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Fostering students' socioscientific decision-making: exploring the effectiveness of an environmental science competition

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Abstract

To make informed decisions has been acknowledged as an essential ability to negotiate socioscientific issues. However, many young people show an inadequate understanding of how to make well-informed decisions, particularly in contexts that are connected to environmental problems. This paper aims to explore the effectiveness of an environmental science competition (BundesUmweltWettbewerb, BUW) to foster students' socioscientific decision-making. Two different instruments, a paper-pencil test ($N = 196$ students) and retrospective interviews ($N = 10$ students), have been used in two successive studies. In addition, both of the applied instruments are investigated theoretically using the "assessment triangle" of the National Research Council (National Research Council, Knowing What Students Know, 2001) as a framework. The results of our studies indicate that participating in the environmental science competition predominantly fosters students' socioscientific decision-making in its pre-selectional phase. We further argue that promoting the selectional phase of decision-making requires explicit and instructional guidance. With respect to the assessment of socioscientific decision-making, a focus on either structural (decision-making strategies) or contextual (decision content) conditions is argued. Outcomes are discussed in terms of theoretical and practical implications.

Keywords: Socioscientific decision-making, Environmental science competition, Assessment of instruments, Socioscientific issues

Introduction

Ongoing developments in science and technology increasingly shape social issues that "require scientific knowledge for informed decisionmaking" (Zeidler & Nichols, 2009, p. 49). These controversial issues at the intersection of science and society, such as genetic engineering and nuclear power, have been called socioscientific issues (SSI) within the science education community (Fleming, 1986; Sadler, 2004). To negotiate these issues, students must reach beyond the mere comprehension of scientific content by embedding their science understanding within a social and political context (Kinslow, Sadler, & Nguyen, 2019; Kolstø, 2001; Romine, Sadler, & Kinslow, 2017). As a result of this embeddedness, SSI serve as a suitable tool to contextualize students' science learning within real-world contexts (Zeidler, 2014). The inclusion of SSI into the classroom presents both new challenges and opportunities for science education. On a practical level, traditional classroom practices are often teacher-focused and content-specific. This dependency might challenge the implementation of debatable and interdisciplinary SSI (Sadler, 2009). Extracurricular learning opportunities, on the contrary, might offer a pathway beyond the traditional framing of classroom practices to address previously neglected societal considerations (Bell, Lewenstein, Shouse, & Feder, 2009). On a more conceptual level, "well-structured decision-making processes are essential"

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(Gresch , Hasselhorn & Bögeholz, 2013, p.2587) to negotiate SSI. Yet, many young people show an inadequate understanding of how to make well-informed decisions, particularly in contexts that are connected to environmental issues (Collins et al., 2007; McBeth & Volk, 2009). This article merges both considerations and investigates the effectiveness of an extracurricular science competition with an environmental focus to support students' socioscientific decision-making. Two different instruments, a paper-pencil test by Eggert and Bögeholz (2010) and retrospective interviews (inspired by Paul, Lederman, & Groß, 2016), have been implemented in two successive studies. In addition, both of the applied instruments are evaluated in the light of the "assessment triangle" (National Research Council, 2001) to provide some assessment-related notes. The "assessment triangle", established by several US-based education scholars, has been used repeatedly in science education research to frame the development and evaluation of assessment instruments (e.g., Opfer, Nehm, & Ha, 2012).

Theoretical background

Socioscientific decision-making

Drawing upon the insights from cognitive psychology, the existence of dual-process models has been widely acknowledged (for a review, see Gerrard, Gibbons, Houlihan, Stock, & Pomery, 2008). These models contain two different systems of thinking: a subliminal (so-called 'system 1') and a deliberate one ('system 2'). When operating in system 1, intuitive and parallel processing of information takes place. Decisions that are made within this first system are predominantly unconscious, automatic, and quick (Glöckner & Betsch, 2008). Conversely, when operating in system 2, people engage in rational thinking. Coming to a conclusion within this system entails the deliberate, analytical, and sequential processing of the given information (Betsch, 2008). It is this second system that initiates informed decision-making on complex problems (Wilson & Keil, 2001).

Complex problems that can be found at the interface between science and society have been labeled as socioscientific issues (SSI) within the science education community (Fleming, 1986; Sadler, 2004). SSI describe socially debated problems with process-related and/or conceptual associations to science (Sadler, 2011). These issues are inherently open-ended; in other words, they are without straightforward solutions (Kolstø, 2001). The respective debate is thus characterized by diverse perspectives and multiple decision-making options (Sadler, Barab, & Scott, 2007). The social embeddedness of SSI additionally provides a framework to contextualize students' science-informed decisions in a meaningful way (Kinslow et al., 2019). As a result, students' decision-making in SSI has been of particular interest to many scholars in science education (e.g., Grace, 2009; Levy Nahum, Ben-Chaim, Azaiza, Herskovitz, & Zoller, 2009; Sadler, 2011; Siribunnam, Nuangchalerm, & Jansawang, 2014).

Decision-making in SSI (socioscientific decision-making) concerns students' ability to reflect upon multiple perspectives while bearing in mind relevant scientific data as well as societal and personal values (Lee & Grace, 2010). In a literature review by Fang, Hsu, and Lin (2019), several models of socioscientific decision-making were analyzed. Resulting from this comparison, Fang et al. (2019) established an overarching framework for socioscientific decision-making that consists of three interconnected phases. Phase 1 includes the recognition and construction of a specific decision-making space. Within this phase, information is analyzed and reasoned to explore possible solution approaches. Since these activities prepare a final decision, this phase is also called the pre-selectional phase (Betsch & Haberstroh, 2005). Phase 2 deals with the selection of a suitable decision-making strategy to assess and decide upon the different solution approaches (e.g., compensatory and non-compensatory strategy). In the following, this second phase is referred to as the selectional phase (Betsch & Haberstroh, 2005). Phase 3 summarizes the conscious reflection on phases 1 to 3 as well as the acting upon the respective decision.

Drawing upon this theoretical framework, socioscientific decision-making is considered as a multi-phased process. An exemplary model for socioscientific decision-making that considers all three phases is the "Göttinger competence model for socioscientific decision-making" by Eggert and Bögeholz (2006). This model comprises four competence dimensions addressing students' understanding and reflecting of values and norms, the development of possible solutions and their assessment (Bögeholz, Böhm, Eggert, & Barkmann, 2014). The first two competence dimensions (*understanding and reflecting values and norms* and *developing and reflecting solutions*) belong to the pre-selectional phase (Bögeholz, 2007). The actual making of a decision (*evaluating and reflecting solutions qualitatively*) is associated with the selectional phase (Bögeholz, 2007). Within this latter phase, the assessment of different options is central. Here, students are commonly confronted with various solution approaches (Gresch, Hasselhorn, & Bögeholz, 2013). In order to make an informed decision, students are required to engage in different decision-making strategies. A highly intuitive procedure characterizes a low level of decision-making (Eggert & Bögeholz, 2006). Conversely, more elaborate decision-making is presented when students engage in a systematic evaluation of all given information (Eggert & Bögeholz, 2006). In many cases, this is described by students' full trade-off of information, meaning that all provided information is assessed regarding its advantageous and disadvantageous features (Jungermann, Pfister, & Fischer, 2005). In addition to this rather rational and individual-based understanding of socioscientific decision-making, a systematic literature review by Garrecht, Bruckermann, and Harms (2018) emphasizes a more social perspective on decision-making. Here, socioscientific decision-making is also perceived as students' empowerment to cooperate in the decision-making process by sharing their thoughts and opinions. Both perceptions, the individual-based and the collaborative one, seem essential in the context of SSI. On the one hand, students are required to tackle these issues independently (e.g., daily consumer decisions). On the other hand, they need to debate local and global issues collectively on a more public level (Sipos, Battisti, & Grimm, 2008).

The assessment of socioscientific decision-making

Diverse methods from both the qualitative and quantitative research spectrum have been used to assess students' socioscientific decision-making. Reitschert and Hößle (2007), for example, conducted interviews with secondary school students to examine the structure of socioscientific decision-making in the context of preimplantation diagnostics. One of their interests concerned students' ability to recognize the moral relevance of a decision situation. Using the method of qualitative content analysis, Reitschert and Hößle were able to divide students' socioscientific decision-making into several quality levels. These levels ranged from a descriptive-pragmatic perception of the problem (level 1) to the (emotionally charged) recognition of the ethical problem (level 2), to the objective recognition of the ethical-moral value-dilemma (level 3). According to Reitschert and Hößle (2007), this kind of assessment can be helpful for teachers to support a transparent and constructive discussion about SSI. Others in the field of science education have used audio and video recordings during group work (e.g., Böttcher & Meisert, 2013) and role-play (e.g., Agell, Soria, & Carrió, 2015) to explore socioscientific decision-making. Besides these qualitative approaches, decision-making has also been examined using quantitative methods. Paraskeva-Hadjichambi, Hadjichambis, and Korfiatis (2015), for example, used paper-pencil tests to assess younger students' use of decision-making strategies and their weighting of criteria. One of their main results drove the establishment of three decision-making types: strong anthropocentric, weak anthropocentric, and ecocentric decision-makers. This differentiation not only highlights the subliminal influence of values during the decision-making process but also illustrates how using strategies can help to reflect upon them. As summarized in Fang et al. (2019), most of these assessment endeavors intend to either investigate informal and evidence-based reasoning (pre-selectional phase) or students' use of decision-making strategies (selectional-phase).

The assessment of instruments used to measure socioscientific decision-making

In order to reflect upon the quality of instruments used to measure decision-making, this study employs a framework by the National Research Council (2001). The so-called "assessment triangle" identifies three critical aspects for evaluation: cognition, observation, and interpretation. The first component, *cognition*, contains the understanding that a "construct should be defined by a cognitive model of learning that articulates how students develop understanding and progress in the sophistication of their thinking in the domain" (Ketterlin-Geller, Perry, & Adams, 2019, p.63). This component describes students' achievements that are intended for assessment. The second component, *observation*, entails the operationalization of this cognitive model. The operationalization results in a product (e.g., an instrument) that collects data through students' responses or behavior. The third component, *interpretation*, explores the question to what extent the observed data match the previously developed cognitive model. Drawing upon these theoretical considerations, the "assessment triangle" can serve as an overarching framework to structure a systematic evaluation of existing instruments (cf. Marion & Pellegrino, 2007). For this paper, it will serve as a rubric to examine both instruments used to assess socioscientific decision-making.

The socioscientific context of sustainable development

On a global scale, human activity has already contributed to an increase of the average temperature by about 0.8–1.0 °C above pre-industrial levels (Hansen, Ruedy, Sato, & Lo, 2010; IPCC , 2018). Resulting from this rapid increase in temperature, extreme weather events such as heatwaves, drought, and heavy rain, as well as their social, economic, and ecological consequences will be a severe risk for life on Earth (IPCC, 2018). In order to stem a further increase, the discussion about how to decrease our carbon footprint and how to live more sustainably needs to be promoted. Participating in these discussions, however, challenges students with complex decision situations that are both factually and ethically complex (Jickling, 1992).

As a consequence, students need to be supported in their ability to make informed and sustainable decisions (Gresch & Bögeholz, 2013). Yet, traditional classroom practices might be of limited use due to disciplinary boundaries and formal requirements such as temporal limits and assessment standards (McKeown & Hopkins, 2016; Sleeter & Flores Carmona, 2017). The less formal and often interdisciplinary nature of extracurricular activities, in contrast, can represent a sound alternative to address students' decision-making in sustainability-related issues (Garrecht et al., 2018). We thus chose an extracurricular learning environment with sustainability-related focus as context of this study: an environmental science competition.

The learning environment: an environmental science competition

The BundesUmweltWettbewerb (BUW) is a project-oriented science competition that invites students (individually or in small groups, aged between 10 and 20) to elaborate on sustainability-related questions. In order to participate in the BUW, two main requirements (R1, R2) have to be fulfilled. First, students have to choose a sustainability-related issue that can be encountered within their local environment. They are then asked to investigate the issue's underlying socioscientific processes. During this step, students engage in the elaboration of scientific as well as ethical considerations that are connected to their issue. Subsequent to these theoretical deliberations, participants are asked to generate and implement practical solution approaches (R1). Secondly, participants have to write a project report that summarizes the development and results of their project. Concrete guiding questions, provided in the BUW-guidelines (2018), lead students' writing. The questions also encourage them to monitor, reflect, and discuss their project critically (R2; see Fig. 1).

The BUW constitutes an extracurricular learning opportunity that implements an inquiry-based learning approach. This approach is exemplified by various self-regulated learning elements throughout students' participation, such as setting project goals, monitoring and evaluating the project development, and approaching scientific problems in an explorative manner. This autonomy in learning can require participants to make sensible decisions (Pedaste et al., 2015; Stefanou, Perencevich, DiCintio, & Turner, 2004). Furthermore, the thematic orientation of the competition requires students to elaborate on complex SSI, which have been acknowledged for their potential to engage students in decision-making about contemporary matters (Grace, 2009; Levy Nahum et al., 2009; Sadler, 2011; Siribunnam et al., 2014).

Based on the competition's inherent structure and the features mentioned above, we claim that the BUW constitutes a suitable opportunity for the development of participants' socioscientific decision-making. As presented in Table 1, we could identify opportunities for practical expressions of socioscientific decision-making based on cognitive and affective norms.

Prior research in the field of science education predominantly focused on classroom interventions. These interventions were often designed to foster socioscientific decision-making in a particular context (e.g., energy usage). This study, in contrast, explores the potentials of an extracurricular intervention to promote socioscientific decision-making in local, self-chosen contexts. This place-based notion might be specifically valuable for students' engagement with SSI (Herman et al., 2018).

Research aim

Although decision-making has been presented as an essential ability to negotiate SSI, many young people show an inadequate understanding of how to make well-informed decisions. This particularly refers to socioscientific contexts that are related to environmental issues (Collins et al., 2007; McBeth & Volk, 2009). From this, a twofold research approach is evolving. First, interventions that aim to develop students' socioscientific decision-making need to be assessed in their effectiveness. Secondly, this presupposes the implementation of suitable instruments to evaluate students' socioscientific decision-making. The aim of this article is to assess an intervention (BUW) in its effectiveness to promote students' socioscientific decision-making in two successive studies (Study 1 and Study 2). In addition to this, the applied instruments of each study will be evaluated in light of the "assessment triangle" (National Research Council, 2001).

Study 1

Study 1 aimed to measure participants' socioscientific decision-making *before* and *after* the competition. The applied instrument builds upon an existing model for socioscientific decision-making (Eggert & Bögeholz,

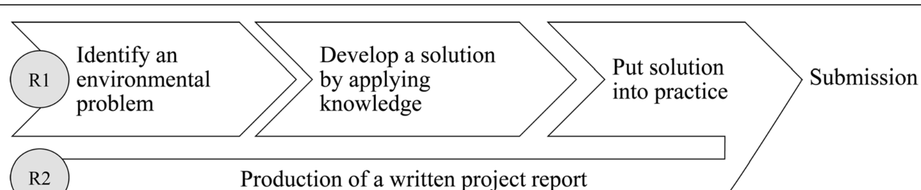

Fig. 1 Steps of participation in the BUW with two main requirements (R1: investigation of SSI and development of solution approach(es), R2: completion of project report)

Table 1 Exemplary aspects of the BUW potentially initiating socioscientific decision-making

Extracts from the BUW-guideline	Practical implementations	Connection to the development of decision-making
"On a personal level, what does this issue mean to you?" (p.14)	Reflect upon individual and societal values and norms	Values and norms (on a personal as well as on a societal level) are implicitly embedded in SSI. They need to be considered when making an informed decision (e.g., Eggert & Bögeholz, 2006).
"What has been done so far to solve the issue?" (p.15) The BUW encourages "to develop solutions based on theoretical considerations and to put them into practice" (p.4)	Available information needs to be assessed, possible courses of action need to be evaluated	Decisions in the context of sustainability-related issues are complex and involve the assessment of various information from different stakeholders (e.g., Sartori, Da Silva, & Capos, 2014).
"If you had to decide between different courses of action, reason your choice of action" (p.15)	Decide between (equally conceivable) courses of action	SSI are complex and ill-structured. Corresponding decision situations display a set of possible options that need to be decided upon (e.g., Arvai, Campbell, Baird, & Rivers, 2004; Jungermann et al., 2005; Siegel, 2006).
"The task [of this competition] is to examine a local environmental issue and to research the cause and its connections" (p.4)	Choose a local, environmental issue	Global SSI, which cannot be experienced within the local environment, might be too abstract for students. However, once the issue is locally interconnected "the problems become immanent and complicated with personal, economic, political and social factors" (Jho, Yoon, & Kim, 2014, p.1147). This place-based notion can help students to connect and engage with the SSI on a personal level (Herman, Zeidler, & Newton, 2018; Zeidler, Herman, & Sadler, 2019).
You can take part "individually or in teams" (p.5)	Different perspectives, opinions, and solution approaches need to be discussed when working collaboratively	The ability to acknowledge different perspectives is a vital element of informed decision-making and reasoning in SSI (e.g., Kahn & Zeidler, 2019).
"You should generate a theoretical and practical overview, […], do experiments […] and transfer knowledge into action" (p.4)	Inquiry-based and self-regulated learning environment	Inquiry-based learning activities can require students to make sensible decisions (Pedaste et al., 2015). The perceived autonomy in self-regulated learning environments encourages decision-making (Stefanou et al., 2004).

2006; see Socioscientific decision-making). Within this study, we distinctly focused on the model's competence dimension: *evaluating and reflecting solutions qualitatively* (Eggert & Bögeholz, 2010). Since this competence dimension is affiliated with the selectional phase, decision-making defines "the ability to systematically evaluate possible courses of action and […] to systematically make a final decision" (Gresch & Bögeholz, 2013, p.734). The center of attention is, therefore, participants' ability to apply appropriate decision-making strategies (selectional phase).

Methods

Study 1 implemented a quasi-experimental pretest-posttest with control-group design to measure a possible development in decision-making due to participation in the BUW.

Sample

As our study involved human participants, ethical approval was obtained from the competent Ministries for Education. Participation in the study was voluntary. All participants and parents were provided with information about the survey beforehand. Parents had to sign an informed consent form for their children to participate.

Overall, $N = 196$ students (55% female) aged between 13 and 20 ($M = 15.65$, $SD = 1.67$) completed a questionnaire before (pretest, October/November 2017) and after (posttest, March/April 2018) the BUW 2017/2018. To authentically match the competition's distribution of participants, our sample was drawn from four federal states (Southern, Northern, and Eastern Germany). Furthermore, students attended three different school types (grammar school, comprehensive school, and pre-vocational school). From $N = 196$ students, $n = 81$ students (73% female) were participants of the BUW 2017/2018 and hence belonged to our treatment group. The remaining $n = 115$ students (47% female) served as a control group.

Collection of data

Participants of the treatment and the control group were given a 45-min paper-and-pencil questionnaire on decision-making by Eggert and Bögeholz (2010). This questionnaire consists of four open-ended tasks in the context of sustainable development (see Table 2). The first two tasks investigate students' ability to evaluate different options to tackle a real-world and sustainability-related issue. Students are required to decide upon the most sustainable option and to explain their decision-making approach. Since all the given options are

Table 2 Description of the instrument's tasks

Task No.	Context	Task	Format of answer
Task 1	Stabilization of codfish population in the Baltic Sea	Evaluate the given options and choose the most suitable one	Open-ended, written answer
Task 2	Containment of invasive plants	Evaluate the given options and choose the most suitable one	Open-ended, written answer
Task 3	Consumer decision on chocolate	Reflect upon fictional students' decision-making	Multiple choice
Task 4	Consumer decision on chocolate	Advice on how to advance decision-making	Open-ended, written answer

perceived as equally conceivable, elaborate decision-making is assumed when students evaluate each option in terms of its advantages and its disadvantages (Jungermann et al., 2005). The third task evaluates students' ability to reflect upon the decision-making of fictional students. In the fourth task, students are asked to advice on how to advance these decision-making approaches. According to the analysis by Eggert and Bögeholz (2010), this questionnaire can be used to adequately describe students' decision-making in the selectional phase.

This questionnaire was administered in a pretest-posttest design (before and after the competition) to all students of the treatment and the control group. While students of the treatment group took part in the intervention (BUW), students of the control group did not take part in any intervention between the pre- and posttest.

Analysis of data

Students' answers (tasks 1–4) were analyzed using the respective scoring guide (Eggert & Bögeholz, 2010). Concerning the first two tasks, students' decision-making processes were central to the analysis. Therefore, students' written answers were scored regarding three aspects: 1) the amount of chosen and rejected option(s), 2) students' use of positive and/or negative aspects to argue for or against the option(s) and 3) whether students explicitly weighted criteria. As stated in Eggert and Bögeholz (2010), elaborate decision-making is understood as students' full trade-off of information. Following this understanding, the maximum score was assigned when students were able to discuss all four options with at least one negative and one positive aspect per option. The latter tasks (reflection upon other students' decision-making and ideas for improvement) scored students' ability to recognize the strategy that was used by fictional students. Scores were also assigned for students' suggestions on how to advance their decision-making (e.g., consider positive *and* negative aspects of an option). Exemplary items, as well as more detailed information on how to score students' answers, are provided in Eggert and Bögeholz (2010) and Gresch et al. (2013). For the analysis of reliability, Cronbach's α was calculated. For the first two tasks of the questionnaire (decision-making strategies), the internal consistency was acceptable with Cronbach's α for task one = .71 (pretest) and .66 (posttest) and for task two = .70 (pretest) and .63 (posttest). For task three and four (reflection), the internal consistency was inacceptable with Cronbach's α = .35 (pretest) and = .34 (posttest). Moderate reliabilities within this second section have been found in other studies (e.g., Gresch et al., 2013). Accordingly, data from task three and four were not used in further analysis. A second person coded about 25% of all questionnaires. The interrater reliability was found to be sufficient (Cohen's Kappa: ≥ .76). Items that were scored differently by the two independent raters were re-examined. In addition to the scoring proposed by Eggert and Bögeholz (2010), the number of arguments used to describe the advantages and disadvantages of each option in task one and task two was recorded in a separate file.

Results

In the pretest, participants of the BUW (treatment group) did not differ significantly from the control group in their decision-making (t (195) = 3.186, p = .989). Table 3 presents the descriptive statistics from the questionnaire's administration at two times (pretest and posttest). For each scenario, students' average performance (according to the scoring guide by Eggert & Bögeholz, 2010), as well as the number of arguments, are provided.

With regard to the development of participants' decision-making, there were no significant changes from the pretest to the posttest in either group (for all $F < 1$).

Table 3 Descriptive statistics of Study 1

Time	Scenario	Decision-making				Number of Arguments			
		Mean		SD		Mean		SD	
		TG	CG	TG	CG	TG	CG	TG	CG
Pretest	Codfish	.58	.55	.48	.42	3.2	4.0	3.0	3.6
	Invasive plants	.60	.63	.46	.40	4.7	5.2	3.7	3.9
Posttest	Codfish	.58	.57	.41	.42	4.3	3.6	3.5	2.9
	Invasive plants	.61	.60	.40	.36	5.3	4.7	3.9	3.5

[Note]TG for students of the treatment group and CG for students of the control group

This was valid for the separate calculation of each scenario (codfish and invasive plant) as well as for the combination of both scenarios and their scores. Conclusively, participants of the BUW did not enhance their decision-making significantly over the course of the competition.

With reference to students' use of arguments, there was no significant difference between the treatment and the control group in the pretest (t (195) = 1.68, p = .355). Combining the pretest data with the posttest data, a statistically significant interaction between time and group was found. This was valid for the calculation of each scenario (codfish: F (1, 195) = 12.05, p = .001, η^2_{part}: .058; invasive plants: F (1, 194) = 5.98, p = .015, η^2_{part}: .03) as well as for their combined calculation (F (1, 194) = 183.38, p = .001, η^2_{part}: .056).

Discussion of results

The purpose of Study 1 was to examine the competition's effect on participants' decision-making using a questionnaire by Eggert and Bögeholz (2010). This questionnaire analyzes decision-making in its selectional phase and, therefore, focuses on students' ability to use appropriate decision-making strategies. Our data show no significant effects on students' decision-making due to participation in the BUW. This result contrasts with previous studies that applied the same questionnaire before and after interventions (e.g., Eggert, Ostermeyer, Hasselhorn, & Bögeholz, 2013; Gresch et al., 2013; Gresch, Hasselhorn, & Bögeholz, 2017).

One explanation could be that the questionnaire was commonly implemented before and after short term interventions. These interventions might have been more precise in their learning aims and outcomes (e.g., Gresch et al., 2017). Besides, previous studies that used this questionnaire predominantly focused on the promotion of students' decision-making strategies (e.g., Gresch et al., 2013). The BUW, in contrast, can be regarded as a long term intervention that does not seek to develop participants' use of strategies explicitly. Thus it is assumed that the poor study results are mainly due to the lack of instructional guidance on how to strategically make a decision (here: full trade-off).

Number of used arguments

As reported in Results, participants of the treatment group did not improve in their ability to use an appropriate decision-making strategy (here: full trade-off; evaluating *each* option mentioning *at least* one advantage and one disadvantage). However, they still showed an increased use of arguments after the competition and compared to the control group. This result suggests that participants of the treatment group did not refer to the whole set of options (at least one advantage and one disadvantage per option; maximum score in the test instrument); instead, they investigated fewer option(s) more in-depth (more than one advantage and/or disadvantage per option; consistent score in the test instrument but more arguments in total). Participants' collaborative work during the competition might explain this development towards a more thorough discussion. A study by Evagorou and Osborne (2013) investigated students' collaborative argumentation in SSI. Similar to our results, they found that some groups were able to provide more arguments than others. In their discussion, the authors interpreted this increase in arguments as students' ability to present more solutions and, in turn, their ability to present a more successful final product. Simon and Amos (2011) similarly assume that "by engaging collaboratively in argumentation activities that make reasoning public, students can gain collective experience of constructing arguments, justifying arguments with evidence, evaluating alternative arguments, and reflecting on the outcomes of argumentation" (p.170). Therefore, we assume that the BUW encourages participants to engage with selected options comprehensively, rather than comparing all the available options on a superficial level. This thorough engagement, in turn, is connected to aspects such as reasoning, which is further associated with the pre-selectional phase of decision-making (Betsch & Haberstroh, 2005).

Discussion of the instrument

To guide the following considerations, we use the three components of the "assessment triangle" (National Research Council, 2001) as a structuring rubric (see The assessment of instruments used to measure socioscientific decision-making).

Cognition: Eggert and Bögeholz's instrument builds upon the "Göttinger competence model for socioscientific decision-making" (Eggert & Bögeholz, 2006) and its competence dimension *evaluating and reflecting solutions qualitatively*. This competence dimension postulates different competence levels from naïve to elaborate decision-making. Elaborate decision-making describes students' ability to engage in adequate decision-making strategies. In the context of sustainable development, the most suitable strategy often displays students' full trade-off. A full trade-off includes evaluating all of the given information concerning its advantageous as well as its disadvantageous features (Jungermann et al., 2005). The importance of trade-offs for informed decision-making has been outlined by several other scholars in the field of science education and psychology (e.g., Arvai et al., 2004; Jungermann et al., 2005; Siegel, 2006). Yet, with a sole focus on students' ability to perform a full trade-off, the actual decision context appears to be subordinate. We critically wonder if students might fall into an automatic process of solely recalling all the given information to obtain the maximum score in the test instrument. This automatism could further lead to a neglect of their personal linkage to the specific decision context.

Observation: To process task 1 and task 2 of the questionnaire, students are required to report on their decision-making approach. Following the cognitive principles described above, the instrument generates higher scores when students perform a full trade-off. This illustrates a proper operationalization of the underlying theoretical model. To enable students to perform a full trade-off, all necessary information is given in the respective tasks. This availability of information initially offers each participant the same conditions and assures a certain degree of comparability between students' decision-making approaches (Coe, 2010). Yet, the translation of information into cognitive processes might be more or less successful for specific subgroups of students, e.g., dependent on their reading level (Lane & Iwatani, 2016). In addition to the comparability, the availability of diverse information encourages students to frame a decision problem from different angles, highlighting economic as well as environmental and social aspects (Arvai et al., 2004). On the flip side, the provision of well-prepared information and a particular decision problem means that students do not need to identify an issue of relevance for themselves. To identify an issue of relevance, however, is an essential aspect of the decision-making process (Lewis & Leach, 2006). Furthermore, most of the decision situations we face in our day-to-day life lack a considerable amount of information (Burke, 1990). This, in turn, raises the question if it would be equally important to teach students negotiating SSI even though a certain amount of information is missing or uncertain.

Interpretation: This instrument features a strict and clearly structured analysis scheme that secured a reliable scoring. Following the theoretical underpinnings, the item score precisely reflects whether or not students are able to use the preferred decision-making strategy. Nevertheless, students' decision-making performances are evaluated based on a manufactured product (their written answers). It seems debatable to assume that this product is a comparable replica of the actual decision-making process (Blömeke, Gustafsson, & Shavelson, 2015). In addition, the analysis scheme assigns scores whenever students explicitly weight criteria in their written answers. On the one hand, this seems reasonable since students should be encouraged to connect SSI with their own values (Oulton, Dillon, & Grace, 2004). Yet, in most cases, the weighting of criteria happens implicitly (Uskola, Maguregi, & Jiménez-Aleixandre, 2010). We therefore expect that some students failed to gain this score since they considered their values indirectly.

Study 2

The second study aimed to supplement the insights from Study 1 by expanding the investigated set of decision-making dimensions. In addition to Eggert and Bögeholz's competence dimension *evaluating and reflecting solutions qualitatively* (Study 1), this study also examines their first and second competence dimension (*understanding and reflecting values and norms* and *developing and reflecting solutions*) as well as the previously introduced cooperative perspective on decision-making (cf. Garrecht et al., 2018).

Method

Based on the results gained in Study 1, Study 2 followed a mixed-methods explanatory design (Creswell, 2014). This includes the collection of additional, qualitative data to explain the previous, quantitative insights (Study 1). In contrast to Study 1, Study 2 is located in an interpretivist paradigm. This paradigm seeks to provide researchers with a deeper understanding of the investigated phenomena from the participants' point of view (Thanh & Thanh, 2015). Informed by these considerations, we decided to implement retrospective interviews to explore participants' experiences with decision-making *during* the competition.

Sample

In the second study, 10 BUW-participants (80% female) from two different project groups were part of our data collection. About half of the participants ($n = 6$) came from Southern Germany, the other group ($n = 4$) lived in Northern Germany.

Collection of data

The development of a suitable instrument was based on Paul, Lederman, and Groß's "retrospective query on learning processes" (Paul et al., 2016, p. 2371). Similar to the sample of our study, Paul et al. (2016) also gathered data from participants of a project-oriented science competition. The method of retrospective inquiry allowed interviewees of their study to connect their conceptions about experimentation with their individual competition project. Based on Paul et al.'s (2016) promising insights, this study likewise engaged in a retrospective inquiry. In total, we developed 26 problem-oriented interview questions that intended to investigate participants' experiences with decision-making during the competition. Interviews lasted about 30 min and were conducted individually.

Analysis of data

The interviews were recorded using a voice recorder. After their transcription, data were processed using MAXQDA 2018 and analyzed using the method of content analysis according to Mayring (2014) and Kuckartz

(2012). Concerning the development of categories, we opted for a hybrid form using a deductive as well as an inductive approach. In a first analysis step, relevant information was deductively drawn from the existing literature to explore participants' decision-making. The selected literature referred to the previously introduced "Göttinger competence model for socioscientific decision-making" (Eggert & Bögeholz, 2006) and Garrecht et al.'s (2018) remarks about the more cooperative notion of decision-making. The respective passages of the literature were extracted, structured, and summarized in several main categories. In a second, inductive analysis step, the main categories were applied to the interview transcripts. Each paragraph of the transcripts was reviewed and used to create finer divisions between the main categories. In other words, this second step aimed to review and differentiate the previously developed main categories into sub-categories that emerged from the interview data. In a last step, the interview transcripts were reviewed once again and relevant passages were assigned to the established categories (coding). A second and independent rater analyzed about 25% of all interviews ($n = 3$) for reliability. The interrater reliability was found to be good (Cohen's Kappa: ≥ .84).

Results

The result section features two overarching interests: (1) Participants' decision-making according to Eggert and Bögeholz (2006) and (2) participants' decision-making in reference to Garrecht et al. (2018).

Participants' decision-making according to Eggert and Bögeholz (2006)

In a first, deductive analysis step, we established three main categories that align with Eggert and Bögeholz's (2006) competence dimensions (Göttinger competence model for socioscientific decision-making). The first two competence dimensions *understanding and reflecting values and norms* (main category 1) and *developing and reflecting solutions* (main category 2) belong to the pre-selectional phase. The third competence dimension *evaluating and reflecting solutions qualitatively* (main category 3) belongs to the selectional phase. In addition to the three main categories, 10 sub-categories emerged from the interview data. The distribution of codes will be described in the following.

Pre-selectional phase: The first competence dimension (*understanding and reflecting values and norms*) encompasses students' ability to "comprehend and reflect on personal and societal values and norms that are inherent to socioscientific issues" (Bögeholz et al., 2014, p.237). Codes ascribed to the first competence dimension (main category 1) were assigned thirty-three times. This main category was further divided into five sub-categories. Three of the sub-categories describe participants' awareness of contemporary and sustainability-related issues: pollution ($n = 5$ codes), the loss of biodiversity ($n = 9$ codes), and scarcity of resources ($n = 6$ codes). The fourth sub-category addresses participants' concern regarding the well-being of humans and other animals ($n = 7$ codes). Codes ascribed to the last sub-category report participants' awareness of an intra- and intergenerational responsibility ($n = 6$ codes).

The second competence dimension (*developing and reflecting solutions*) summarizes students' ability to reflect upon complex information as well as their ability to develop possible solutions (Bögeholz et al., 2014). The second competence dimension (main category 2) assimilated ninety-five codes and was further split into five sub-categories. The first two sub-categories summarize participants' dealing with information. The first sub-category describes participants' quest for information and is called 'information research' ($n = 36$ codes). The second sub-category is named 'handling of sources' ($n = 6$ codes) and reports how participants evaluated the origin of information. The third sub-category links to the development and evaluation of solutions and is called 'scientific working' ($n = 42$ codes). Codes were assigned whenever students showed elements of inquiry-based working. The fourth sub-category gathers students' views regarding the 'generation of possible solutions' ($n = 9$ codes). The last sub-category reports students' 'evaluation of possible solutions' ($n = 2$ codes) in the light of economic, ecological, and social consequences.

Selectional phase: The third competence dimension (*evaluating and reflecting solutions qualitatively*) describes students' "ability to systematically evaluate possible courses of action and […] to systematically make a final decision" (Gresch & Bögeholz, 2013, p.734). Codes assigned to this third main category describe the systematic evaluation of options and participants' consideration of respective advantages and disadvantages ($n = 15$ codes).

Participants' decision-making in reference to Garrecht et al. (2018)

The second, overarching interest refers to the cooperative perspective on decision-making. In a deductive step, this perspective was outlined as the main category: 'empowerment'. In a second, inductive step, this main category was split into two sub-categories: 'agents of change' and 'empowerment of scientific interest'. There was no overlap with the codes assigned in Participants' decision-making according to Eggert and Bögeholz (2006).

Agents of change: Codes were assigned to the first sub-category whenever participants regarded themselves as agents of change ($n = 23$ codes). In other words, this sub-category describes participants' positive experiences when sharing their knowledge and encouraging others to act more sustainably.

Empowerment of scientific interest: In this second sub-category, participants perceived empowerment as a self-regulated driving forward of their scientific interests ($n = 8$ codes).

For an overview, Table 4 presents exemplary quotes from the participants for each of the main categories.

Discussion of results

Participants' decision-making according to Eggert and Bögeholz (2006)

Pre-selectional phase: Concerning the first competence dimension (*understanding and reflecting values and norms*), a majority of participants demonstrated awareness of three contemporary hazards: (1) the loss of biodiversity, (2) pollution, and (3) scarcity of resources. This awareness can mostly be explained by the thematic orientation of interviewees' BUW-projects. Both groups either addressed the jeopardies connected to marine pollution or the decrease in biodiversity within their projects. Additionally, sustainability-related issues such as the loss of biodiversity have been picked up frequently in students' social media conversations (Andersson & Öhman, 2017). Since young adults demonstrate a lively exchange with social media, these issues might be well-represented topics for them. The ability to identify such relevant issues, as demonstrated by the interviewees, is further understood as a prerequisite for students' engagement in a reasoned discussion and respective decision-making (Lewis & Leach, 2006). About half of the participants explicitly linked these hazards to health consequences for humans and animals. This, the ability to anticipate consequences, appears highly important for the protection of present and later generations and constitutes an essential facet of informed decision-making (Kelly, 2006; Reitschert & Hößle, 2007). Last but not least, half of the interviewees also mentioned an intra- and intergenerational responsibility. This mentioning seems reasonable since our intergenerational responsibility is widely accepted as a cornerstone of sustainable development (Brundtland Commission, 1987).

With regard to all three competence dimensions, the second dimension (*developing and reflecting solutions*) accumulates the highest number of codes ($n = 91$). Every single interviewee shared experiences that connected to the quest for information or the evaluation of its sources. This information research prepares an informed decision and both aspects are "considered to be an important sub-process of decision making" (Lindow & Betsch, 2019, p.24). The critical assessment of information seems particularly important concerning the propagation of so-called 'fake news' (Lazer et al., 2018), which can lead to decisions that are based on a biased sample and lack essential information (Glöckner & Betsch, 2008). Another aspect that was outlined by the majority of interviewees concerned their inquiry-based working

Table 4 Exemplary quotes from the participants

Reference	Main category	Exemplary quotes
Eggert and Bögeholz (2006)	Understanding and reflecting values and norms	**Sub-category: intra- and intergenerational responsibility** "It's quite obvious […] when I'm 80 years old, there won't be any oil anymore […] and that's something I don't want to witness. And that's why I believe it's important to start thinking about it now. Because this isn't something that only my children, grandchildren, and great-grandchildren witness […] but even I am witnessing this and I don't want to blame myself for this." [Student 1–00:03:44–00:04:23]
	Developing and reflecting solutions	**Sub-category: Scientific working**"I think the most exciting part is to plan and to conduct an experiment and to analyze it afterwards. To see the difference between the things you actually had planned and what turns out to be the result. Problems often arise while working. We, for example, said that we want to do a pilot study first. And this pilot study showed us that the product wasn't working because the pump wasn't strong enough. And therefore the experimental setup has changed accordingly." [Student 9–00:26:21–00:27:01]
	Evaluating and reflecting solutions qualitatively	"Actually, it's never the case that there are only equivalent options […] it's more like a different weighting or a hierarchy where we have to say what's more important […] so different aspects are unequally important. And it's of little avail to have the most awesome product when, in the end, it's so expensive that nobody is going to use it." [Student 9–00:25:18–00:26:12]
Garrecht et al. (2018)	Empowerment	**Sub-category: Agents of change** "I do believe that my attitude towards sustainable development has changed because I realized during the project work that one can actually do something using simple methods […] and many people like the idea and this shows how excited they are that young adults support the environment and care for a sustainable development" [Student 7, 00:14:44–00:15:20]
	Empowerment	**Sub-category: Empowerment of scientific interest** "I think the greatest difference is that we thought of a research question on our own, that we planned the experiments on our own and that we don't have a strict procedure to follow. If you think about a placement, for example in chemistry, [...] having a note that says what we need and what we have to do and so on. And this is, of course, different [in the competition context] because we don't have somebody who thinks for us" [Student 8–00:33:43–00:34:27]

during the competition. Inquiring a problem in a self-regulated manner highlights the active and autonomous notion of learners (Ebert-May, Brewer, & Allred, 1997). This autonomy might be especially empowering in the context of decision-making (Stefanou et al., 2004).

Selectional phase: The third competence dimension (*evaluating and reflecting solutions qualitatively*) was already investigated in Study 1. In this previous study, no significant developments in participants' decision-making were detected. Conversely, when using the methodological tool of retrospective inquiry, supportive statements were found in 80% of the interviews. This result indicates that participants indeed evaluated different courses of action as part of their competition experience; yet, they were not able to apply these strategies explicitly during the written test in Study 1. This result further underpins the previous consideration that dealing with decision-making strategies is solely an implicit aspect of the BUW. Based on this result, one might wonder whether or not the BUW should offer participants more explicit guidance on how to use decision-making strategies. On the one hand, students' deliberate use of decision-making strategies is acknowledged as an important aspect when processing various information to reach an informed conclusion (e.g., Lindow & Betsch, 2019; Papadouris, 2012). On the other hand, any explicit learning intervention would reduce aspects of the self-regulated learning environment, which has been positively accentuated by participants.

Drawing upon the total number of codes, we assume that participants of the BUW engaged in a fair amount of decision-making. Overall, the distribution of codes reveals that participants' decision-making can be predominantly located within the pre-selectional phase. The results furthermore indicate that the selectional phase requires more instructional guidance concerning the appropriate use of decision-making strategies.

Participants' decision-making in reference to Garrecht et al. (2018)

Agents of change: During the interviews, every single participant expressed feelings of empowerment. For students, empowerment meant to act more sustainably or to encourage others to do so. This understanding portrays participants as capable mediators and accountable social actors in the context of sustainable development (James & Prout, 1990). It is also consistent with results found in a study by Herman et al. (2018), showing that place-based learning opportunities can increase students' expression of care. Similar to the participants of Herman et al.'s study, participants of the BUW also engaged in a place-based SSI. This local connectedness of their project might have encouraged their personal engagement with the SSI during and after the competition. As a result, participants might have felt empowered to share their experiences in this respect. Furthermore, the dynamic interaction between participants and other students potentially inspires a culture of shared decision-making, which can bring forward joint actions for sustainable development (Celino & Concilio, 2011).

Empowerment of scientific interest: The second subcategory describes participants' empowerment in the context of their learning. Most participants considered the competition's self-regulated learning environment as positive and enriching. The self-regulated learning environment was exemplified by, for example, choosing their own project idea, structuring scientific experiments, and general project management. To organize one's learning processes can encourage students to become autonomous learners (Kopzhassarova, Akbayeva, Eskazinova, Belgibayeva, & Tazhikeyeva, 2016). Supporting autonomy and ownership, in turn, can motive students to engage with the context of sustainable development (Madsen, Nordin, & Simovska, 2016) and decision-making (Stefanou et al., 2004).

Development of decision-making

Retrospective questioning aims to compare students' understanding at two different moments in time. Analyzing the collected data showed no concrete evidence which indicated a development in students' understanding of socioscientific decision-making. One explanation could be that making decisions is an everyday task since our early years. A basic understanding of how to weigh information, for example to reach a decision, is already found in young children (Kachergis, Rhodes, & Gureckis, 2017). As a consequence, the procedure of making a decision might be hard to retrieve as a deliberate concept. This lack of awareness might be further strengthened by the implicit nature of everyday decision-making (Haidt, 2007). A second explanation targets the use of decision-making strategies. Many researchers propose the use of decision-making strategies for the elaboration of SSI (Eggert & Bögeholz, 2010; Seethaler & Linn, 2004; Siegel, 2006). However, applying appropriate strategies seems difficult for students, even when they are confronted with a decision situation at that very moment (Hong & Chang, 2004). To assess the use of strategies through *retrospective* methods seems debatable since strategies are not like experiences that can be recalled.

Based on these considerations, applying a method of retrospective inquiry to investigate the *development* of socioscientific decision-making processes might not have been the most suitable approach in this particular context. In light of an interpretivist paradigm, this study allowed broader insights into participants' experiences with decision-making *during* the competition.

Discussion of the instrument

We want to clarify that the results of Study 2 heavily depend on the underlying theoretical constructs, research questions, and interview structure. Study-dependent results do not give direct feedback about the quality of the research tool in general.

Cognition: Retrospective questioning aims to compare students' understanding at two different moments in time. Hence, the underlying cognitive model of the research interest must be distinguishable in separate and observable characteristics. Examining concepts about scientific processes such as experimentation, for example, seems to be highly suitable for this method (Paul & Groß, 2017). In contrast, other research foci might be less appropriate (e.g., socioscientific decision-making).

Observation: The central interest in retrospective research is participants' self-reporting of past experiences (Cox & Hassard, 2007). From an economic perspective, collecting information retrospectively, rather than having several measurement points, is much quicker (Beckett, Da Vanzo, Sastry, Panis, & Peterson, 2001). However, the accuracy of recalled processes might be imprecise. Some interviewees might have trouble remembering the necessary experiences to outline the process and offer adapted "post hoc rationalizations" (Basturkmen, Loewen, & Ellis, 2004, p.251) instead. As claimed in Development of decision-making, changes in decision-making might not even be noticed and, therefore, not processed or stored in the memory (Sudman, Bradburn, & Schwarz, 1996). Depending on the particular study context, such as sustainable development within this study, the effects of social desirability must also be considered (Cerri, Thøgersen, & Testa, 2019). Nevertheless, the retrospective inquiry "allows the student to reflect on all phases of a learning task" (Chamot & Kupper, 1989, p.252) and hence offers unique insight into their learning history.

Interpretation: The interviewee constitutes the central interest when using retrospective interviews. This participant-centered data collection can initiate a shift in power between the researcher and the participant (Aléx & Hammarström, 2008). This shift enables participants to elucidate their individual understandings, which enabled us to detect both understandings of decision-making (the systematic and the more cooperative one). Yet, these kinds of qualitative data are exposed to the risk of subjective interpretation and a rigorous data analysis might thus be hampered (Anderson, 2010).

Conclusion

This study aimed to assess an environmental science competition (BUW) in its effectiveness to promote students' socioscientific decision-making. In addition, both of the applied instruments were evaluated in light of the "assessment triangle" (National Research Council, 2001).

Effects of the BUW on participants' socioscientific decision-making

With respect to Study 1 and participants' decision-making *before* and *after* the BUW, no significant developments were recorded. Study 2 explored participants' experiences with decision-making *during* the competition. The results suggest a distinct predominance of experiences that can be ascribed to the pre-selectional phase of decision-making.

Drawing upon the theoretical division by Fang et al. (2019), this paper considered socioscientific decision-making as a multi-phased process. Regarding the selectional phase, the results of our studies suggest that enhancing students' decision-making requires explicit and instructional guidance on how to apply decision-making strategies. Since the BUW does not offer such explicit learning opportunities, it seems reasonable that participants of the competition did not improve in the respective decision-making phase. Although the qualitative data of Study 2 revealed evidence that participants of the competition had to choose between different courses of action, they were not able to explicitly apply these strategies during the written test in Study 1. Concerning the pre-selectional phase, the results of Study 1 demonstrated significant (yet weak) improvements in participants' number of used arguments. This increase might indicate participants' enhanced ability to elaborate on SSI more in-depth by proposing a higher number of solutions. This interpretation was strengthened by qualitative evidence from Study 2, which revealed students' profound knowledge regarding their project. Based on the insights from Study 2, we also assume that the self-regulated and inquiry-based aspects of the competition positively affected decision-making in its pre-selectional phase. Last but not least, both notions of decision-making (the individual-based and the more social one) were found to be part of the competition experience.

Measuring socioscientific decision-making

The instrument applied in Study 1 conceptualizes decision-making as students' use of appropriate decision-making strategies. In the context of sustainable development, weighing positive and negative aspects of each option is assumed as a suitable strategy (Eggert & Bögeholz, 2006; Siegel, 2006). This instrument therefore considers decision-making on a structural level. The socioscientific context of the task seems rather interchangeable since the use of strategies usually happens on a meta-cognitive level (e.g., Sakschewski, Eggert, Schneider, & Bögeholz, 2014; task content: energy-related issue). Study 2 applied retrospective interviews which enabled the exploration of rational as well as social aspects of decision-making. This second instrument ergo investigates decision-making on an explorative level and is highly dependent on the research context (e.g., decision-making in a science competition). Overall, we were able to examine socioscientific decision-making on two levels: a structural level (interest in students' application of adequate decision-making strategies, Study 1) and a content level (interest in students' reasoning in more contextual terms, Study 2). This differentiation goes in line with the results by Fang et al. (2019). For an overview, Table 5 summarizes selected characteristics of each instrument as used within the studies.

This subdivision can potentially help future research endeavors to clarify and refine respective aims and outcomes. Last but not least, the implementation of several instruments supported a more holistic perspective on the development of students' decision-making (Kuckartz, 2014). These insights deepened the idea of decision-making as a multi-phased process.

Limitations

A limitation (and a strength) of this study is the intervention's embeddedness in a real-world context. The treatment group displays a highly selective group of strongly motivated students willing to work on a sustainability-related project. Thus, the recruitment of a suitable control group with similar characteristics was not a trivial task. While we could ensure a comparable interest in biology as one highly relevant factor, other variables might have been important as well. However, due to a lack of testing time, this was not possible which might be considered as a possible limitation of our study. Over the course of the studies, students took part in regular school activities and events connected to their personal development. Concerning the amount of information needed, we assume that it is nearly impossible to control all these variables under the given conditions. As a result, we only have limited explanatory power that results are due to participation in the BUW.

Implications and further research

The results of this paper clarify the potential of inquiry-based learning opportunities with regard to the exploration of SSI. Inquiry-based learning opportunities, such as the BUW, often follow a more progressive pedagogy and thus provide learning contexts that are more autonomous and student-centered (Lindahl, Folkesson, & Zeidler, 2019). As the results of this paper suggest, these learning contexts are particularly suitable to foster students' decision-making in its pre-selectional phase. Another implication targets the teaching practice: Only if teachers are aware of the multi-phased structure and the different aspects of decision-making, they can sensibly evaluate the potentials of their learning opportunity. Vice-versa, teachers can help researchers to understand the practicability of a learning context. This interconnectedness emphasizes the importance of bridging the gap between research and practice, particularly in education.

Based on our research endeavor, several questions remain unanswered. Currently, we assume that inquiry-based elements of the competition contributed to participants' engagement and decision-making. We suggest a separate study to make detailed statements about their effects. This study should be set within similar contextual conditions featuring different treatment groups that partake or do not partake in self-regulated and inquiry-based learning processes. Additionally, a recently published study by Hancock, Friedrichsen, Kinslow, and Sadler (2019) explores teachers' collaborative selection of SSI for an SSI-based framework. Yet, we think it would be at least equally interesting to track students' criteria and choices when it comes to the selection of SSI. This investigation might provide valuable insights into trending contexts of interest amongst adolescents, which could be used by practitioners and researchers alike for instruction design purposes. The BUW requires participants to choose a local SSI as one of the first requirements of participation. Thus, it might offer the optimal environment for such a research endeavor.

Table 5 Characteristics of the instruments as they have been used within the two studies

	Study 1	Study 2
Reference	Eggert and Bögeholz (2010)	Paul, Lederman and Groß (2016)
Format of data collection	Paper-pencil-test; open-ended, written answer	Interview; semi-structured guideline
Conceptualization of decision-making	Appropriate use of decision-making strategies	According to Eggert and Bögeholz (2010) and Garrecht et al. (2018)
Assessment focus	Structural nature	Explorative nature
Adaptability of context	Yes	No
Decision required?	Yes	No

The wide-ranging consequences of the global increase in temperature will affect the security of individuals and populations worldwide (IPCC, 2018). More than ever, we are in severe need for educational activities that promote novel ideas on how to combat these consequences while equally supporting students in how to make informed decisions. Concerning this paper's analysis, the BUW appears to be one of these educational activities which can address both the development of sustainability-related ideas and the development of decision-making.

Abbreviations

BUW: BundesUmweltWettbewerb; SSI: Socioscientific issues

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Authors' contributions

All authors (CG, ME, TH, UH) took part in the conceptualization of the study and the selection of methods. CG was responsible for data collection and data curation. CG and TH analyzed the data set. CG wrote the original draft of the paper. All other authors (ME, TH, UH) were part of the review and editing process. The authors read and approved the final manuscript.

Authors' information

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

As our study involved human participants, ethical approval was obtained from the competent Ministries for Education (Baden-Württemberg, Hamburg, Schleswig-Holstein and Brandenburg). Participation in the study was voluntary. All participants and parents were provided with information about the survey beforehand. Parents had to sign an informed consent form for their children to participate.

Consent for publication

Not applicable. Data cannot be traced back to individuals. All student participants were instructed to write a predefined code on their worksheets and paper-based tests, so that data was already de-identified during collection.

Competing interests

The authors declare that they have no competing interests.

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