rights, genetic engineering, genetic technology, drug development, bioethics, ethics, knockout mice, transgenic, cloning, testing, stem cell research, selective breeding, xenotransplantation, dissection, vaccination, biotechnology, scientific research, (epigenetic) modification, medical research, IVF, mice as models, artificial organs, future medicine.

Using a final list of keywords, the indices of the selected textbooks as well as the textbooks themselves were screened for potential passages. In total, the review of textbooks yielded 86 passages (45 derived from English textbooks and 41 from German textbooks) that concerned animal testing in a narrow sense (e.g. the use of knockout mice in animal studies and the cloning of animals) as well as the modification of animals in a broader sense (e.g. production of monoclonal antibodies and artificial or selective breeding). Passages that did not show a link to animal testing were excluded. To examine how animal testing, as an exemplary ethical issue in biology, has been incorporated in standard teaching passages, six different criteria were developed as an analysis framework (Table 2). To increase reliability, all relevant text passages were coded at least twice by two or more authors. Differences in coding were discussed in the larger group of authors until consensus was found.

Table 1 Inductively developed categories for the analysis of curriculum documents

Main category	Sub-category	Description	Symbol	Example text passage
Content level	Content -	Topic has an ethical component but it is *not* mentioned and it is *not linked* to a value statement/ethical aspect	C-	'Clones are artificially created, genetically identical individuals'
	Content +	Topic has an ethical level and is linked to value statement/ethical aspect	C +	'Farming techniques reduce biodiversity. The balance between conservation and farming'
Theory (task level)	Theory -	Student tasks in which ethical issues are *not* explicitly mentioned	T-	'Students describe different procedures of prenatal diagnostics and reproductive techniques'
	Theory +	Students are directly asked to undertake ethical analysis or to evaluate ethical implications	T +	'Be able to evaluate the ethical implications of using untested drugs during epidemics'
Practice (task level)	Practice -	Students have to undertake practical work that would require ethical considerations but these considerations are *not* required	P-	'Students could dissect mammalian lungs, the gas exchange system of a bony fish or an insect'
	Practice +	Students have to undertake practical work that requires ethical considerations and they are explicitly asked to make these considerations	P +	'Dissect an insect to show the structure of the gas exchange system, taking into account the safe and ethical use of organisms'
Methodological considerations		Describes didactic/methods/concepts of 'good lessons', touching upon ethical considerations	M	'Specification should encourage students to: understand how society makes decisions about scientific issues'

Table 2 Developed criteria used to analyse selected biology textbooks

Category	Source	Definition	Coding
Deductive criteria			
Content	-	What is the broader theme of the passage?	Categories
Number of passages and tasks related to animal testing	-	The number of passages found within the textbooks and tasks within each passage that concerns animal testing	Number
Ethical agency	Bazzul (2015)	Are students required to undertake ethical exercises within the tasks that are related to animal testing? 1) **Direct ethical exercise**: 'Students are asked *explicitly* to recommend or defend a 'right behavior' or 'correct course of action' in terms of explicit or implicit obligations and responsibilities related to what individuals or organizations ought to do' (Bazzul, 2015, p. 28). Students are framed as ethical actors within the task (i.e. student needs to take a position, decision, or action which include something that 'should' be done or is 'correct' and relates to their (or somebody else's) explicit or implicit responsibility) 2) **Indirect ethical exercise**: Students are required to make ethical considerations regarding animal testing within the task; however, students are not asked to reflect upon the right course of action (e.g. list advantages and disadvantages of animal testing)	Direct/indirect/not applicable

Table 2 (continued)

Category	Source	Definition	Coding
Ethical frameworks	Mandal et al. (2016); Garbutt and Davies (2011)	What ethical framework is presented within the passages? **Deontological framework:** Passages coded with *Deon* show at least aspects of deontological reasoning (e.g. 'Is it right to genetically modify pigs in this way, just for our own benefit?') **Utilitarian view**: Passages coded with *Util* show at least parts of utilitarian calculations. (e.g. 'It is hoped that future developments will enable the use of animal organs and tissues for transplantation, so saving and improving the lives of many people') **Virtue ethics**: Passages coded with *Virt* refer to a morally good person in the context of animal testing. (e.g. 'At the very least it would be expected that any biologist would ensure that any animal was treated with due care and respect') **More than one framework:** Passage shows reference to at least two of the above mentioned frameworks **Not applicable**: Animal testing is either not sufficiently present to detect an ethical framework within the passage or the passage in question does not show any ethical reasoning and solely enumerates, for example, benefits for humans. (e.g. 'Pigs were modified so they had useful properties for humans, for example, faster meat growth')	Deon/Util/Virt More than one framework/not applicable
Inductive criteria			
Representation of animals		How does the passage represent animals? **No ethical considerations:** Animals are regarded as means to an end and as 'products' that can be used and modified by humans for their purposes (output focus). No ethical considerations are displayed with regards to the procedure of animal testing **Ethical considerations:** Ethical considerations are displayed with regards to the procedures of animal testing (e.g. suffering of animals and justifiability of animal testing) **Not applicable:** The representation of animals is not sufficiently presented in the passage	No ethics/ethics/not applicable
Interaction		Do tasks require a discussion *between* students about an issue connected to animal testing?	Yes/no

4.3 Phase III—Student Teacher and Teacher Interviews

To explore the extent to which ethical issues are addressed and used in practice, science student teachers and qualified science teachers from both England and Germany were interviewed. The sample ($N = 16$) consisted of four English and four German student teachers (all of them, except one, with a focus on biology) as well as three English and five German science teachers (all of them, except one, with a focus on biology). Ethical approval from the home institution and host university as well as informed consent from each participant were obtained before conducting the interviews. Ten of the sample were female and six male.

All interviewees participated in individual, semi-structured interviews that lasted about 20 to 25 min. The interviews were conducted on the basis of a predesigned interview guide, which was structured into three main parts: (i) personal background (subject background, teaching experience and understanding of bioethics), (ii) experiences with ethical issues during the teacher education programme (only applicable to the student teacher interviewees) and (iii) experiences with teaching ethical issues in the science classroom (perceived benefits, risks and challenges). For this paper, we focus particularly on the last part. All interviews were audio-taped, transcribed and processed using the software MAXQDA.

With the aim of identifying benefits, risks and challenges that are connected to the teaching of ethical issues within the science classroom, the interview data were analysed using the method of qualitative content analysis which provides for the development of deductive (i.e. from theory) and inductive (i.e. from the material) categories (Kuckartz, 2012; Mayring, 2014). In a first step of data analysis, existing literature that explored participants' experiences with ethical issues in their science teaching (e.g. Bossér et al., 2015; Kara, 2012) was reviewed and summarised for the development of deductive sub-categories. This initial set of sub-categories was thoroughly discussed by the authors. In a second, inductive step, these sub-categories were applied to the interview transcripts to either develop new sub-categories or to create finer distinctions between them. In a final step, the resulting list of sub-categories (deductive and inductive; see Table 3) was applied to all interview transcripts. In an effort to assess the reliability of the codes, about 25% of the interviews ($N = 4$) were independently coded by two coders. The inter-rater reliability was found to be adequate (Cohen's Kappa: 0.62), and all disagreements were discussed between the authors.

5 Results and Discussion

The primary purpose of this study is to explore the implementation of ethical issues in science education with a particular focus on biology in two different countries. The data collection comprised three successive phases to mirror a development from policy (intended curriculum; phases one and two) to practice (implemented curriculum; phase three). The results of the investigation are discussed with respect to each phase.

Table 3 Categories used for analysis of the interviews, with exemplary quotations

Category	Sub-category	Exemplary quotes from the interviews	Reference
Benefits	*Teacher*—motivating students (e.g. real-life connection)	'The students engage completely with it. Because they know it's something that's important, 'cause they've heard about it, outside of the classroom, and they can see that it applies to real life, at any age that they're at, they know that it does'. (Student teacher 3E)	E.g. Lee and Chang (2010)
	Teacher—decreased preparation for class	'As a teacher there's less to plan, I would say, as long as I know the structure of where it's gonna go …[1] it's more down to the kids' learning. So beneficial for me would be less planning, no marking'. (Student teacher 1E)	E.g. Kara (2012)
	Teacher—building student–teacher relationships (e.g. getting to know the students on equal terms)	'I think these are the moments, the key moments where you build relationships with your students'. (Student teacher 4E) 'Das ist halt auch einfach interessant wie … noch so ein bisschen mehr über die zu erfahren'. (Student teacher 1G)	Inductive
	Students—becoming scientifically literate citizens (e.g. critical thinking, evaluation of media content and the nature of science)	'It does add in terms of them being … making them more scientifically literate citizens in a world where science is increasingly, you know, part of everyday life and an understanding of science at some level is important. Thinking about the issues in the world whether that be euthanasia, population growth, climate change, energy etc. etc. etc.'. (Teacher 3E)	E.g. Cross and Price (1996); Lee and Chang (2010)
	Students—becoming democratic citizens (e.g. building communicative competence to participate in democracy)	'Halt einfach so Sachen für's Leben lernen, wie argumentieren und halt einfach an gesellschaftlichen Diskussionen teilzuhaben […] einfach begründet seine Meinung kundtun'. (Student teacher 1G) They will need to know how to have these discussions, which correct vocabulary to use and phrases […]'. (Student teacher 4E)	E.g. Stradling (1984)
	Teacher—personal motivation (e.g. learning new things themselves, talking about things that matter to them)	You know, it gets boring teaching Newton's Laws a lot. So doing something a bit different, challenging myself, forcing myself to learn new things, kind of gives you a little bit of confidence about other areas as well'. (Teacher 1E)	E.g, Day and Bryce (2011)
	Students—fostering socioscientific decision-making (e.g. come to conclusion based on different arguments; acknowledge different viewpoints)	'[…] dass sie natürlich in der Lage sind, aufgrund ihres Wissens und aufgrund ihrer Erfahrung Handlungsoptionen für ihr Leben zu finden. Das heißt sich selbst natürlich nicht nur aufgrund persönlicher Einstellungen, sondern auch aufgrund von echten Fakten zum Beispiel auch zu orientieren und dann Entscheidungen zu treffen und das heißt, das betrifft die Bewertungskompetenz […]' (Teacher 5G) 'I want them to have all the facts in front of them, that's the, the hard bit, making sure they do have every bit of information in front of them so they can make their own judgements'. (Student teacher 2E)	E.g. Kara (2012)
Risks	*Teacher*—repercussions from parents/society/groups, including legal repercussions	'I mean with the climate change protests, like I'd love to be like "Go! Strike!" […] but would I lose my job?' (Student teacher 1E)	E.g. Borgerding and Dagistan (2018)

Table 3 (continued)

Category	Sub-category	Exemplary quotes from the interviews	Reference
	Teacher—not reaching predetermined learning goals (e.g. students leaving with 'wrong' point of view, that there is no real outcome at the end of the lesson)	'Wie ich's schaffe, nachher das Ergebnis zu haben, was ich mir vorher ausgedacht habe?' (Student teacher 1G) 'One big risk that I come across daily is students still leaving with misconceptions. […] and every now and then I see one student kind of like switch off at that point and I'm like, "Oh no, I've just given them the wrong point of view"' (Teacher 2E)	Inductive
	Students—indoctrination	'I wasn't sure to what extent I wanted to scaffold it without … forcing any opinions on them. I wanted them, I want them to be free to make their own judgement'. (Student teacher 2E)	E.g. Kara (2012)
	Students—reactions and interactions (e.g. classroom dynamics and power relationships; students voicing strong opinions, students feeling offended)	'There's a definite risk of that, you have to be quite wary of making sure that kids aren't just shouting their opinions, but it's something that they can justify and back up'. (Student teacher 3E) 'Aber wie sich jetzt die Schüler untereinander verstehen, ob die sich trauen ihre Meinung offen zu sagen, ob die mir als Lehrkraft vertrauen, wie das Miteinander, einfach der Umgang untereinander ist'. (Student teacher 1G) 'But you don't want it to get out of hand either, 'cause you, there are kids who will throw wild comments out there'. (Student teacher 2E)	E.g. Bossér et al. (2015)
Challenges	*Internal*—teachers' lack of content, professional and/or methodological knowledge or experience	'I think having the knowledge, ehm, you have to be quite knowledgeable about the subject … both scientifically and socially, in order to guide the debate, and because you have to provide that balanced argument […] you're going in with your own bias'. (Student teacher 3E)	E.g. Borgerding and Dagistan (2018)
	External—lack of (appropriate) material	'Das fehlt aber auch noch oft als Unterrichtsmaterial. Also das muss man alles selber erstellen und das ist teilweise schwierig'. (Teacher 1G) 'The content that is provided for us, the stuff we've purchased and brought in, quite often it's quite dry'. (Teacher 2E)	E.g. Kara (2012)
	External—lack of time	'Ich glaube oder befürchte, das geht echt oft unter, […] stellst fest 'Verdammt, das Halbjahr ist vorbei' und ich glaub das sind dann tatsächlich leider oft die Themen, die dann entweder zu kurz kommen oder eben ganz unter den Tisch fallen'. (Teacher 2G)	E.g. Pedersen and Totten (2001)
	External—inadequate circumstances (e.g. lack of support from school, challenging group size or inadequate age)	'[…] und das ist halt einfach schwierig, weil du ja auch teilweise 30 Kinder in der Klasse hast und dann … so 20 davon, für die passt das vielleicht total gut. Für 5 kommt's schon zu spät und für 5 ist es eigentlich noch zu früh'. (Teacher 2G)	E.g. Kara (2012)

Table 3 (continued)

Category	Sub-category	Exemplary quotes from the interviews	Reference
	Internal—teachers' methods to facilitating independent learning (e.g. problem-based learning)	'To stop it just descending into an all-out riot you might have like a talking stick or something. Or a student will come to the front of the class trying to keep it very managed. Also ensuring that maybe the kids don't pick what side of the argument they're on but you actually get them to go into groups'. (Student teacher 3E)	E.g. Bossér et al. (2015)
	External—assessing students' prior knowledge and providing necessary content/methodological knowledge to enable student to engage in a discussion	'But you also need to have quite a good understanding of the biology to have an informed debate or discussion. So, I think if you just drop it into a lesson as a "oh, and what do you think about genetic engineering?" without exploring different ideas about it then it is a bit of a waste of time'. (Teacher 3E)	E.g. Ekborg et al. (2013)

[1]Within the table, […] indicates that a passage has been omitted and … indicates that the interviewee paused

Table 4 Comparison of the English and German science and biology curricula

Curriculum	P-	P+	T-	T+	C-	C+	M
English	13	18	31	60	12	20	18
German	0	0	19	28	28	17	44

5.1 Phase I—Curriculum Documents

Sixteen curriculum documents from England and Germany were analysed using seven inductively developed criteria to explore the extent to which the science and particularly biology curricula take ethical issues into account. Results can be found in Table 4; four particular insights will be discussed below.

No references to practical work (P+/P−) were found in German biology-related curriculum documents. In the English biology-related curriculum documents, ethical considerations in the context of practical tasks are found rather frequently.

As part of the English examinations at age 16 and 18, students are required to demonstrate their knowledge and understanding of scientific experimentation. As concluded in Childs and Baird (2020), practical work is regarded as an important teaching and learning component within English science classrooms. However, as these authors note the required practical work primarily focuses on conducting experiments, while the conceptual planning and development of experiments have a rather limited role. As a result, students' scientific inquiry, which extends from the design process to the evaluation as well as developing an understanding about the inquiry (i.e. nature of science; see Abd-El-Khalick et al., 2004), is not promoted holistically due to this 'cook book recipe-like format' (Childs & Baird, 2020, p 373). Scientific inquiry is one of the four competence areas in the German science curriculum (*Erkenntnisgewinnung*). Yet, in contrast to England, questions on practical tasks are not mandatory in Germany's final examinations, and teachers have relatively free choice of when and how to use practical tasks within the science classroom (e.g. Kultusministerkonferenz, 2005, 2020), which might explain the lack of evidence found within our analysis.

In the German curricula, the most common code refers to methodological considerations (M), while in the English curricula, the most common code refers to students being asked to undertake an ethical analysis (T+).

Twenty years ago, in the wake of the mediocre to poor performance of German students in the Programme for International Student Assessment (PISA), the debate concerning the aims and outcomes of German science education amplified (Bögeholz et al., 2017; Kiper & Kattmann, 2003). Fuelled by the publicly expressed concerns about the effectiveness of the German education system, the understanding of 'efficient' science education grew beyond mere knowledge transmission (i.e. Vision I; input-orientation) towards an understanding of science literacy that promotes the acquisition and utilisation of competencies (i.e. Vision II; output-orientation; Moschner, 2003). For science education, four distinctive competence areas have been released with one of the four (*Bewerten*; socioscientific decision-making in the following) explicitly acknowledging students' ethical considerations as part of their science learning (see also Hostenbach et al., 2011). This historic development might explain the predominance of methodological considerations intended to provide teachers with

guidance for planning and designing their lessons to promote the development of competencies. In contrast, the English curricula address ethical issues largely at a task level, requiring students to undertake ethical analysis or to evaluate ethical implications of particular topics (e.g. evaluate the use of stem cells and understand ethical and economic reasons).

It is clear that the German and English curricula differ greatly in their structure and overall nature. Comparing these curricula should thus be done with caution. The data provide preliminary evidence that ethical considerations are considered an inherent part of science education in both countries. Whereas the German curricula situate ethical reasoning in the broader context of promoting the competence area of socioscientific decision-making, the English curricula orient ethical debate along specific content or practices.

5.2 Phase II—Textbooks

Following a three-step process, 86 passages were identified that referred to animal testing. Six criteria were developed for the analysis of these passages, and the results are presented in Table 5.

Since textbooks are built upon the curricular guidelines of each country, they can be understood as a link between policy (intended curriculum) and practice (implemented curriculum; Valverde et al., 2002). In phase II, we analysed 86 passages that focused on the issue of animal testing. From a more general point of view, the analysis of data suggests that while we analysed roughly the same number of passages in the English (45 passages) and German (41 passages) textbooks, the passages within the English textbooks displayed more than twice as many tasks that concern animal testing (28 versus 12). Typically, the tasks in the English textbooks introduced the content in smaller steps, whereas the tasks within the German passages appeared to give a broader overview. In the following, findings of each category will be briefly discussed.

5.2.1 Ethical Frameworks

Especially with regard to the German textbooks, only a few passages required students to ponder the ethical stance of animal testing. The large majority of the analysed passages merely scratch the surface by indicating what could function as a door opener for a deeper discussion (e.g. ‘Pigs were modified so they had useful properties for humans’.). This finding suggests that the guiding of students’ ethical considerations is not yet sufficiently embedded in German biology textbooks. Similar results were found in a study by Mikelskis-Seifert et al. (2013), who analysed 9178 tasks (i.e. instruction for students on what to do) of 19 German textbooks. In total, only about 1% of the analysed tasks required students to explore their personal view and to conclude an opinion on the issue under debate. Both findings suggest that teachers should be open to adapt passages or to use other resources besides the traditional textbook to adequately support students in pondering the ethical stance of animal testing.

With regard to the English textbooks, several passages contained arguments that could be assigned to at least two different ethical frameworks. As discussed in Saunders and Rennie (2013), great worth is seen in adapting such a pluralist approach, because using and acknowledging different frameworks can be important to develop one’s own reasoning and also to understand where other people are coming from. Broadening students’ views

Table 5 Comparison of the English and German textbook passages

Category		English textbooks		German textbooks	
Content		Genetic engineering (e.g. stem cell research; cloning) (21) Breeding and artificial selection (5) Medical research (e.g. vaccination and drug development) (13) Transplantation (also xenotransplantation) (3) Preparation of animals for practical work (e.g. dissection) (2) Ethics (2)		Genetic engineering (e.g. stem cell research; cloning) (18) Breeding and artificial selection (5) Medical research (e.g. vaccination and drug development) (12) Transplantation (also xenotransplantation) (0) Preparation of animals for practical work (e.g. dissection) (3) Ethics (1)	
Number of passages (and tasks) related to animal testing		45 (28)		41 (12)	
Ethical agency		Direct: 7	Indirect: 21	Direct: 1	Indirect: 11
Ethical frameworks	Deon	13		0	
	Util	19		7	
	Virt	1		1	
	More than one framework	9		1	
	Not applicable	22		34	
Representation of animals	No ethics	23		31	
	Ethics	16		1	
	Not applicable	6		9	
Interaction		Yes: 2	No: 42	Yes: 1	No: 40

concerning different approaches to and opinions about this topic might be especially valuable since animal testing is often presented as being a straightforward ethical issue.

5.2.2 Ethical Agency

The degree of ethical agency can be derived from two types of questions. Direct ethical questions, according to Bazzul (2015), frame students as ethical actors 'where students are actually led to decide on a course of action' (pp. 26–27). Indirect ethical questions require students 'solely' to consider different perspectives and ethical implications without actually deciding what ought to be done. The results of our data analysis provide convincing evidence that neither the English nor the German textbook tasks require students to elaborate many direct questions, i.e. deliberate on what ought to be done. In turn, a large majority of tasks required students merely to list the main advantages or disadvantages of using animals or particular techniques in research or to explain why animal testing is considered an ethical issue.

While textbooks will not be the only source of information for young people, they can play an important role in framing students' perspective on particular issues (e.g. Hussein, 2018; Román & Busch, 2016). For example, in a study by Morris (2014), who also analysed English science textbooks, it was concluded with regard to the issues of genetic technology and climate change that perspectives from the social science disciplines have hardly been recognised. Such a limited view could be a barrier for students to appreciate the different perspectives on the issue under debate. While animal testing constitutes an effective issue to engage students with the complexity of SSI (Garrecht et al., 2021), the analysis revealed that this possibility was not sufficiently exploited in the textbooks studied.

5.2.3 Representation of Animals

Not only have animals played a major role in the history of biological breakthroughs, they can also be found in the science classroom (e.g. during dissection, as preserved animals or as classroom pets). Yet, the ethical consequences of using animals thus have received very little consideration in the science education literature (Mueller et al., 2017). This low level of attention seems also to be reflected in the biology textbooks used in school, as indicated by our findings, with a majority of passages only representing animals as a means to an end for human purposes. Similar results were found in a recent South Korean geography textbook study, where animals were mostly represented as a passive component of the natural environment (Cho et al., 2020). Such one-sided representations possibly limit students' development of a critical view regarding how we use animals and might be another reason why many students experience difficulties in attempting to elaborate on their views in the debate about animal testing (Dias & Guedes, 2018).

5.2.4 Student Interactions

While traditionally much of the interaction in the classroom is between the teacher and their students (see Lemke, 1990), the interaction *among* students can be of particular relevance for meaning making (or consensus finding) in an ethical discussion. Allowing this more dialogic discourse in the classroom gives students an opportunity to develop, argue and justify their ideas, concerns and views (see Duschl & Osborne, 2002). Yet, the analysis suggests that hardly any of the textbook passages, neither in the English nor the German

textbooks, provide for students' interaction. While discourse and interaction are key components of socioscientific decision-making, one explanation for the lack of respective tasks could be that, in contrast to the other competence areas, socioscientific decision-making illustrates a fairly novel area within the German context (Bernholt et al., 2012). Its conceptualisation and assessment is therefore still a major concern for the science education community. Socioscientific decision-making has been in English science curricula for longer, but in common with many other countries, there are a number of challenges to its implementation (Chen & Xiao, 2021).

The findings provide evidence that in both countries, students' ethical elaborations are addressed rather rarely in biology textbooks, as illustrated by the example of animal testing. While it is impossible to draw direct conclusions about teaching on the basis of a textbook analysis, textbooks continue to be considered the favourite material by many teachers (see Gropengießer, 2020).

5.3 Phase 3—Student Teacher and Teacher Interviews

To explore the benefits, risks and challenges connected to teaching ethical issues in the science classroom, 16 interviews with science student teachers and qualified teachers with a special focus on biology from both England and Germany were analysed (see Table 6).

To structure the interview results, we will address three different stages: First, the challenges that apply to the *preparation* of the lessons will be discussed. Then, the benefits, risks and challenges that apply *while* teaching the lessons will be considered. Finally, we discuss the benefits and risks that *result* from having taught bioethical issues in the science classroom.

5.3.1 Preparation of the Lessons

The analysis of interview data revealed that during the preparation of a lesson covering an ethical issue, the interviewees were mostly concerned about shortcomings at both a macro (curriculum) and a micro level (lack of appropriate material).

On a macro level, the results from phase 1 provide evidence that ethical considerations are considered an inherent part of science education in both countries. While almost all interviewees indicated that they were aware that ethical issues are an aspect of the curriculum, many communicated that they put the emphasis on teaching students the fundamental ideas, content and skills necessary for scientific inquiry. One possible explanation that emerged from our data is that many participants view students' content knowledge as the basis of every scientific discourse. In other words, students *need* a good understanding of the biology to 'have a really well-founded discussion, which is what we would actually like, then they simply need a basis that is, of course, also based on a lot of content knowledge' (Teacher 2G),[2] as similarly noted by Lee and Witz (2009). As one teacher puts it, an ethical discourse 'doesn't actually add anything to the core objective of enabling the children to pass their science exams' (Teacher 3E). This latter statement further ties in well with Bencze and Carter's review (2011), which argues that traditional science education occurs to generate two types of students: knowledge producers (i.e. those who produce economic goods and services) and consumers (i.e. those who consume economic goods and services). Following this line of reasoning, it does not seem far-fetched that some interviewees in our study saw their role as teachers as preparing 'successful' students in the sense of producing a scientific

[2] In the discussion, German quotes are translated into English for readability.

Table 6 Results of interview category analysis

Main category	Sub-category	Total number of codes (Eng/Ger)	Number of interviewees who mention this sub-category
Benefits (of implementing SSI in the science classroom)	*Teacher*—motivating students	32 (18/14)	15
	Teacher—decreased preparation for class	1 (1/0)	1
	Teacher—building student–teacher relationship	10 (5/5)	8
	Students—becoming scientifically literate citizens	16 (8/8)	11
	Students—becoming democratic citizens	3 (2/1)	3
	Teacher—personal intrinsic motivation	11 (4/7)	9
	Students—fostering decision-making skills	35 (11/24)	13
Risks (of implementing SSI in the science classroom)	*Teacher*—repercussions from parents/society/groups	10 (5/5)	8
	Teacher—not reaching predetermined learning goals	10 (3/7)	8
	Students—indoctrination	16 (6/10)	10
	Students—reactions and interactions	38 (17/21)	13
Challenges (obstacles that need to be overcome in order to implement SSI in the science classroom)	*Internal*—teachers' lack of content, professional and/or methodological knowledge or experience	22 (13/9)	9
	External—lack of (appropriate) material	8 (2/6)	7
	External—lack of time	18 (8/10)	11
	External—inadequate circumstances	18 (7/11)	10
	Internal—teachers' methods to facilitate independent learning	15 (6/10)	11
	External—assessing students' prior knowledge and providing necessary content/methodological knowledge to enable students to engage in a discussion	19 (6/13)	8

workforce (see also Wallace, 2018). Dealing with ethical issues, as an aspect of science education that aligns with Vision II, would therefore often fall short.

> It is, and every time in the classroom where these opportunities come to have this debate about ethics, religion whatever, I have to cut it short. I have to say this is a science classroom, we are learning science because I have a million other things to go through with them within one hour. (Student teacher 4E)
> I think or fear that this often gets forgotten […] and I think that unfortunately these are often the topics that either get short shrift or fall completely under the table. (Teacher 2G)

This perceived pressure to teach science mainly according to Vision I already exists at the beginning of the teaching profession (Kara, 2012). Similar to our results, a lack of time and the pressure to cover the required content of the science curriculum were identified by pre-service biology teachers as severe factors that impede addressing ethical issues in the science classroom. Another explanation for this focus, as discussed by some interviewees in our study, could be that the outcomes of ethical discourses are more difficult to assess than the learning of content knowledge.

On a micro level, the overall school ethos and colleagues seem to impact teachers regarding the incorporation of ethical issues. The large majority of interviewed teachers described a supportive school environment, highlighting that they feel free in designing their lessons, whereas one interviewee emphasised that his school is:

> […] definitely more focused on the academic – sort of more, yeah the more fact-based, academically-practical-based side of things. It is not saying that they are not interested. It's just not something that really we've been pushed in particular. (Teacher 1E)

Some of the participants stated that ethical issues could be discussed in more depth with their science colleagues, while several advocated stronger collaboration between teachers (disciplinary and interdisciplinary, e.g. religion and biology). Considering the many positive aspects that have been observed in the context of collaborative teaching, e.g. increased collegiality and efficiency among teachers and improved understanding and performance among students (Vangrieken et al., 2015), SSI can be interpreted as valuable door openers since they inherently incorporate different viewpoints that make interdisciplinary exchange more natural for both the teacher and the learner.

Another concern mentioned by several interviewees with regard to the preparation of their ethics-related lessons addressed the lack of appropriate teaching material. The existing teaching material was described as 'quite dry' (Teacher 2E) and 'mostly mundane and standardised' (Teacher 5G), a point also made by other teachers. As a result, teachers spent time looking for or designing material for these lessons. Many participants also admitted that teaching ethical issues requires them to refresh their own knowledge which requires increased preparation effort.

> I had to do quite a lot of research prior to it, to make sure that I'm well informed on the issues and especially because bioethics, generally the scientific ethics, tends to be about things that are at the cutting edge of science, almost by definition. You've got to make sure you are well read. It is no use me churning out my knowledge on stem cell research that might be 10 years out of date. So, my experience was sort of needing a lot of research, putting in a lot of planning and preparation time. (Teacher 1E)

Unexpectedly, while for some interviewees it was this additional effort that made them fear they might not have sufficient knowledge of the science subject matter under debate, it was the same additional effort that was mentioned by other interviewees as motivation to teach ethical issues in science. Such teachers felt they would learn new things to broaden their horizons, and do something different for a change, because it 'gets boring teaching Newton's Law a lot' (Teacher 1E). This finding connects to recent studies on the impact of teachers' mindsets on their teaching and, consequently, students' learning (e.g. Frondozo et al., 2020). Our insights add to the current SSI-based research on teachers' motives (e.g. Ekborg et al., 2013), indicating that a teacher's mindset (belief about the malleability of their own learning and teaching ability) might play a role in whether or not ethical issues are addressed in the science classroom.

5.3.2 Teaching Bioethical Issues

The data analysis showed that interviewees communicated a range of risks and challenges about teaching ethical issues that included both their own and students' shortage of knowledge and skills.

The most frequently found concern that teachers mentioned regarding their own practice was that of not being knowledgeable enough (see also Forbes & Davis, 2008). In our study, this 'lack of knowledge' included both insufficient content knowledge and insufficient experience regarding suitable methodological approaches.

> In my experience, I can describe it in such a way that I would like to say that when I tried to teach such topics at the very beginning, perhaps even before my traineeship, and of course I didn't have a clear … idea of 'how to proceed with this', the whole approach and the results turn out relatively flat. (Teacher 5G)
> Like I said, it requires quite a lot of independent research and I know, there are certain areas that I would feel more comfortable having had some training or even just some talks about and I know it's the same for my colleagues. (Teacher 1E)

A possible explanation could be that these issues were insufficiently addressed in their teacher education programme as reported by the large majority of interviewed student teachers. As a result, several interviewees communicated that they did not feel prepared to teach such issues, especially with regard to the methodological challenges. Similar to the results of other studies that explored the challenges faced by teachers when implementing SSI (e.g. Bossér et al., 2015), this study yields evidence advocating for a stronger anchoring of ethical topics as part of teacher education programmes. Besides their concern of not being knowledgeable enough themselves, the interviewees also mentioned that they are concerned that students are not knowledgeable enough to partake in these open discussions. This was either because of students' inadequate procedural knowledge about how, for example, to behave during a discussion or their insufficient content knowledge about the issue under debate.

This perceived insecurity by teachers (for their own and their students' capabilities) goes hand in hand with another insight that became apparent from the data: teachers' concerns about classroom dynamics during ethical debates. 'Students' reactions and interactions' was not only the most prevalent code within this study but also comprised four different aspects of teachers' fear of losing control over the situation: dealing with extreme viewpoints and offensive behaviour, protecting students and their feelings, managing students' interactions as a group (e.g. classroom climate and bullying) and teachers' vulnerability (e.g. what

students' think of the teacher's viewpoint). All of these aspects, to a differing degree, reflect teachers' wish to feel safe and in control of the situation, thus touching on the existing power relationships in the classroom. Unlike the elaboration of well-structured problems within the traditional science education framework, the elaboration of SSI provides neither a single nor a clear-cut solution (Zeidler, 2014). This reduction in control (e.g. regarding the preparation or the course of a lesson) might be challenging for science teachers on two levels. First, several studies point to the fact that many science teachers hold naïve views of science (e.g. existence of a universal method that can be applied to reach conclusion; Erdas Kartal et al., 2018; Lederman & Lederman, 2014), concluding that these teachers might struggle with the lack of control due to the open-endedness of these issues. Secondly, bringing SSI to the classroom means recognising and accommodating students' diverse set of knowledge, values and experiences (Chang Rundgren & Rundgren, 2010). SSI instruction, therefore, demands a certain degree of openness concerning the course of discussion as well as the willingness to allow students some control over their learning experience. Contrarily, several research endeavours, such as the study by Day and Bryce (2011), reveal that science teachers seem to hold onto a strong classification of science and feel less comfortable engaging in open-ended inquiry compared to their colleagues from the humanities (see also Lee & Yang, 2019; Vázquez-Bernal et al., 2021). As a result, discussions are still a rather unusual practice in the science classroom, and students often lack opportunities for practice (e.g. Driver et al., 2000; Duschl & Osborne, 2002; Reis & Galvao, 2009).

The same mechanism, namely the wish to be in control of the situation, might explain another concern that was highlighted by the interviews: not reaching a predetermined learning goal. A handful of interviewees reported that they were afraid that science lessons that include ethical debates either turn into babbling without any measurable outcome, which also connects to the lack of suitable assessment methods for ethical issues in the science classroom (see Tidemand & Nielsen, 2017), or that students leave the classroom with the 'wrong' point of view.

> […] how I manage to have the result afterwards, what I also – what I have planned before. It's easier with to do with scientific topics; I don't know, you're supposed to work out the leaf structure or microscope it or whatever and work it out. Then, then I can control it relatively well what the students should take away from the lesson as an output, I would say. I find it more difficult with bioethical topics to reach, I would say, a consensus that I, as a teacher, would like to see. (Student teacher 1G)

Consequences from Having Taught Bioethical Issues Regarding the consequences of teaching bioethical issues in a science classroom, the most prevalent ideas concerned the opportunity to motivate students (for science).

> Because they know it's something that's important, 'cause they've heard about it, outside of the classroom, and they can see that it applies to real life, at any age that they're at, they know that it does. And once you show – once you put a newspaper headline up on the board, even if they haven't heard about, they go 'uh, it's in the news, it must be an important thing'. So that immediately kind of engages them and it's then I'm taking a scientific concept and applying it to the outside world as well, so, for them, they see it as a real – it's not just a classroom subject, it's an actual real life subject. So, they get involved completely, they enjoy it, they often want to keep going and you're trying to get them out of the room by the end of the lesson. (Student Teacher 3E)

Expanding the findings from Tidemand and Nielsen (2017), the interviewees of our study did not so much use SSI to deliver biological—otherwise abstract—content in an exciting and for students relatable way but described them as suitable spaces to let students ponder their own stance on current scientific developments. Highlighting this, the implementation of ethical issues was also used as an opportunity to prepare students as future citizens. In this context, the interviews revealed two aspects of citizenship that SSI can help with: students becoming scientifically literacy citizens (e.g. students are able to evaluate scientific information displayed in the media) and students becoming democratic citizens (e.g. communicative skills to participate in societal decisions). As a result, teaching ethics in science is perceived to assist students to deal with society when they are in positions that require them to be responsible:

> That's what … we want to educate the students to be, that they are informed citizens and they can only evaluate an article about a new research method if they have practised it at some point. (Teacher 1G)

Students' societal empowerment as described above was mentioned by a majority of interviewees as strongly related to promoting students' socioscientific decision-making. In this sense, socioscientific decision-making was interpreted by some interviewees as a 'major element of being a citizen in a democratic society' (Tal et al., 2011, p. 12). Promoting socioscientific decision-making comprised different aspects of the decision-making process—from the role of values, to considering different points of views, to sharpening the awareness of not forcing opinions on anybody else. In the German context, interviewees frequently referred to the educational reforms discussed earlier, with one of the four competence areas acknowledging students' ethical considerations as part of their science learning (see also Hostenbach et al., 2011).

Last but not least, one of the main benefits perceived by the participants of this study was the potential of such issues for the student–teacher relationship. This was described in terms of the opportunities to get to know students on a personal but also professional level (e.g. their current learning performance). In addition, the open-ended and ill-structured nature of SSI dismissed the 'traditional' right-and-wrong-thinking of the science classroom, leaving room for mutual and genuine learning:

> There's the opportunity to build strong positive relationships with your students because you're kind of showing that 'okay I value your opinion, I trust your opinion'. It might be that, you know, I'm 32 and you are ... whatever age you are, 13, but we can still have a – you can talk to them and you can respect their views as adults […] (Teacher 1E)

Besides the range of positive effects of introducing ethical issues into the classroom, some participants referred to their role as an unbiased teacher, talking about their insecurities regarding how to withhold one's own opinions, so as not to influence students in their thinking:

> I guess I kind of come back to my point before about not wanting to [...] put preconceived ideas into their mind. (Student Teacher 2E)

Potentially as a result, several interviewees shared their fear of facing (legal) repercussions, for example, from students' parents (e.g. is parental consent required before teaching controversial topics such as the issue of abortion?). One student teacher mentioned that she is well aware that she is 'not just speaking to the students, you're also speaking to home […] so I find the risks outweigh the benefits' (Student Teacher 4E).

6 Summary and Concluding Recommendations

Many science educators have argued in favour of including socioscientific issues (SSI) in general, and ethical issues in particular, in school science. However, there have been a number of objections to this proposal, and it is widely acknowledged that such teaching places additional demands on science teachers. Our study examined the curricula, textbooks and views of both student and established teachers in England and in Germany regarding the teaching of ethical issues in secondary school science, particularly the ethical issues surrounding animal tests.

Our examination of the curriculum documents for secondary or upper secondary school science showed that in both countries ethical considerations feature strongly. In England, with its long tradition of practical work, students are quite often expected to address ethical issues in the context of practical work they undertake. In Germany, teachers were provided with guidance for planning and designing their lessons, whereas in England, the emphasis was more on students undertaking ethical analyses or evaluating the ethical implications of particular topics.

While there were differences between the English and German textbooks, in both countries, the overall treatments of the ethical issues of animal testing were generally 'thin', and little opportunity was given for students to consider different ethical frameworks. Many opportunities were missed to help students to engage more deeply with the issues. Given the importance of textbooks, this finding is worrying.

The teacher and student teacher interviews revealed that while interviewees were aware of the inclusion of ethical issues in the curriculum, they generally gave this less emphasis than fundamental science, though some warmly welcomed the requirement to address ethical issues in their teaching. However, a number of interviewees referred to the lack of appropriate teaching material. Many also had concerns that such teaching could give rise to classroom management issues or that they might be accused of indoctrinating their students.

Overall, it is clear that there is a considerable gap for many teachers and student teachers between the intentions of the curriculum with regard to the teaching of ethical issues in school science and what they feel is feasible. Given the increasing acknowledgement of the need for school science to address so-called wicked socioscientific problems, this is a concern.

We recommend that:

- Curricula should be more explicit about what they require with regard to the inclusion of ethical issues in science topics.
- Textbooks should introduce and exemplify a range of ethical frameworks that can be used by students in the ethical analysis of socioscientific issues. They should also provide more focused tasks for students, including ones where students are expected to articulate and defend their views and possible actions that both they and society might take.
- Teacher education should do more to help science teachers to address ethical issues in school science lessons.

7 Limitations and Further Research

There are several limitations that should be considered when interpreting the results of this study.

First, the comparison of curricula undertaken as part of this study does not aspire to be comprehensive and only addresses a narrowly focused question, limiting the results' generalisability regarding other aspects of the studied curricula. Although we found differences within the presentation and weighting of content, it is almost impossible to predict to what extent these variations will lead to differences in students' learning, since the time frame over which the curricula are supposed to affect students' learning is too long. Besides, other variables such as teaching experience and teaching preferences also influence the implementation of the curriculum in the classroom. By investigating the contexts of German and English science teachers and their available material, on a more general note, this study can only give a limited insight. With ethical issues being relevant to *all* citizens, future studies should also explore the implementation of ethical issues in science education in other parts of the world.

Secondly, the analysis of textbooks focused on an exemplary and yet very specific topic of animal testing. While animal-related issues seem to be emotionally salient for students (see Reiss, 2017), other animal-related SSI closer to students' everyday experiences (e.g. diet and factory farming) might be more prominent in biology textbooks and potentially show more ethical points of reference. A follow-up study should clarify the presence of ethical considerations for other animal-related SSI and also broaden the cultural view by analysing textbooks that are used in countries that do not follow Western traditions. Besides, we acknowledge that in a textbook analysis only the textbooks themselves are examined, but not how they influence and affect students (Gropengießer, 2020). Therefore, no direct conclusions can be drawn about students' learning from the textbook analysis.

Thirdly, in qualitative research, coding describes the process of purposively breaking down data to make sense of them in relation to one's research interest (Elliott, 2018). In this study, some categories (e.g. ethical agency and interaction) were more straightforward to code than others. The category of ethical framework presented us with a number of challenges (e.g. where do we draw the line about whether something is coded as being part of a utilitarian calculation and when is it too thin so to be thus coded?), leading to intensive discussions and several revisions of the analysis scheme before we reached a high degree of consensus within the research team. Last but not least, this work refers to document insights (curricula and textbooks) as well as interviewees' self-reported behaviours. Further work needs to be undertaken to establish what teachers teach and what students learn.

Appendix 1

Table 7

Table 7 Curriculum documents used for the data analysis

English documents	German documents
The National Curriculum in England – Key Stage 3 and 4 framework document Section: Science (2014)	Bildungsstandards im Fach Biologie für den Mittleren Schulabschluss (KMK, 2005)
AQA: GCSE Biology (2016)	Bildungsstandards im Fach Biologie für die Allgemeine Hochschulreife (KMK, 2020)
AQA: AS and A-Level Biology (2017)	Fachanforderungen Biologie: Sekundarstufe I und II (Schleswig–Holstein; 2019)
Edexcel: A Level Biology B (2018)	Bildungsplan des Gymnasiums: Biologie (Baden-Württemberg; 2016)
Edexcel: GCSE Biology (2018)	Rahmenlehrplan für die gymnasiale Oberstufe: Biologie (Berlin; 2006)
OCR: Biology A Level – Biology B (2018)	Rahmenlehrplan für die Jahrgangsstufen 7–10: Biologie (Berlin; 2015)
OCR: Biology A Level – Biology A (2020)	Kernlehrplan für die Sekundarstufe I Gymnasium in Nordrhein-Westfalen: Biologie (Nordrhein-Westfalen; 2019)
OCR: GCSE in Biology A (2020)	Kernlehrplan für die Sekundarstufe II Gymnasium / Gesamtschule in Nordrhein-Westfalen: Biologie (Nordrhein-Westfalen; 2013)

Appendix 2

Table 8

Table 8 List of English and German biology textbooks used for analysis

English textbooks	German textbooks
Edexcel A level: Biology 1 (includes AS level) Lees et al. (2015a)	*Linder Biologie SII: Gesamtband* Bayrhuber et al. (2019)
Edexcel A level: Biology 2 Lees et al. (2015b)	*Linder Biologie SI: 5.-6. Schuljahr* Erdmannet al. (2008)
Edexcel AS/A level: Biology B1 Fullick (2015)	*Linder Biologie SI: 7.-10. Schuljahr* Konopka et al. (2009)
Edexcel A level: Biology B2 Fullick (2015b)	*NATURA: Biologie für Gymnasien. Oberstufe* Becker et al. (2012)
Biology 1 for OCR Jones (2007)	*NATURA 1: Biologie für Gymnasien* Baack et al. (2013)
Biology 2 for OCR Jones (2008)	*NATURA 2* Becker et al. (2014)
OCR A Level Biology 2 Fosbery et al. (2016)	*MARKL Biologie 1* Markl and Gauß (2014)
OCR Biology A2 Hocking et al. (2008)	*MARKL Biologie 2* Markl and Gauß (2015)
GCE Edexcel A2 Biology – Students' book Fullick (2009)	*MARKL Biologie: Oberstufe* Markl (2018)
GCE Edexcel AS Biology – Students' book Fullick (2008)	*Prisma Biologie 5/6* Bergau et al. (2005)
AQA Certificate in Biology (iGCSE) Fullick et al. (2012)	*Prisma Biologie 7–10* Bergau et al. (2006)
GCSE Edexcel Biology Billings et al. (2017)	
OCR Gateway GCSE Biology Locke (2016)	
AQA GCSE Biology Fullick and Coates (2016)	

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Data Availability Information on the analysed data is available from the corresponding author on reasonable request.

Code Availability Not applicable.

Declarations

Ethical Approval Ethical approval from the home institution (IPN Kiel) and host university (UCL) was obtained.

Consent to Participate Participation in the study was voluntary. Informed consent from each participant was obtained before conducting the interviews.

Conflict of Interest The authors declare that they have no conflict of interest.

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