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To cite this article: Tore van der Leij, Martin Goedhart, Lucy Avraamidou & Arjen Wals (2023): Designing a module for supporting secondary biology students' morality through socioscientific issues in the human-nature context, Journal of Biological Education, DOI: [10.1080/00219266.2023.2174160](https://doi.org/10.1080/00219266.2023.2174160)

To link to this article: <https://doi.org/10.1080/00219266.2023.2174160>



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Designing a module for supporting secondary biology students' morality through socioscientific issues in the human-nature context

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ABSTRACT

In addressing contemporary socio-ecological challenges it is imperative to engage individuals with the moral dilemmas in the human-nature context. A socioscientific-issues (SSI) approach to secondary biology education can contribute to engaging students in moral dilemmas and reflecting on their values. Following a design research methodology, we aimed to: (1) develop a set of design principles of an intervention in Dutch upper secondary SSI biology education, aimed at supporting secondary biology students' morality in the human-nature context; (2) concretise the design principles as a module. We describe the different phases of this study (orientation, design, and evaluation phase). The practical output of the study is a module, which was refined and improved during the design phase, and then implemented by two biology teachers. In this paper, we present an exemplary example of a lesson from the module. As theoretical output, we discuss the role of the design principles: *nature of the dilemmas*; *Four Component Model of morality*; *group work*; and *ethical matrix*. Based on experiences in classrooms, we provide recommendations for further research and practice.

ARTICLE HISTORY

Received 8 December 2022

Accepted 3 January 2023

KEYWORDS


Upper secondary biology education; students' morality; educational design study; socioscientific issues; human-nature context

Introduction

Humanity faces crucial challenges in creating a sustainable future. These challenges, as they are expressed in, for instance, the Sustainable Development Goals (UNDP 2019), are inevitably value-laden, and require forms of reasoning and engaging in moral dilemmas centred on the tense relationship between humans and nature. Biology education cannot shy away from engaging students in such reasoning and engagement as many sustainability challenges are related to key topics in the Dutch biology curriculum (e.g. self-organisation of ecosystems and the earth system, biodiversity, sustainability, interaction with (a)biotic factors (CvTE, 2020a; 2020b)). In general, science educators in different contexts are looking for ways to meaningfully engage their students in such challenges (e.g. Bencze, Sperling, and Carter 2012; Christenson, Chang Rundgren, and Höglund 2012; Grace 2009; Herman 2015, 2018; Hermann and Menzel 2013; Jones et al. 2012; Juntunen and Aksela 2014; Lee and Grace 2010; Rundgren, Eriksson, and Rundgren 2016; Sternäng and Lundholm 2011; Tal and Abramovitch 2013; Vesterinen, Tolppanen, and Aksela 2016; Walsh and Tsurusaki 2018).

Already more than 25 years ago, scholars, like Fensham (1988) and Solomon and Aikenhead (1994) emphasised the importance of teaching and learning science in its political, social and

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 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/00219266.2023.2174160>

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cultural contexts in Science-Technology-Society (STS) approaches. In doing so, little attention was paid to how students' values, ethics and moral reasoning could influence the point where science, technology and society meet and affect each other. This was addressed through the socioscientific issues (SSI) approach to science education which emphasises the 'ethical dimensions of science, the moral reasoning of the child, and the emotional development of the student' (Zeidler et al. 2002, 344).

Ever since SSI were introduced in science education, science education scholars argued for engaging students in moral dilemmas and reflecting on their values (e.g. Corrigan et al. 2020; Gough 2002; Grace and Ratcliffe 2002; Nielsen 2012; Oulton et al. 2004; Zeidler and Keefer 2003; Zeidler et al. 2005). Likewise, many international education reform documents (e.g. European Commission 2015; P21 Partnership for 21st Century Learning, 2015; UNESCO 2016) as well as national curricula and educational policies (e.g. ACARA 2021; NRC 2012) emphasise the importance of enabling students to engage with moral dilemmas and values, which also applies to the Dutch context of this study (CvTE 2020a,b).

During the past decades, several empirical studies examined different components of students' morality in secondary science education (e.g. Bencze, Sperling, and Carter 2012; Berne 2014; Grace 2009; Kolstø 2006). With 'morality' we refer to different integrated competencies as necessary conditions for moral functioning. These competencies have been described in the Four Component Model (FCM) of morality (cf. Narvaez and Rest 1995; Rest et al. 1999), which comprises the following components: (a) Exploring values, as a means to becoming more sensitive to the moral nature of the issue; (b) Making an informed choice for a specific moral value; (c) Applying the chosen moral value in a concrete situation; (d) Attuning behaviour to the chosen moral value.

Despite the fact that these empirical studies have contributed to insights into students' morality, one limitation that cuts across these studies is that they focused only on a single or a few components of morality (Van der Leij et al. 2021a). For instance, some of those studies focused on students' moral sensitivity (e.g. Boerwinkel, Knippels, and Waarlo 2011; Fowler, Zeidler, and Sadler 2009), while other studies focused on students' moral reasoning (e.g. Juntunen and Aksela 2014; Sadler and Donnelly 2006).

This present study differs from the above studies in that it is aimed at gaining insight into the pedagogical characteristics of a classroom-based intervention in which the consideration of multiple morality components is supported. To make this possible, the FCM of morality (Narvaez and Rest 1995; Rest et al. 1999) served as a theoretical underpinning for the design of a classroom intervention supporting different morality components. Based on data collected during the implementation of the intervention (cf. Table 1 below), in Van der Leij et al. (2021b) and Van der Leij et al. (accepted) we reported two empirical studies in which we, respectively, investigated the nature of students' morality, and students' use of values in their moral argumentation and decision-making.

Supporting biology students' morality in the Netherlands

In Dutch education, SSI are often used as contexts to teach biological concepts, while the moral aspects and values are often neglected (e.g. Van der Zande et al. 2009; see also this paper). At the time of the execution of the investigation reported in this paper (2016–2018), little empirical research had been conducted in Dutch biology education on students' morality, e.g. on students' moral argumentation and decision-making (Van der Zande et al. 2009), and on the use of SSI aimed at encouraging students' morality (Van der Zande et al. 2012). The little empirical research into supporting components of biology students' morality was conducted in a genomics context (Boerwinkel, Knippels, and Waarlo 2011) or in university (Aalberts, Koster, and Boschhuizen 2012).

A non-empirical study by Knippels and Van Harskamp (2018) provided a set of guidelines to support the implementation of socio-scientific inquiry-based learning (SSIBL). The authors

Table 1. Phases, activities and (partial) yields of this study.

Phase	Activities (period)	(Partial) Yield	Phase yield
Orientation phase	Review of the literature (2016-2017)	Insight into knowledge base regarding supporting biology students' morality	Themes ↓ Initial design principles
	Biology textbook analysis (2017,2021)	Insight into how textbooks deal with supporting students' morality	
	Expert interviews (2017-2018)	Insight into needs and views regarding pedagogies aimed at supporting students' morality	
Design phase	Design + feedback on prototype of module (2017-2018)	Insight into expected practical feasibility and effectiveness	Adjustment design principles
	Evaluation of feedback sessions (2018)		
	Prototype revision & finalizing intervention design		
Evaluation phase	Implementation of module; post-intervention interviews with students: data collection (written assignments, audio recordings of group conversations and individual interviews) (2018)	Insight into actual practical feasibility and effectiveness	(Tentative) Design principles
	Evaluation: data analysis (2018-2021)		

reported on a pre-service science teacher training programme in the Netherlands in which the guidelines were practised and discussed. The SSIBL guidelines are expected to support the development of various components of students' morality in SSI. No design-based study had been conducted on the design principles of upper secondary SSI biology education aimed at supporting various components of students' morality.

Study focus

This study is aimed at the development of a research-based classroom intervention¹ in Dutch upper secondary biology education, which supports various components of students' morality in moral dilemmas centred on the tense relationship between humans and nature (practical output). More specifically, regarding such moral dilemmas, the intervention aims to support students' moral sensitivity, moral reasoning, moral motivation and moral behaviour. These components are explained and discussed below.

Together with the development of the intervention, this study aims to contribute to the development of more universal (i.e. applicable in contexts other than the one of this study) design principles to inform SSI secondary biology educators on supporting students' morality (theoretical output) (cf. Plomp 2013).

We follow a design research approach, in which design principles are central. Design principles are considered heuristic statements expressed as experience-based suggestions (cf. Plomp 2013; Van den Akker 1999), in our case for pedagogical characteristics of SSI biology education with a focus on supporting various morality components. The following research question guided our investigation:

What are the characteristics of an intervention for supporting upper secondary biology students' morality in the human-nature context?

Methodology

Given that our study aims to obtain both practical and theoretical insights in supporting upper secondary biology students' morality in the human-nature context, we adopted an educational design research (EDR) methodology, aimed at the development of a research-based intervention as well as at gaining insight into key design principles of that intervention (Nieveen 2009; Plomp 2013).

EDR methodology includes a number of characteristics (Van den Akker et al. 2006), which are also typical for this study: (1) The research is aimed at developing an intervention in a real world setting, namely Dutch secondary biology education; (2) The research is cyclical in nature, starting with the analysis of the literature (theory) and current practice (including interviews with biology teachers and teacher trainers), followed by design and prototype feedback sessions, after which evaluation and revision take place, whereupon the intervention is implemented as a teaching module in the curriculum of two biology teachers; (3) The research is process-oriented, aimed at understanding the teaching and learning processes and improving the intervention; (4) The research is utility-oriented, aimed at the design of an intervention which is practicable for biology teachers; and (5) The research is theory-oriented: the intervention design is – partially – based on a conceptual framework and upon theoretical propositions.

Thereby, evaluation sessions of the prototype and the implemented module contribute to theory building (i.e. design principles for the pedagogical characteristics of SSI secondary biology education with a focus on supporting students' morality, which are more general and applicable in other settings); (6) Finally, our research involves practitioners in different phases (biology teachers, teacher trainers), which increases the likelihood that the intervention will become relevant and practicable in similar settings (Plomp 2013). The above characteristics are illustrated in the description of the various phases, which follow hereafter.

Phases

Table 1 shows the different phases of our study, as well as the activities and the (partial) yields of the different phases.

Orientation phase

Review of the literature

Our systematic literature review (Van der Leij et al. 2021a) on supporting secondary science students' morality theoretically informed the design of our pedagogical approach. In this study, we showed how morality is conceptualised in the science classroom in the light of sustainability issues, and how it can be developed in peer group discussions (Berne 2014; Grace 2009; Juntunen and Aksela 2014), and through reflection on personal values (Kolstø 2006; Jones et al. 2012; Rundgren, Eriksson, and Rundgren 2016; Walsh and Tsurusaki 2018).

Furthermore, the pedagogical approach of our intervention was informed by the SSI framework (Zeidler et al. 2005), which emphasises four areas of pedagogical importance, namely: (1) nature of science (e.g. students are encouraged to decide upon the trustworthiness of knowledge claims by

investigating the types of arguments from different stakeholders); (2) classroom discourse (emphasising the crucial role of developing students' views about science through argumentation in the construction of shared social knowledge via discourse about SSI); (3) mutual respect during discussions (contributing to students' awareness of their normative values which influence their moral decision-making); and (4) emphasising the moral nature of SSI (contributing to students' awareness of the moral nature of the dilemma, stimulating their moral reasoning).

Moreover, as stated above, the Four Component Model of morality (FCM) (Narvaez and Rest 1995), as a theoretical-conceptual framework, informed the design of the intervention. Finally, the ethical matrix (Mephan 2018) served as a heuristic to explore and reflect upon arguments and moral values of the various stakeholders, encouraging students to reflect on their own values and to communicate about them with other group members.

Biology textbooks

To obtain an overview of how Dutch biology textbooks, intended for 15–16-year-old pre-university students, support students' morality in the human-nature context, we analysed the two most widely used textbooks in terms of how they deal with SSI and what kind of student activities they encourage (e.g. individual or group tasks, what component of morality is supported, and how?). According to Van Maanen (2021), the two most used biology textbooks (for upper secondary pre-university level) are 'Biologie voor jou' (Gommers et al. 2019) and 'Nectar' (Bijsterbosch et al. 2020).

The analysis of the textbooks shows that the SSI are mostly used as a context to teach and apply biological concepts. We found that the SSI vary widely, both within and between the two textbooks. Some examples of SSI in 'Biologie voor jou' are climate change, (pros and cons of) different forms of agriculture, extinction of animal species, return of the wolf to the Netherlands, feeding of large herbivores during severe winters, and eutrophication. Some examples of SSI in 'Nectar' are the ecological capacity of Easter Island, coral bleaching (climate change), fishing in the Wadden Sea (World Heritage), and (pros and cons of) different types of animal husbandry.

In 'Biologie voor jou' 20, and in 'Nectar' 13 student tasks are situated in SSI in the human-nature context. Most tasks are individual tasks (85% in both textbooks) and are aimed at applying biological concepts. The latter is illustrated by the following task from 'Nectar' (Bijsterbosch et al. 2020, 274):

'Explain that the (availability of fresh water on Easter Island) has exacerbated human influences on the ecological crisis. Use the term "carrying capacity" in your explanation'.

Note that students could also use geography concepts in this task, which illustrates the multi-disciplinary nature of SSI. Furthermore, our analysis revealed that group tasks encourage students to defend a point of view from a (specified) perspective, often resulting in an exchange with the whole class. This is illustrated by the following task from 'Biologie voor jou' (Gommers et al. 2019, 85), in which students re-enact a television talk show on the question 'May the wolf return to the Netherlands?' about the controversy over the return and resettlement of wolves, who lived there until the nineteenth century. The talk show features a discussion between four guests with different opinions. To prepare for the discussion, the students delve into their point of view (perspective). Each 'guest' defends their position and the rest of the class acts as audience.

Few tasks support specific morality components, and if they do, they are mostly aimed at stimulating taking perspective, or aimed at teleological moral reasoning,² as illustrated by the following task from 'Nectar' (Bijsterbosch et al. 2020, 271):

'The Wadden Sea is a world heritage site. Given this, argue what you think is more important: the seal population, or the food supply for people and the sustenance of fishermen'.

In summary, the biology textbooks include multiple SSI in the human-nature context, which are often used as contexts to teach and apply biological concepts. The textbook analysis showed that the number of group tasks is limited. It appears that few tasks are aimed at stimulating specific morality

components, and in the few cases that they are, they are mostly aimed at taking perspective, or teleological moral reasoning. Consequently, we can conclude that the textbooks are of limited use as sources for the design of the intervention.

Interviews

During the orientation phase, different experts were individually interviewed, namely secondary biology teachers, teacher educators, a 'green pedagogue' (involved in creating education connecting children with nature), and environmental philosophers. On the one hand the interviews were aimed at gaining insight into the interviewees' (mainly those of the teachers) needs (e.g. Could you specify your needs considering the development of teaching material on dealing with morality?), while on the other hand they focussed on the interviewees' views regarding important pedagogical characteristics of (SSI biology) education aimed at supporting students' morality (e.g. Which educational activities do you consider suitable to support morality? What could the philosophical phase, being part of moral reflection, look like?).

Six biology teachers participated because of their affinity with the subject. All the interviewed teachers were qualified to teach in upper secondary biology education. Teacher experience varied: five teachers had more than 10 years of experience, while the other teacher was teaching for the second year. Furthermore, we interviewed four educational experts, three of them were teacher educators in biology, social studies and philosophy. They all paid attention in their pre-service training programmes to the ways teachers can support students' morality. In addition, a 'green pedagogue' was interviewed, who was involved in creating education connecting children with nature. Finally, two philosophers were interviewed, a university professor in environmental philosophy and an author publishing about the relationship between philosophy and nature conservation. The duration of the semi-structured interviews was about 60 minutes, and they were audio-recorded and transcribed verbatim.

The findings of the interviews are shown in the appendix (table A). The table represents different themes, subdivided into categories and illustrated with representative quotes.

The interviews provided information about several themes that became critical for the intervention's development and design. A first theme from the interviews is 'SSI', in particular the nature of the issues that will become part of the intervention. Philosopher 2 described them as issues 'that demand something from us', meaning they are moral dilemmas, with multiple perspectives, and multiple values, which prompt students to reflect upon their position towards the issue.

Second, the interviews provided information about 'pedagogical issues'. For instance, in line with the results of the review of the literature, the interviewees emphasised the importance of working in small groups, which would increase the involvement of a larger proportion of students. The interviewees also stressed that the introduction of the SSI is critical, which contributes to the students' emotional involvement (e.g. beginning with a story, linking the SSI to news from the media, posing a triggering question).

Regarding supporting specific morality components, the interviewees indicated the importance of learning to take perspective. Furthermore, they recognised the difficulty of coming to a moral judgment. All emphasised the importance of supporting the moral reflection process. More specifically, they stressed the importance of encouraging the process of taking both affective and factual arguments into consideration, as well as students' reflection on the fundamental values that are important to them ('what position do I take?'). According to interviewees, stimulating students' moral behaviour is desirable, but often practically impossible to implement in (current) Dutch biology education, largely due to time constraints.

With regard to pedagogical issues, the interviewees stressed the importance of developing teacher skills to supporting biology students' morality, for instance taking on the role of moderator asking the right questions during group evaluations.

A third theme that emerged from the interviews was students' skills, interests, and self-confidence. According to the interviewees, secondary biology students often have difficulties with

specific cognitive skills related to morality, for instance to consider a topic from multiple perspectives. Regarding self-confidence, they indicated that positioning themselves as vulnerable is often difficult for the students, especially in a larger group.

To conclude, the interviews provided information about ‘resources’, in which the interviewees indicated a need for a low-threshold teaching method in which students work in small groups. They also emphasised the importance of a teaching method in which different morality components are supported, emphasising their dissatisfaction with the way in which supporting morality is addressed in current biology text books.

Reflection on orientation phase

All in all, the results of the textbook analysis and interviews show the importance of developing teaching materials aimed at supporting students’ morality. Furthermore, the results of the interviews, as well as those of the literature review and the analysis of the textbooks contributed to the determination of initial design principles (pedagogical characteristics) of a first prototype of an intervention, which are presented below, in the description of the design phase.

Design phase

Design principles

Following the outcome of the orientation phase and the evaluations of the prototype sessions (described below), the following design principles (pedagogical characteristics) became leading in the design of the module to be implemented:

(a) Students are informed about the multi-perspectivist nature of SSI in the human-nature context. As such, we emphasise the moral nature of SSI, which is consistent with Zeidler et al. (2005). We do not deny the conceptual-scientific dimension of SSI, as students also analyse the kind of arguments used by different stakeholders (factual or appreciative), which often have a conceptual-biological nature.

One of the interviewed philosophers described SSI as dilemmas that illustrate ‘the sharp edge of our relationship with nature’ and issues that ‘demand something of us’. According to Bagnoli (2013), multiple values are inherent to moral dilemmas. If there is no general criterion for ranking these values – as in most cases – a moral dilemma is inevitable (Williams 1981). As such, SSI as moral dilemmas seldom boil down to only two choices. They are more often complex, multifaceted, reflecting multiple perspectives (Jickling et al. 2021).

(b) The ethical matrix (cf. Mephan 2018) serves as a heuristic to explore different perspectives. The matrix is based upon three moral values (well-being, autonomy, justice), which serve as a ‘starting point’ for discussing moral dilemmas, given that few people disagree about these values. As such, they provide reference points with which agreements and disagreements, factual uncertainties and different assumptions can be interpreted (Mephan 2018). The idea is that the students contemplate about these values (and different arguments) from various stakeholders’ perspectives, which prompts them to reflect upon their own position. Table 2 shows an example.

(c) The students work in groups of four, in which they alternately work on individual and group tasks (cf. Information box I in the appendices, which presents an illustrative example of a lesson). The purpose of the individual tasks is to encourage personal reflection, while the purpose of the group tasks is values clarification by taking perspective of different stakeholders and other group members, and to communicate about these values.

Our systematic literature review (Van der Leij et al. 2021a) already showed that peer group deliberation is important for the development of students’ morality (e.g. Berne 2014; Grace 2009; Juntunen and Aksela 2014). The theoretical underpinning for this can be traced back to the work of Piaget (1932), who already highlighted the importance of peer interactions in which students are encouraged in processes of cooperative decision-making and problem-solving, and working out common rules based on fairness (cf. Kohlberg 1976).

Table 2. Ethical matrix: 'Should wolves have every opportunity to resettle in [country]? Why?'.

(Factual and appreciative) arguments (quotes from recent media)	well-being (health/ welfare)	autonomy (freedom/ choice)	justice (fairness)
<i>Sheep-/livestock farmers</i> There is no place in [country] for the wolf. You see that sheep farmers quit because of the wolf. It's really no fun when you come to your herd in the morning and half the animals are dead on the ground.	'It's really no fun . . . half the animals are dead on the ground'.	'sheep farmers quit because of the wolf.'	'There is no place in [country] for the wolf.'
<i>Wolves</i> Wolves should be allowed to go their own way in nature. The wolf is coming, we must learn to deal with it. Packs of which one of the dominant animals has been shot are less able to hunt Red deer and other large wildlife . . .'	'Packs of which one of the dominant animals has been shot are less able to hunt Red deer and other large wildlife . . .'	'Wolves should be allowed to go their own way in nature'.	'The wolf is coming, we must learn to deal with it'.
<i>Citizens</i> Some mothers don't dare to let their children play outside anymore. If you come across a wolf: watch the animal in peace, try to take a photo or video and be happy, not many people have seen wolves. The few times when humans were regarded as prey, there were special circumstances and incidental cases: the supply of natural prey was extremely low and livestock was often difficult for wolves to obtain.	' . . . be happy, not many people have seen wolves'.	'Some mothers don't dare to let their children play outside anymore'.	'The few times when humans were regarded as prey, . . . incidental cases'

Later research also showed the importance of students' engagement in group deliberations, in which they strive for reconciliation or integration of moral arguments, arguments which (often) conflict with each other. Such deliberations are aimed at achieving a shared moral position (Berkowitz and Gibbs 1983). Similarly, Habermas (1991) described 'communicative discourse' as a prerequisite for arriving at a social construction of a rationally defensible morality (Nucci 2013).

(d) The module is aimed at supporting different morality components, as conceptualised by the FCM of morality (cf. Narvaez and Rest 1995; Rest et al. 1999). More specifically, the module was aimed at: (a) exploring values, as a means to become more sensitive to the moral nature of the issue (also referred to as moral sensitivity); (b) making an informed choice by reflecting upon different arguments and moral values (also referred to as moral reasoning); (c) Relating the moral values to the moral agent's (student's) personal values (also referred to as moral motivation); (d) Attuning behaviour to (b) and (c) (also referred to as moral behaviour, ethical implementation, or moral courage). Of a more practical nature, with regard to the latter component, given (time) constraints, students are only encouraged to reflect on possible behaviour instead of displaying behaviour in the dilemma.

Prototype evaluation sessions

Before the module was implemented, as part of the design phase, a prototype of the module was presented and provided with feedback during several meetings: one meeting with a group of twelve preservice biology teachers (enrolled in a teacher training programme), with their teacher trainer, and a second meeting with four secondary biology teachers, each with broad experience with teaching pre-university biology classes. During these meetings the first author presented the background and design of the module, and prototypes of the teacher and

student manuals were discussed and provided with feedback. Also, the exemplary dilemma 'Should we feed large herbivores in 'Oostvaardersplassen' during severe winters? Why?' was thoroughly evaluated by examining the participants' views on the quality and practicality of the module prototype. These evaluation sessions were audio recorded and transcribed verbatim.

The evaluations revealed that in general the participants were positive about the potential contribution of the intervention to supporting students' morality. However, regarding the limited time teachers have, they gave several suggestions for adjustments. For instance, the original idea was to implement an intervention for 2–3 months in which students would address eight different dilemmas. Consequently, the first author (after consultation with participants in the prototype sessions) decided to reduce the number of dilemmas (SSI) from eight to five. Likewise, we decided to reduce the number of quotes in the ethical matrix. Finally, we agreed that students would not explicitly be encouraged to use biological concepts in their moral argumentation, even though the dilemmas obviously lent themselves to doing this (and we have evidence that they did (Van der Leij et al. 2021b)).

Evaluation phase

During this phase the module was implemented by two biology teachers, each with over 20 years of teaching experience; one of them is the first author of this paper. Both teachers saw the need to design new course material as well as to develop their competencies to support students' morality. Sixty 15–16-year-old science major students participated, divided over three classes in two comprehensive schools, located in semi-urban towns in the northeast of the Netherlands. Table 3 shows an overview of the module's implementation.

In the appendix (Information box I), we present the lesson about one of the addressed dilemmas as an illustrative example: 'Should we feed the large herbivores in "Oostvaardersplassen" during severe winters? Why?'

Evaluation of implemented module

During the implementation phase, data were collected from various sources (written assignments, audio recordings of group conversations and post-intervention individual interviews³). Based on these data, two empirical studies were conducted, in which we investigated the nature of the students' morality (Van der Leij et al. 2021b), and the kind of values they used in their moral argumentation and decision-making (Van der Leij et al. [accepted](#)). In this paper we describe some additional findings, related to the intervention's practical feasibility, effectiveness and educational value based on teachers' and students' reflections. As part of the evaluation of the module, the participating teachers kept a diary and they regularly had email contact, which contributed to

Table 3. Overview of the module's implementation: introductory lesson and the addressed moral dilemmas.

Week ¹	topic/moral dilemma	label
1	Introductory lesson on the role of ethics in socioscientific issues	intro
2	Should we feed the large herbivores in 'Oostvaardersplassen' during severe winters? Why?	feeding
3	Should wolves have every opportunity to resettle in the Netherlands? Why?	wolf
4	Should we stop eating meat? Why?	meat
5	Should we ban the use of neonicotinoids? Why?	neonics
(7–8) ²	Should we stop the rehabilitation of seals from the Wadden Sea? Why?	seals

¹ The classroom time was 50 minutes per week.

² Individual interviews after the intervention.

several (minor) revisions on-the-run. Likewise, three students gave detailed written feedback on the student manual and on the weekly lessons.

Teachers' observations

Already during the first dilemma lesson (cf. Table 3), we learned from the teachers' observations that students needed more time to get used to 'the way of working'. For instance, the 'matrix task' (i.e. analysing the arguments and moral values of different stakeholders) took more time than anticipated. Therefore, giving students sufficient time to work on the more reflective individual and group tasks, the teachers decided to adopt a stricter lesson plan from the second dilemma lesson onwards. As part of this, the students received a completed matrix halfway the lesson as a comparison with their own analysis.

During the course of the implementation phase, teachers' observations indicated that the students became more competent in categorising the quotes from the ethical matrices into arguments and moral values, which was evidenced by the shorter time they needed for this task.

Students' feedback

From the students' feedback we learned that – in general – the introductory videos contributed to an increase of their interest in the dilemmas. However, it was not always obvious to them who the different stakeholders were or whether all stakeholders were considered equally. For instance, according to the students, the video introducing the 'wolf' dilemma 'highlighted the issue from different angles', while the 'meat' video 'mainly presented proponents' (favouring to stop eating meat).

It also appeared that the extent to which they considered a dilemma as meaningful differed. For instance, students considered 'meat' as a meaningful dilemma ('It's quite a big problem and people find it difficult to stop eating meat' and 'It is very much about how you view animal well-being, and how much you value it'). Their involvement of personal values in the moral reflection process seemed to be related to their personal relation with the dilemma. For instance, in her feedback on the 'wolf' lesson, one student wrote that she managed 'well' to include her personal values in her moral reflection, since '(she) had a personal connection (to the issue)' (i.e. her granddad lost sheep due to a wolf attack, TL).

During the module the students increasingly indicated that the 'matrix task' functioned well, i.e. they expressed their ability to interpret the quotes about the type of arguments and moral values. Students' perceptions of the contribution of the ethical matrices to their insights into the moral values of the stakeholders varied. In their feedback on the first lesson, one student indicated it was 'confusing that multiple moral values could be applied' (which was also evident from the teachers' observations). Following on this, during the subsequent lessons, the teachers emphasised that 'the focus should be on the ability to reason why a certain moral value applies', meaning that there is 'not one right answer, more answers/ explications are possible'.

Finally, all three students considered the language in the student manual sufficiently comprehensible ('It is clearly explained what you need to know'). Additionally, they noticed that discussion about values overlapped with other school subjects. One student needed more examples to illustrate different ethical approaches, and one student considered the manual 'not useful', by indicating that she already knew a lot of information that was in the manual and that it was too extensive, and therefore confusing.

Conclusion and discussion

The aim of this study was twofold: on the one hand its purpose was to develop a research-based intervention in Dutch upper secondary SSI biology education, which supports students' morality in the human-nature context; on the other hand, it aimed to contribute to the development of more

universal design principles that can help inform SSI secondary biology education seeking to support students' morality.

In doing so, we aimed to find an answer to the following research question:

What are the characteristics of an intervention for supporting upper secondary biology students' morality in the human-nature context?

With regard to the practical output, the study resulted in a module, which was implemented by two biology teachers. Regarding the theoretical yield, a number of design principles emerge from this study, which we describe as experience-based suggestions for the pedagogical characteristics of SSI biology education with a focus on supporting students' morality. We will discuss these design principles hereafter.

Design principle: nature of the dilemmas

In discussing the students' feedback (above) we already noticed that the extent to which the students considered a dilemma as meaningful differed. The worksheets of six students, which served as the basis for our empirical study into students' use of values in their moral argumentation (Van der Leij et al. [accepted](#)), showed that, at the beginning of the lesson, they all considered the dilemmas 'meat' and 'neonics' as 'important' to 'very important' (cf. Information box I, appendices). An important characteristic of these dilemmas is that they are both situated in a sustainability context, which resulted in students using values, in which they considered future generations as important moral objects.

Moreover, students' use of values indicated that they valued natural resources, as humanity depends on them for its well-being and survival (cf. Van der Leij et al. [accepted](#)). As such, in contemplating these dilemmas it was evident that the students were stakeholders themselves, for instance, as (meat) consumers, or as inhabitants of the earth, which is being threatened by global warming.

At the end of the lesson the students were asked if, compared to the beginning of the lesson, they considered the dilemma to be just as important, or more or less important (cf. Information box I, appendices). For 'meat' and 'neonics' they indicated that they were 'just as important', or (even) 'more important', which shows that they consider sustainability dilemmas (like climate change, biodiversity) meaningful.

The 'feeding' and 'wolf' dilemmas were considered less important (ranging from 'neutral' to 'important'). In Van der Leij et al. ([accepted](#)) we showed that these dilemmas evoke certain moral-ethical preferences of what nature 'is' or 'should be' (e.g. humans have a role in feeding large herbivores during severe winters, the wolf deserves the opportunity to resettle in the Netherlands wherever (s)he likes). However, unlike the dilemmas 'meat' and 'neonics', in these dilemmas⁴ the student is not (or less obvious) a stakeholder, which (plausibly) influenced their perception of the importance of the dilemma.⁵

Design principle: Four Component Model (FCM) of morality

The FCM of morality (Narvaez and Rest 1995; Rest et al. 1999) served as a theoretical-conceptual framework in the design of the intervention. Hereafter we describe in what way the intervention (i.e. its pedagogical characteristics) supported the various morality components.

Moral sensitivity: At the introduction of the SSI, a short video clip showing the dilemma's complexity with different perspectives (arguments, (moral) values), made the students aware of its moral nature. Moreover, the video made the students become emotionally involved (and motivated) to address the dilemma.

Moral reasoning: To support this morality component, the students were encouraged to analyse the involved moral values for the different stakeholders, and the kind of arguments – factual, or appreciative – used. As such, these tasks contributed to students' ability of taking perspective and identifying the involved moral values. In addition to these analytical tasks, the students were

prompted to reflect upon the (most) important moral values, arguments, and stakeholders, and to communicate about them with the other group members.

In Van der Leij et al. (2021b) we reported about the nature of students' morality. The data for this empirical study came from the post-intervention individual interviews with 12 students (cf. Table 1), during which they discussed a moral dilemma related to the rehabilitation of seals. We found that the students showed different kinds of moral reasoning, which we conceptualised as either rational, or as predominantly based on emotions (cf. Sadler and Zeidler 2005). Also, although not explicitly stimulated or required, it appeared that most of the students used biological conceptual knowledge in their moral reasoning. Given these results, the design of the intervention was effective in encouraging this morality component.

Moral motivation: To support this morality component, the students were asked about (more) personal values that play a role in their moral reflection process, and to reflect on how these relate to the moral values that were more central to the previous morality component. Moral motivation focuses on the question 'what would I do?', while moral reasoning focuses on 'what should I do?' (cf. Korthals 1986). Hence, engaging personal values in the moral reflection process is important. We found evidence that a number of students experienced an 'inner conflict' between predominantly rational arguments and emotion-based moral sentiments (Van der Leij et al. 2021b). As such, the intervention was effective in terms of triggering this morality component, as well as the process of moral reflection as a whole, which usually involves conflicting moral values, and/or exceptions (cf. Black 2013).

Moral behaviour: According to Knippels and Van Harskamp (2018), the knowledge gained and reflection from the previous phases (i.e. in this study, the different tasks, aimed at supporting students' moral sensitivity, moral reasoning and moral motivation) informs students' decision-making processes, where a decision intrinsically holds possible actions. In the science education literature, there are several examples of taking action, for instance writing a letter (to a newspaper) in which students substantiate their point of view with regard to a topical SSI, designing a poster or leaflet and presenting it to peers, or discussing opinions at home with family (e.g. Knippels and Van Harskamp 2018; Saunders and Rennie 2013).

Also in our intervention, at the end of each lesson, as a group task, the students were prompted to reflect upon possible behaviour in the dilemmas' context (cf. Information box I, appendices). Some examples in which students discussed this with each other, taken from audio recordings of this task, are:

'I don't really think we can influence this' (Sarah, wolf).

'All you can do is eat less meat, right?' (Milo, meat).

'No. I don't think so, because it makes no sense. Because, if you do that on your own, it doesn't make any difference, because the demand (for meat) only drops a tiny bit (Vernon [response to Milo], meat).

These (illustrative) quotes show that the dilemmas' nature – which, as we argued above, affects the student's relationship with the topic – seems to influence the concreteness with which students reflect on possible behaviour. Moreover, due to limited time, the students did not take action.

Design principle: Group work

During the intervention, the students alternately worked on individual and group tasks. The purpose of the individual tasks was to encourage personal reflection, while the purpose of the group tasks was values clarification by taking perspective of the other group members (and of the dilemmas' stakeholders), to communicate about these values, and include these values in taking a personal stance.

From the teachers' observations we learned that during the group discussions there was a considerable difference in the contributions of the individual group members, and also between the groups. Some groups had long, vivid conversations, while others quickly came to a consensus

after little discussion. Of course, there will always be differences between individual students and groups in terms of the ability of conducting a conversation, articulating one's opinion, listening to each other, making oneself vulnerable by showing emotions and/or personal values, and so on.

As for coaching groups in which there was very little discussion, observations from the teachers' diaries pointed out the importance of asking additional, prompting questions like 'What do you mean by? ... Why?' Therefore, the teachers agreed to re-emphasise the 'rules of the game for conducting a group discussion' (see appendix, Information box I, based on Overbeek, Knippels, and Waarlo 2014) to give all students the opportunity to share their views.

Working in groups served another, more practical purpose. Namely, because the dilemmas were discussed in small groups, more students were more involved than in a whole-class discussion. Consequently, it encouraged the process of moral reflection in each individual student.

Design principle: Ethical matrix

The ethical matrix with quotes from topical media sources (mainly newspapers) present arguments from different stakeholders (perspectives), where the arguments reflect different moral values (cf. Table 2). The matrix serves as a heuristic that encourages students to interpret and weigh arguments and moral values from different perspectives.

We found that although the students had to get used to working with the matrix in the beginning, during the implementation they became more competent in categorising the quotes into arguments and moral values, which was evidenced by the shorter time they needed for this task. In that regard, it seems that the ethical matrix is a valuable tool for clarifying the arguments and moral values of the various stakeholders (values clarification) within SSI biology education.

An important criterion for including specific stakeholders in the matrix was that they should have 'ethical standing', meaning they are subjects of ethical consideration in their own right. Traditionally, moral values are limited to human interactions. However, given that we considered non-human entities (like animals and ecosystems) as stakeholders as well, we extended the boundaries of these interactions by adopting a broader conceptualisation of 'stakeholders with ethical standing' (cf. Mephan 2018). In doing so, we encouraged students to explore perspectives other than human and its associated values.

Overall, we think the ethical matrix is a useful tool for several reasons. It does not limit users to following a single ethical theory, or to put forward one ethical principle. Second, it makes abstract ethical theories (like deontology, utilitarianism) concrete and relevant for students. Finally, the matrix can help to clarify the consequences of a certain decision for the various stakeholders (cf. Mephan 2018).

Transferability of results

Instead of referring to the generalisability of results, which is more common in research with an experimental design, Denscombe (2014) refers to the results' 'transferability', which is 'an imaginative process in which the reader of the research uses information about the particular instance that has been studied to arrive at a judgment about how far it would apply to other comparable instances' (p.299).

In line with this, according to Gravemeijer and Cobb (2013), EDR (like this study) aims for ecological validity. For this study, this means that the resulted design principles can serve as a basis for adaptation to other situations, i.e. to some extent, they are transferable to other situations. More specifically, the design principles can serve as a frame of reference for other (biology) teachers who want to focus their education on supporting students' morality, and adapt it to their own personal context. Feedback from these teachers on how they adapted it to their classroom situation, and how and to what extent it contributed to their personal goals, further increases the ecological validity of the design principles.

Recommendations for research and practice

Whereas the implemented module in our intervention consisted largely of student-directed activities, following the literature (e.g. Bencze, Sperling, and Carter 2012), we consider it worthwhile further exploring student-directed activities in supporting students' morality. For instance, it may be possible to have students choose a topic they feel related to. Consistent with our findings on the dilemmas' nature, we recommend that SSI be used in which students are (or become) stakeholders themselves. Likely, this will positively contribute to a more emotional relationship between students and topic.

The importance of a relational pedagogy is emphasised in recent SSI science education literature. For example, place-based SSI science education potentially contributes to students' moral sensitivity by teaching and learning morality in authentic contexts (e.g. Herman, Zeidler, and Newton 2020; Kim, Ko, and Lee 2020), which in turn positively supports other morality components. Needless to say, the role of the teacher in such educational strategies should be taken into consideration as well.

The kind of biology education we realised in this study differs – for various reasons – from the current teaching practice of many teachers. Science education literature reveals that many science teachers feel often uncomfortable with teaching SSI science education (e.g. Bennett et al. 2010; Day and Bryce 2011; Oulton et al. 2004). Therefore, we recommend that both preservice and in-service biology teachers are trained to strengthen their pedagogical content knowledge (PCK) about supporting biology students' morality.

Finally, it is likely that the influence of the intervention on students' morality development is limited, given the module involved a relatively small number of lessons over a limited period of time. Literature shows that morality development is a complex process, with many influences, many of which lie outside the school. For instance, some of these appear to be of a biological nature (e.g. hormonal changes during puberty), while others indicate social influences on moral development, like the importance of family (parents) and (other) authority figures, like teachers, but also – certainly during adolescence – the influence of peers (e.g. Hart & Carlo, 2005).

With regard to the latter, 'group work' was a consistent choice as a design principle in our intervention. Nevertheless, given the intervention's limited influence, we consider it recommendable to support students' morality development throughout their schooling, and make it (more) central to other subjects as well. Recent developments in the Netherlands focusing on the importance of citizenship education, which includes students' moral development as an important objective (Curriculum.nu 2019; SLO 2021) seems to be a positive and hopeful development in this regard.

Notes

1. According to Plomp (2013) an intervention is used as a 'container' term referring to all entities that can be designed and implemented. Later in this article we often use the term 'module', for example when it concerns the implemented educational material.
2. Central to teleological moral reasoning, 'the value of an action – and thence its ethical character – derives entirely from the value of its consequences' (Curry 2011, 43), which implies that decisions (often) use a measurement-based cost-benefit analysis to decide what is the 'right thing to do'.
3. The post-intervention individual interviews formed the basis for investigating the nature of students' morality (as described in Van der Leij et al., 2021b).
4. During the post-intervention interviews, the students were not explicitly asked about how important they thought the 'seals' dilemma was. However, given the dilemma's nature, it is likely that we would find similar results.
5. Meanwhile, the wolf in the Netherlands is present in more and more places, and several packs have established themselves, which has led to multiple confrontations with (sheep) farmers. As such, the dilemma has become even more 'hot' (cf. Simonneaux, Panissal, and Brossais 2013), making it likely that nowadays (more) students consider it as (very) important.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The research for this paper is supported by DUDOC (PhD grant for science education research), funded by the Dutch Ministry of Education, Culture, and Science.

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