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Promoting Reflections on Decision-Making in Socio-Scientific Issues

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Abstract

Socioscientific issues (SSIs) require reflective decision-making. Findings have indicated that decision-making is more often based on heuristics than rational considerations. To improve one's decision-making, it is essential to reflect upon decisions to increase awareness of the initially applied heuristics. Furthermore, research has indicated that decision-making depends on the decision-maker's perspective on an SSI. Using a 2x2-experimental-design, we have investigated effects of two variables on secondary students' ability to reflect their own decision-making. Variables were (1) instruction regarding the "method of reflection", and (2) the "perspective adopted on an SSI", which was either individual or collective. Data on students' reflections were collected three times. Findings showed that students who had learned a specific method of reflection outperformed others regarding the quality of their reflections. Thus, this study provides evidence for the effectiveness of explicitly teaching and learning in terms of reflecting on one's own decision-making in the context of an SSI.

Keywords

reflection, decision-making, science education, secondary students

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1 Introduction

Fostering decision-making competence (Bewertungskompetenz) is a cross-curricular objective in each science subject (biology, chemistry, and physics; KMK, 2020a; 2020b; 2020c; NGSS, 2013), as well as being central for fostering scientific literacy in general (OECD, 2019, p. 98). Decision-making competence is important in evaluating and solving simple structured problems (e.g., increasing the energy efficiency of a technical device), as well as more complex societal problems (e.g., moving towards a society not based on fossil fuels and mitigating climate change). The latter type of problem raises questions of personal lifestyle, as well as socio-political issues, which have strong relations to scientific methods and findings. This is why they are referred to as socioscientific issues (SSIs) in science education (e.g., Zeidler, 2015). In general, socioscientific decision-making competence is manifested in students' application of scientific knowledge in their own lives (e.g., Sadler, 2004; Fang, 2019) and their participation in discussions and social opinion-forming in modern technology-driven societies about science and technology based problems. The demand for the promotion of socioscientific decision-making competence is particularly urgent due to a multitude of societal problems with strong relationships to the natural sciences, as well as the humanities and social sciences (e.g., climate change). Thus, we generally understand fostering decision-making competence as an inter-subject endeavour, but the perspective adopted in our study is limited to teaching and learning science.

Regarding the psychological foundations of decision-making, so-called dual-process models describe deliberative and intuitive decision-making modes, as well as an interplay between both (e.g., Evans, 2008). Deliberate decision-making is characterised by the application of elaborate, rational, and deliberative strategies (e.g., so-called trade-off strategies) in which advantages and disadvantages are weighed and balanced against one another. On the other hand, in their everyday lives, people most often use effortless, fast, and frugal strategies, which are also known as heuristics, when making intuitive decisions (Dittmer et al., 2016). Psychological research tends to indicate that deliberate decision-making is rare in daily life. In addition to the fact that the use of heuristics is fast and effortless, research indicates that intuitive decision-making is sometimes quite effective and even superior (e.g., Gigerenzer & Gaissmaier, 2011). However, complex problems typically deserve to be addressed with complex strategies instead of "quick and dirty" strategies. Therefore, decision-making-competent people must have self-reflective abilities to understand the interplay between the intuitive and deliberative modes, become aware of their own decision-making routines and behaviour, and make well-informed decisions about whether it is sufficient to apply intuitive strategies or it is worth making the effort to use deliberative strategies.

Processes of reflection can be stimulated in teaching by initiating recurring phases of reflection (Moon, 2000, p. 166). In our study, processes of reflection are stimulated with the aim of making a person aware of their own decision-making processes. Here, reflection thus promotes metacognition (Ertmer & Newby, 1996) about one's own decision-making. Thus, in our study, we aim to explore whether and, if so, to what extent reflection in the context of decision-making can be explicitly and effectively promoted in science education. There is a need for tried and tested ways of implementing the promotion of decision-making competence in the classroom. The reason for this are justified objections from school practice to working with decision-making on multi-perspective questions, which is unfamiliar to

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science education teachers (Langlet et al. 2022). Furthermore, Leubecher et al. 2024 showed biology textbooks offer too few tasks to promote decision-making competence.

2 State of research on decision-making competence

In the following, we will briefly outline two fields of research our own study is based on: first, research on the reflective component of decision-making competence and, second, the perspective adopted regarding the problem at hand, which can be either individual or collective, depending on whether a single person or a social group is affected by a particular decision, makes the decision and the time at which consequences occur.

First to the reflective component of decision-making competence: Fang et al. (2019) present in their review a decision-making framework which comprises the following three steps: "formulating the decision-making space, positing a suitable decision-making strategy to make a decision, and reflecting on the decision-making process" (Fang et al., 2019, p. 431). They conclude that only a minority of studies focusses the third phase, hitherto there is a research gap with regard to empirical studies that focus on reflection of decision-making and its fostering. (Fang et al. 2019). In subject-matter education in the natural sciences, there are two perspectives on the final phase, the reflection of decision-making: (1) the view of reflection as the evaluation and critical review of decision-making, which results in the appreciation of compensatory, effortful decision-making strategies (e.g., Eggert & Bögeholz, 2006; Hostenbach et al., 2011), and (2) the view of reflection as a means of conscious decision-making and an opportunity to learn about the nature of one's own decision-making (Sander, 2017; Dittmer et al., 2016; Reitschert & Hößle, 2007). The latter is more in line with the focus of this study.

In addition to these various theoretical perspectives on the role of reflection in decision-making, empirical studies have emphasised the importance of promoting students' decision-making competence. Jimenez et al. (2023) describe how students during a course which focuses three phases of a structured decision-making process used tradeoffs for choosing an option and developed multiple perspectives during the reflection of their decision-making. Even though the authors did not aim at evaluation the effectiveness of the course a majority of students successfully used tradeoffs and included multiple perspectives. They conclude that including structured decision-making processes in science education is a promising approach.

The following short term interventions have been shown an improvement of students' reflections on and evaluations of decisions made by others: Eggert et al., (2010, p. 306) and Hsu & Lin (2017) used succesfully metacognitive prompts concerning the task and the used strategy for solving the task to foster reflection. In two studies students' reflections of decisions made by others was promoted with the help of tasks which guided students independently through the steps task analysis, choosing a suitable strategy, reflection of the adequacy of the applied strategy and goal setting for the next task (Gresch et al., 2013, p. 2593; Gresch et al., 2017, p 102f.). In addition, Papadouris (2012, p. 608) applied in a course metacognitive prompts to familiarize students with the role of subjectivity in decision-making, reliability as a criterion for assessing decisions and strategies for increasing the reliability of a decision. One result was the improvement of students' ability to work out reasoning flaws in given decisions (Papadouris 2012). It is unclear whether metacognitive prompts promote reflection on one's own decision-making as well since in the studies cited, only reflections on

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decisions made by others were analysed. In contrast, Garrecht et al. (2020) concluded that an environmental science competition does not enhance students' reflections on decisions made by others. Interesting for the development of a teaching intervention is the finding that reflection, in the sense of evaluation, can be fostered by exchange with peers (Lee & Grace, 2012).

The cited empirical studies have all adopted perspective (1), viewing reflection as a tool for evaluating, critically reviewing, and ultimately improving students' decision-making.

Fewer empirical studies have focussed on reflection as a means of (2) conscious decision-making. Böttcher and Meisert (2013) show that a reflective attitude towards one's own decision-making is better stimulated in learning environments based on indirect instruction, in which students develop their own decision-making strategies, as compared to direct instruction. Furthermore, Menthe (2012) indicates that an everyday context, such as the choice of tapwater or mineral water, results in self-reflections on decision-making. Thus far, research indicates that reflection, as a means of conscious decision-making, can be better stimulated by indirect instruction in a context that is relevant to students' everyday lives.

As shown, reflection as a metacognitive activity has been studied in relation to reflection on decisions made by others while teaching interventions with a specific focus on metacognitive prompts enhance students' ability fo reflect decisions made by others. However there is still a research desideratum regarding the effect of explicitly teaching and learning a method of reflecting on one's own decisions. Thus, one basis of our research project is the question of whether integrating a method of reflection in science education promotes students' ability to reflect their own decisions as a facet of decision-making competence.

Roughly speaking, an SSI that requires a decision to be made can be characterised by the perspective within which it is stated. In turn, an SSI's perspective can be characterised by the answers to the following questions (e.g., Dittmer et al., 2016):

- How do the consequences of a particular decision occur in "space and time"? Consequences may be spatially close or distant and may occur in the near or far future.
- What are the "range and scope of the consequences" of the decision? Does it matter to only a single person, or does it affect society or even the world as a whole?
- "Who is making the decision?" A decision can be made by a single decision-maker. Consider a young student deciding whether to eat a vegan diet in the future to mitigate climate change. In contrast, some decisions are made by a group of people. Now, consider a committee at a university deciding whether to implement a vegan day in the cafeteria to mitigate climate change. In both examples, the scientific context (climate change) is the same, but people are concerned in different ways.

In our study, an SSI viewed from an *individual perspective* is decided by an individuum and characterised by consequences that occur close by in the near future and affect a single person. In contrast, an SSI viewed from a *collective perspective* is decided by a group of people, has consequences at a spatial distance and in the far future, and has consequences on a societal scale.

The perspective taken influences the extent to which personal experiences and knowledge will be activated in decision-making, as well as the choice of a decision-making strategy (Sadler, 2004; Herman et al., 2020). Nevertheless, prior research has primarily considered the

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role of an SSI's context and how it may affect students' decision-making (e.g., Christenson et al., 2012). So, it has not yet been systematically investigated whether and, if so, to which extent the perspective adopted on an SSI affects students' decision-making and ability to reflect.

Based on the identified two research desiderata we have explored whether reflecting on decisions about an SSI is affected by (a) a teaching intervention where students are explicitly teached how to reflect a decision and (b) the specific perspective adopted regarding an SSI, which can be individual or collective. This leads to our research questions:

Does students' ability to reflect their own decisions change as a result of ...

> [F1] ...a brief intervention in which students are taught a specific method of reflecting on their own initial decisions,
>
> [F2] ...the perspective adopted regarding an SSI, which can be either individual or collective?

3 Methods

3.1 Study design and sample

To answer both research questions, an intervention study was conducted using a 2x2-experimental design (Table 1) with the two independent variables: *method of reflection* (reflection versus content) and *perspective on SSI* (individual versus collective).

The topic of the lesson was electromagnetic radiation in general and mobile-phone radiation in particular. The SSI was described using both individual and collective perspectives. The individual perspective on electromagnetic radiation concerned the question of which cell phone to buy. From a collective perspective, the question of whether new legal distance regulations between residential buildings and mobile phone masts were necessary was raised.

In a pre-study, students were asked in a questionnaire about their interest in individual and collective perspectives adopted on physical topics. The individual perspective (buying a cell phone) and the collective perspective (distance regulations between residential buildings and mobile phone masts) adopted on the topic electromagnetic radiation did not differ regarding students' interest. As a result, it can be assumed that any learning effect detected in our study is not due to the difference in interest in each perspective on the SSI.

In the main study, the SSI, from an individual or collective perspective, was explored, and each student was asked to make a decision. A method of reflection was taught and practiced in both *Reflect* groups (Table 1). To achieve this goal, students were engaged in a classroom discussion where they explored general key components of reflection: purpose, content (Aufschnaiter et al., 2019; Nguyen et al., 2014), attitude, and format (Moon, 2004, p. 136ff.). They sought to deepen their understanding of reflection by analysing an example. The example showed a reflective dialogue between two individuals focusing on a decision-making processes. This way, the students identified how questioning techniques can enhance a reflective process. The students were finally involved in an exercise where they used their

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initial reflection skills by discussing their own decision-making processes in a context concerned with electromagnetic radiation.

The two *Content* groups only learned about the subject matter of the lesson (electromagnetic radiation). For this purpose the students worked out the difference between ionizing and non-ionizing radiation using the electromagnetic spectrum and tried to make the radiation from the cell phone visible experimentally (Dengler 2008). Students in the *Reflect-individual* and *Content-individual* conditions made decisions from an individual perspective on an SSI. Students assigned to either the *Content-collective* or *Reflect-collective* condition made decisions from a collective perspective. All teaching materials are available on request from the first author.

		independent variable 1	
	method of reflection … / perspective on SSI	… taught	… not taught
independent variable 2	Individual	Reflect-individual	Content-individual
	Collective	Reflect-collective	Content-collective

Table 1: Two independent variables led to four experimental teaching conditions

Each intervention class lasted 180 minutes. Time on task was held constant across all interventions. Data were collected directly before and after each intervention, as well as 3 months after the intervention, to test the stability of the effects (a pre-post follow-up design). The pre- and post-tests were administered on the same day. This was due to the COVID-19 pandemic. Specifically, the participating schools restricted external visitors, like us, to a single day visit.

The pre-, post-, and follow-up tests each consisted of the same task, reflecting on one's own decision, which will be referred to as the *reflection task* (appendix). The reflection task involved two SSIs, one stated from an individual perspective and one stated from a collective perspective, on the same topic, the energy consumption of local versus online shopping. At first, this physical topic was briefly described and afterwards the two adopted perspectives. The individual perspective asks whether a school textbook should be bought either online or in a local store. The collective perspective focuses on the question of a legal ban on free shipping. The prompt was as follows: "Describe in writing and in detail in complete sentences how you would like to receive the book/ whether you would be for or against such a ban. Take a critical look at your decision and reflect on it." The prompt and its suitability for identifying and describing the students' ability to self-reflect on their decision-making had been tested in preliminary studies (Ratzek et al., 2020). The reflection tasks, which were carefully translated from German into English, can be found in the appendix.

Our sample consisted of eight intact secondary school classes (11^{th} to 13^{th} grades; N = 164). Two classes were randomly assigned to each of the intervention groups. The distribution of classes and students across the four experimental conditions is shown in Table 2. The distribution ultimately proved be slightly unbalanced. From pre-test to post-test and from

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post-test to follow-up-test, the total sample size decreased due to sample mortality and the resulting missing data.

	Reflect-individual	Content-individual	Reflect-collective	Content-collective	Sum
$N_{classes}$	2	2	2	2	8
$N_{students}$ pre-test	35	43	34	52	164
$N_{students}$ post-test	34	42	33	52	161
$N_{students}$ follow-up test	23	40	30	46	139

Table 2: Allocation of classes and pupils to the four intervention groups

3.2 Data analysis

The reflection task was evaluated by applying qualitative content analysis (Schreier, 2012). A system of categories was derived in a deductive-inductive manner and tested in a second pre-study (Ratzek et al., 2021). The system of categories was initially based on the two deductively derived top-level categories: *elements of decisions* and *levels of reflection* and can be viewed in the appendix.

Under the top-level category *elements of decisions*, options, strategies, and attributes were subsumed as the three basic elements of a decision. We understand a decision as making a choice among *options* (Betsch et al., 2011, p. 3, 69; Pfister et al., 2017, p. 16). *Options* can be described and compared based on the *attributes* that characterise and qualify each option (Pfister et al., 2017, p. 16). The particular process by which a decision is made based on available information is called a decision-making *strategy* (Pfister et al., 2017, p. 96).

To describe in more detail how students discussed *options*, *attributes*, and *strategies*, fine-grained sub-categories were developed inductively. We differentiated between whether the choice of options or strategies was *justified*, for example, by stating a supporting attribute, or *not-justified*. Moreover, we further distinguished between whether the students simply *named an attribute* or were *deeply engaged in discussing, evaluating, or prioritising an attribute*. In addition, the category *others* was applied whenever a student evaluated or described his/her decision on a meta-level without addressing any *options*, *strategies* or *attributes*. All text sections coded with the category *attribute* were further differentiated inductively according to the specific ideas expressed. One student (ID 117) wrote “Going to the bookstore would cost me time”. Here the attribute *time* is named and used to characterize the option local bookstore for buying a book (Table 3).

The top-level category *levels of reflection* subsumes five sub-categories in ascending order. These sub-categories allow detailed descriptions of the depth and quality of students’ reflections on their decisions. They were partially derived from Nowak et al. (2019). These subcategories refer to different levels of reflection and indicate how sophisticated the reflections were and how broad the adopted perspectives were. The first and the second sub-category exclusively refer to one’s own decision-making and its description and evaluation. Student 117 for example describes ordering the book online as hier/her chosen option (Table 3). The third sub-category indicates further perspectives, potential conceptual categories that

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might be applied as an alternative to an initially made decision or perceived as negative aspects of one's own decision. In Table 3 student's answer illustrates this by buying the book in a local bookstore as an alternative to the chosen option online order. Moreover, the fourth sub-category indicates whether these alternatives were explicitly compared with one's own initial decision or not. The fifth sub-category indicates whether one's perspectives were broadened with a view to future decision-making and whether consequences were derived from what has been learned about an SSI and the reflection on one's own decision-making.

Both top-level categories were ultimately assigned to each coding unit. The independent coding of 20% of the data by two independent coders resulted in a satisfactory intercoder-reliability of κ=.84 for the *elements of decisions* and κ=.82 for the *levels of reflection*. After coding all the results of the reflection tasks, the qualitative coding was scored to determine the differences between the four experimental conditions on a quantitative basis The points awarded per code can also be found in the category system. A score was awarded for each *element of decision* addressed at each *level of reflection*. The more cognitively demanding and comprehensive the consideration of an element was, the higher was the score assigned to it. This scoring procedure was based on the findings of a third pre-study, in which the teaching of the reflection method was tested (Ratzek et al., 2020), as well as on the work of others (e.g., Gresch et al., 2013, p. 2600). It is, for example, less cognitively demanding to simply choose an option than it is to additionally justify why the option was chosen. Thus, the category non-justified option is rewarded with 1 point and the category justified option with 2 points. Student 117 for example got 2 point for stating a justified option. Simply naming an attribute is rewarded with 1 point while engaging with it receives 3 points. By naming the attribute *time* both at the level of reflection *description* and *naming an alternative* student 117 got 1 point for each level of reflection (Table 3). Finally a non-justified strategy is rewarded with 2 points and justifying a strategy with 3 points since adopting a reflecting strategic is more demanding. The scores for all addressed elements at each level of reflection were summed up. The overall score for each student is called reflection-score (RScore).

Coding unit	Qualitative coding		Quantitative coding
	Element of decision	Level of reflection	
If the book is not available there [in the local bookstore],	naming of the attribute *time*	Describing	1
I would order it online.	justified option	Describing	2
Going to the bookstore would cost me time. I could do much more productive things in the meantime.	naming of the attribute *time*	Naming an alternative	1
Reflection Score			*4*

Table 3: Excerpt from a student's (ID 117) processing of the reflection task as an example of qualitative and quantitative coding.

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Due to the COVID-19 restrictions mentioned above, data analysis for the reflection task had to be adapted to the short time span of 3 hours between the pre- and post-test. As a result of the limited time, students may have become tired of answering the same questions twice in such a short period of time. Nevertheless, we assume that any factors the students mentioned on the pre-test were not forgotten until the post-test was administered, even if they were not mentioned again. As a result, only factors that were newly expressed on the post-test were counted as reliable data on learning gains, and based on these, the *RScore* for the post-test was obtained. In a nutshell, we have decided to set the *RScore* on the pre-test as a baseline and determine differences between the intervention groups in terms of the number of new factors raised by the students on the post-test. This argument does not apply to the follow-up test, in which all statements made by the students were included in the scoring.

4 Results

In the following, the results regarding the reflection task are presented to answer the research questions. First, between-group comparisons at each of the three test times, and, second, within-group comparisons for each group across pre- and post-test are presented. At the outset, it should be noted that a balanced test design was lacking due to the sample restrictions reported above (Table 2).

4.1 Between-group comparison at pre-test

First, the four groups were compared regarding pre-test results. A Levene test proved homogenous group variances (df = 3; Levene-statistic = 0.95; $p > .05$). Therefore, a two-way Analysis of Variance (ANOVA) was performed (Table 4). Post-hoc Tukey-Kramer tests and Cohen's *d* show that the *RScore* of the *Content-collective* condition was significantly lower than the *RScores* of all other groups (Table 5 and Figure 1).

Source of Variation	Sum of squares	df	Mean square	F	p-value	Omega square effect size
Method of reflection	416	1	416.2	13.23	0.00037	0.07 small
Perspective on SSI	204	1	203.5	6.47	0.012	0.03 small

Table 4: Results of the two-way ANOVA with *RScores* from pre-test

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Intervention groups		Difference in means	Confidence level	Adjusted p-value	Cohen's d effect size
Reflect-individual	Reflect-collective	-0.82	4.09, 2.44	0.91	
Reflect-individual	Know-individual	0.37	-2.89, 3.63	0.99	
Reflect-individual	Know-collective	4.85	1.58, 8.11	0.001	0.84 large
Reflect-collective	Know-individual	1.2	-2.07, 4.46	0.78	
Reflect-collective	Know-collective	5.67	2.41, 8.93	0.0001	1.07 large
Know-individual	Know-collective	4.47	1.21, 7.74	0.0027	0.82 large

Table 5: Results of the post-hoc Tukey-Kramer tests with *RScores* from pre-test

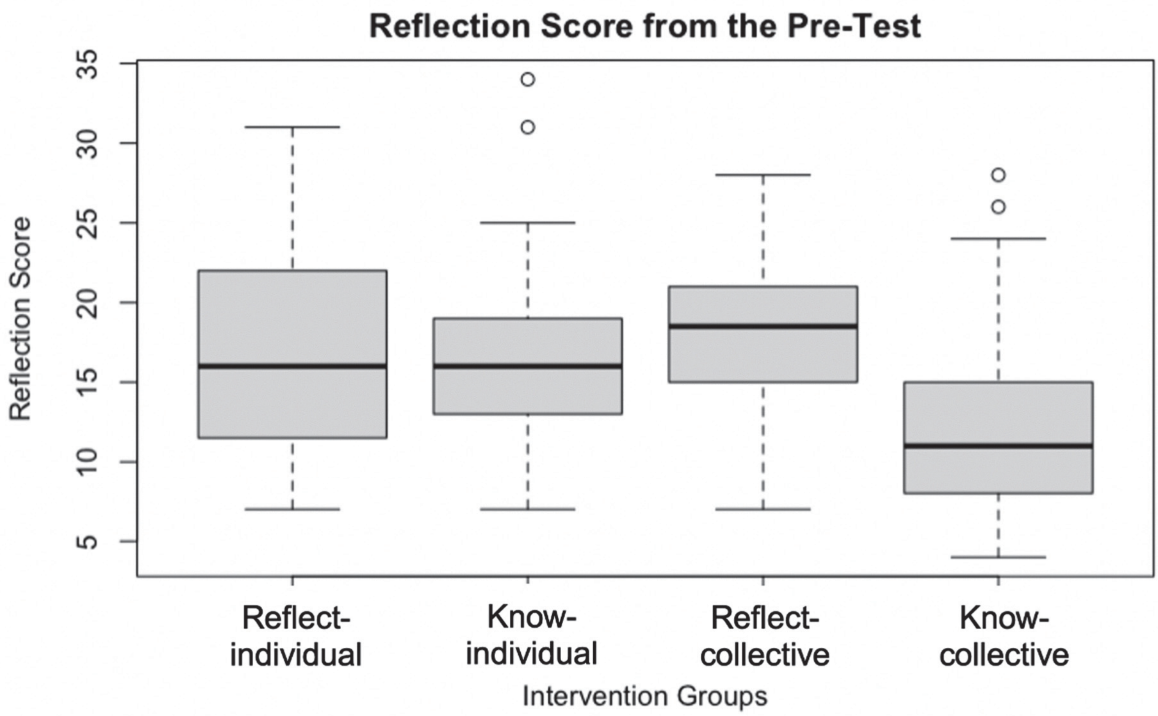

Fig. 1: Boxplot with the *Rscores* from the pre-test

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4.2 *Between-group comparison at post-test*

A Levene test showed heterogenous group variances (df = 3; Levene-statistic = 8.09; p < .001). Therefore, a modified Brown-Forsythe test, as a nonparametric variant of a two-way ANOVA, was conducted. It revealed a large main effect for independent variable 1 (*method of reflection*) but no effect for independent variable 2 (*perspective on SSI*) as a key result (Table 6). Post-hoc group comparisons with Games-Howell tests showed differences among all experimental conditions, except *Reflect-individual* and *Reflect-collective*, as well as *Content-individual* and *Content-collective* (Table 7 and Figure 2).

Source of Variation	Sum of squares	df	Mean square	F	p-value	Omega square effect size
Method of reflection	1,805.6	1	1,805.57	58.64	1.9e-11	0.32 large
Perspective on SSI	9.9	1	9.87	0.27	0.60	

Table 6: Results of a modified Brown-Forsythe test with *RScores* from post-test (pre-test data as baseline)

Intervention groups		Difference in means	Confidence level	Adjusted p-value	Cohen's d effect size
Reflect-individual	Reflect-collective	3.26	-0.92, 7.44	0.178	
Reflect-individual	Content-individual	-4.36	-7.79, -0.93	0.008	0.83 large
Reflect-individual	Content-collective	-5.86	-9.2, -2.52	1.61e-04	1.18 large
Reflect-collective	Content-individual	-7.62	-10.83, -4.41	4.63e-07	1.56 large
Reflect-collective	Content-collective	-9.11	-12.22, -6.01	4.55e-09	1.98 large
Content-individual	Content-collective	-1.49	-3.36, 0.37	0.16	

Table 7: Results of the post-hoc Games-Howell tests with *RScores* from post-test (with pre-test data as baseline)

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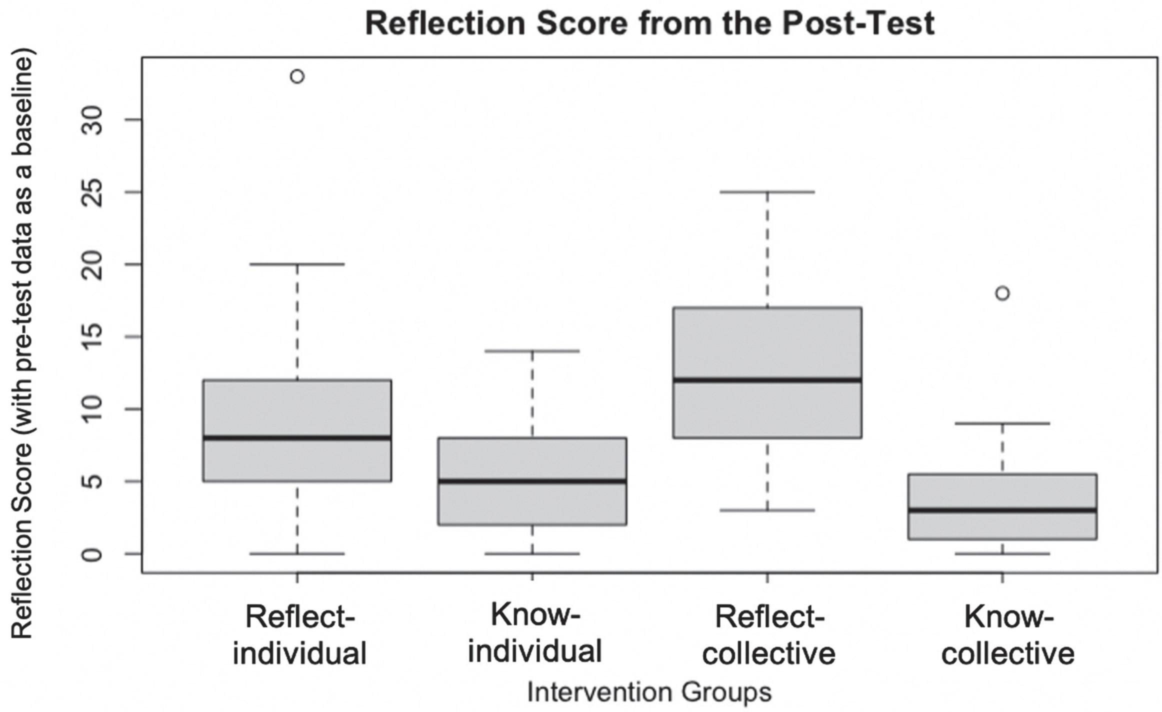

Fig. 2: Boxplot with the *Rscores* from the post-test (with pre-test data as a baseline)

4.3 Between-group comparison at follow-up test

A Levene test indicated homogenous group variances (df = 3; Levene-statistic = 0.45; p > .05), and therefore, a two-way ANOVA was performed. The ANOVA showed a main effect for independent variable 1 (*method of reflection*) but, again, no main effect for independent variable 2 (*perspective on SSI*) (Table 8 and Figure 3).

Source of Variation	Sum of squares	df	Mean square	F	P value	Omega square effect size
Method of reflection	290	1	289.8	12	0.00071	0.07 small
Perspective on SSI	10	1	10.21	0.42	0.52	

Table 8: Results of the two-way ANOVA with *RScores* from follow-up-test.

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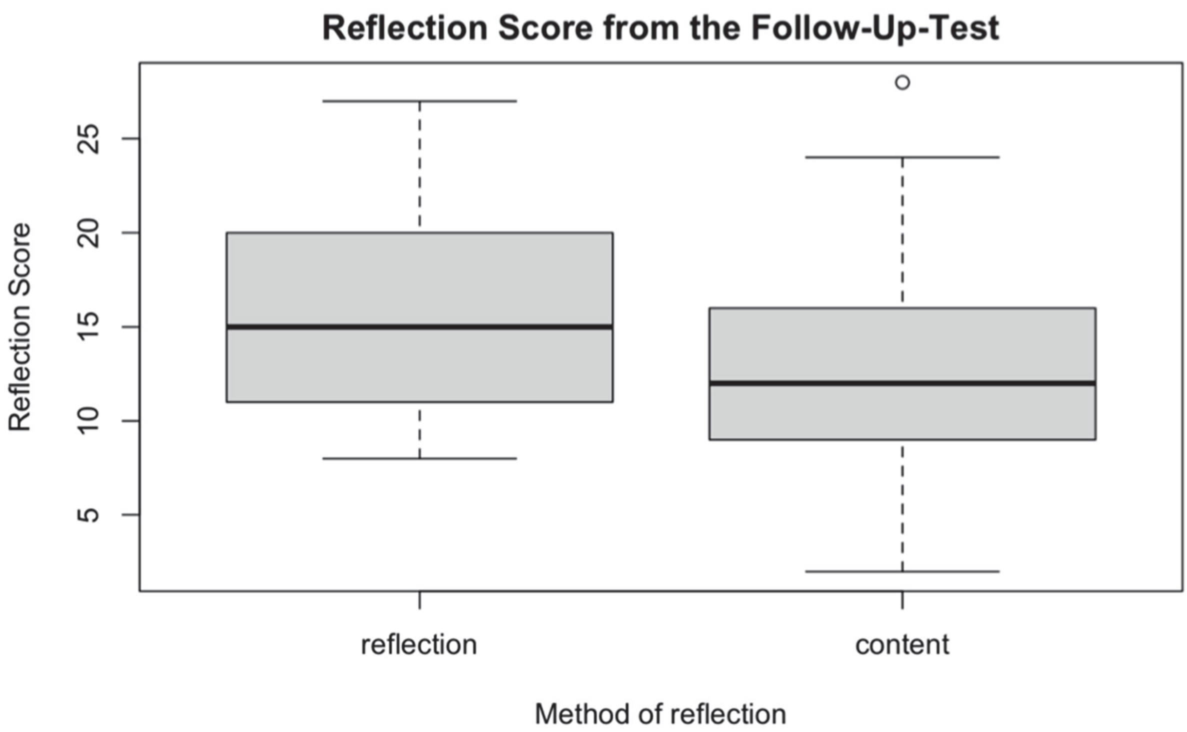

Fig. 3: Boxplot with the *Rscores* from the follow-up-test

4.4 *Within-group comparison*

By adjusting the score in the post-test, the within-group comparison cannot be used to show a possible stability of learning gains from the post- to the follow-up test. However, Wilcoxon tests were used to compare the pre-tests with the unadjusted post-tests.

The results for the four intervention groups are described in turn below, and the median *Rscores* for all intervention groups are presented in Table 9.

	median-RScore	
	pre-test	post-test
Reflect-individual (N = 34)	16	17
Content-individual (N = 42)	16	12
Reflect-collective (N = 33)	18.5	18
Content-collective (N = 52)	11	7.5

Table 9: Median *RScores* for all intervention groups on the pre- and post-tests

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Reflect-individual: The Wilcoxon test reveals no significant differences between the median *RScores* on the pre- and post-tests ($p > .05$).

Reflect-collective: The Wilcoxon test reveals no significant differences between the median *RScores* on the pre- and post-tests ($p > .05$).

Content-individiual: The Wilcoxon-test shows significantly different median *RScores* on the pre- and post-tests ($p < .001$, $r = 0.7$). According to the effect size measure *r* (Rosenthal et al., 2003), this corresponds to a strong effect (Cohen 1988).

Content-collective: The Wilcoxon-test shows significantly different median *RScores* on the pre- and post-tests ($p < .001$, $r = 0.67$). According to the effect size measure *r* (Rosenthal et al., 2003), this corresponds to a strong effect (Cohen 1988).

5 Discussion

Our research questions of whether students demonstrate a change in their ability to reflect on their own decisions as a facet of decision-making competence after a teaching intervention as a result of [1] the learning and practicing of a *method of reflection* and [2] the *perspective on the SSI* can be answered as follows:

Post-test date collected immediately after the intervention indicate a main between-groups effect due to variable 1 (*method of reflection*). However, in this study, no significant main effect has been detected due to independent variable 2 (*perspective on SSI*). The experimental conditions *Reflect-individual* and *Reflect-collective*, in which students explicitly learned and practiced a method of reflection, showed increasing learning results on the post-test.

Finally, the follow-up test showed a weak effect for the independent variable *method of reflection*, indicating that the *ability to reflect on one's own decisions* can be increased and stabilised by explicitly teaching students how to reflect. However, prior research has assumed that for sustainable effects, long-term learning activities are required (Prediger, 2005, p. 252; Leinonen et al., 2016, p. 2).

The within-group comparisons only partially complement the between-group comparisons. The within-group comparisons for the two *Reflect*-groups show no significant differences between their pre- and post-test while the comparisons for the *Content*-groups are significant. The *Content*-groups achieved lower median RScores in the post-test compared to pre-test. This corroborates the results of the between-group comparison and suggests that the learning effect of the intervention was low for the *Content*-groups. The consistent median RScore of the *Reflect*-groups may indicate a positive effect of the intervention and thus supports results of the between-group comparisons.

Overall, although the results of the within-group comparisons complement the between-group comparisons, they do not provide clear-cut evidence, particularly with respect to the effect of the independent variable *perspective on the decision problem*.

Our study has several limitations. First, our sample may have been too small and unrandomised. Second, due to COVID-19 restrictions, a matched-pair design was not allowed, because intact classes had to be assigned to the experimental conditions group-wise, without

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mixing students from different classes across experimental conditions. Third, COVID-19 conditions let to high time pressure and several design adaptions. The short time that elapsed between the pre- and post-tests may have led to fatigue among the students, which is especially visible in the significant deterioration of the post-test results for the *Content*-groups. Fourth, due to the design and the adjustment of the RScore in the post-test, comparisons between the post- and the follow-up test are not possible, which is why no statement can be made about the stability of learning gains. Fifth, the same instrument was administered on the pre-, post-, and follow-up tests. In doing so, we followed the general idea that any change can best be detected without changing the instrument. Nevertheless, low student interest in performing well and general fatigue may have resulted from administering the instrument twice in a row.

Future research should repeat our study with increased sample sizes and an increased time between pre-test, intervention and post-test. Students should then either be matched across conditions, which in our case, was unfortunately impossible due to the COVID-19 pandemic, or they should be randomised. In addition, to better understand the effect of the individual and collective perspectives, the processing of the reflection task during the pre-test should be examined in more detail. Furthermore the study should be repeated with regard to the structure of the available data, it could be enlightening not to evaluate the tasks at the three test times separately, but to develop a category system based on codes which describes the differences between the tasks in more detail. Finally, in our study, only small stable effects on the part of teaching an explicit method of reflection on students' ability to reflect have been detected. Given the short intervention, this is nevertheless an encouraging result because teaching decision-making and reflecting on decisions should hardly be limited to a single subject and a limited amount of time. Thus, we expect any teaching effects to be larger if decision-making and reflection are taught and learned repeatedly across multiple subjects and age groups.

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Appendix: Reflection task

Task 1: Online Shopping

Today, you can buy many goods both in a store or by ordering online and having them delivered to your home. Physical energy must be expended to transport the goods and to store them (e.g., for heating and lighting or means of transport).

1a) Imagine that you want to buy a book, you can either buy the book at the bookstore around the corner, or you can order the book online and have it delivered to your home. **Describe** in writing and in detail, in complete sentences, how you would like to receive the book.

Finally, take a critical look back at your decision and **reflect** on it.

1b) Imagine you are a member of the German government. A meeting is being held to discuss a ban on free shipping for online shopping.

Describe in writing and in detail, in complete sentences, whether you would be in favour of or against such a ban.

Finally, take a critical look back at your decision and **reflect** on it.

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