International Journal of Environmental & Science Education, 2015, **10**(3), 493-513

How Students' Values are Intertwined with Decisions in a Socio-scientific Issue

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•*Received 30 January 2015* •*Revised 14 February 2015* •*Accepted 17 February 2015*

The present study incorporated a scaffolding decision making procedure on an authentic environmental socio-scientific issue and investigated how students' decisions are intertwined with their values. Computer-based activities provided necessary information and allowed for the consideration of multiple aspects of the issue, the study of the effects of every possible solution and the formulation and balancing of criteria. The optimization strategy for decision making was adopted. Data collection relied on 51 sixth grade students (11-12 years old). Open-ended written tests were given to students before and after the learning intervention with two tasks: application of the optimization strategy and a meta-reflection question explaining their decision. Children incorporated several criteria in the decision making process, however, what guided their decisions were the criteria which were given the greater weight. These criteria were connected with substantive arguments and were based on decisive values. Three value-driven patterns of decision makers were revealed: strong anthropocentric, weak anthropocentric and ecocentric. The ability of assigning weight in conflicting criteria is a cornerstone for the emersion of how values are interrelated with decisions. Values arise when preferences are in conflict and decisions are made by weighting alternatives in comparison to our preferences. In conclusion, students have to learn to develop solutions that represent a compromise between economic, ecological, and socioeconomic dimensions, which include establishing a value hierarchy. The ability to weight decision criteria and to disclose underlying value considerations may be an elaborate way to work with multifaceted socio-scientific issues.

Keywords: sustainability, decision making, optimization method, environmental values

INTRODUCTION

Dealing with socio-scientific issues, such as sustainability issues, typically confronts students with problem or decision-making situations that are both factually and ethically complex (Bogeholz & Barkmann, 2005). Those concerned

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doi: 10.12973/ijese.2015.256a

ISSN: 1306-3065

about human impacts on the environment commonly stress the importance of values in motivating people to care for the natural world around them (Grace, 2008) and often propose that changes in values lead to more sustainable behavior and policy (Dietz, Fitzgerald, & Shwom, 2005). But how values are translated into decisions, having the power to move the world towards sustainability?

Several empirical studies on students' decision-making suggest that values have a great impact on environmental decision making (Hogan, 2002; Jimenez-Aleixandre & Pereiro-Munoz, 2002; Ratcliffe, 1997), since students' decisions are more value-based than knowledge-based (Acar, 2010) and that decisions are the result of the interaction between evidence and values (Grace, 2008; Kolstø, 2006). However, in those studies which deal with values, the value orientation was supposed by the criteria mentioned by the students. Therefore, values were rather implicitly and not explicitly characterized.

The present study incorporated the optimization decision-making strategy on an authentic socio-scientific issue and investigated how the decisions of 11-12 years old students are explicitly intertwined with their values.

Theoretical framework

The use of criteria in students' decision-making for socio-scientific issues, in relation to values

Socio-scientific issues are complex, controversial and ill-structured real-world problems that involve social and ethical considerations (Sadler, 2004; Zeidler, Sadler, Simmons, & Howes, 2005; Zeidler & Sadler, 2007). Typical examples of environmental socio-scientific issues are those that are concerned with sustainability issues (e.g. conservation biology, the sustainable use of biodiversity, human impacts on local and global ecosystems). The three domains of sustainability (social, economic and ecological), and their interdependencies, have become the fundamental bases of education for sustainability (de Haan, 2010; Sauve, 1996; Scott & Gough, 2003).The construction of students' criteria for decision-making received attention in several studies. For example, Uskola, Maguregi and Jiménez-Aleixandre (2010), in a university case study with 18 students, found that students were able to determine and use a variety of criteria, both explicit and implicit, to justify and support their selection. On an explicit level, students identified social and ecological criteria as the predominant ones that guided their selection. In this sense, the economic criterion was not assigned any importance by the majority of the students; however, this criterion received the most implicit references. Jiménez-Aleixandre and Pereiro-Munõz (2002) analyzed the criteria constructed by 38 students of 17 to 21 year-olds during the process of deciding whether to install a drainage pipe in a marsh. They concluded that the students prioritized ecological criteria over economic concerns. In an analysis of how 24 students of 14 year-old engaged in a debate concerning an environmental management decision about the invasive zebra mussel, Hogan (2002) found that economic, social and ecological criteria receive special attention and are present almost every time, when addressing environmental issues. The results revealed that the science of environmental management is conducted within a context of values since students expressed values from both biocentric and anthropocentric points of view during their discussions. In the specific study, biocentric values were evident when students showed concern about the eradication of a species or favoured preferential treatment for endangered rather than common species. On the other hand, anthropocentric values appeared in student's discussions when they favoured or discounted organisms based on weather humans use them for their survival, recreation or aesthetic enjoyment. In 2006, Kolstø investigated students' ways of using values and different types of knowledge in their argumentation and decision-making. Secondary school students were interviewed about their decision-making on a controversy related to electric power transmission lines and childhood leukaemia. Findings highlighted that students' decisions on this issue were more value-based than knowledge-based and that argumentation based decisions were the result of interaction between evidence and values. In addition, when Sadler and Zeidler (2004) investigated the value dimension of decision- making regarding genetic engineering dilemmas in high school students, they identified three patterns characterizing students' decision-making as rationalistic, emotive and intuitive informal reasoning. Further, Simonneaux (2001) working with 17 high school students, examined the values supporting students' arguments in terms of the "orders of importance". She found that collective values were instrumentalized and were greater than individual interests; with democracy being the most appropriate "order of importance". In another study, Patronis, Potari and Spiliotopoulou (1999) categorized the arguments used by 14 year-old students during a debate about the planning of a major road near their school as 'social', 'ecological', 'economic', and 'practical'. This categorization schema was adapted by Wu and Tsai (2007), who transformed the 'practical' category into 'science-oriented or technology-oriented', while analyzing the reasoning mode of 70 students of 15-16 years old debating on whether or not a fourth nuclear power plant should be built in Taiwan. In her study focused on values, Ratcliffe (1997) identified values and criteria articulated by 34 students of 15 years-old working with structured decision-making tasks on different science issues. She found that values should be clarified on the basis on which the decision is to be made and concluded that values play an essential role in environmental education.

The optimization as a reasoning strategy for dealing with socio-scientific decision-making situations

The optimization strategy, which is enacted in this study, seeks to provide a structure for the synthesis of the strengths and weaknesses of the available options and to enroll as a method that helps students to explicitly evaluate and assign weight to alternatives, in order to reveal the values which lay behind a decision.
Decision-making has been described in the cognitive psychology literature in terms of a dual-process model (Kahneman, 2003; Klaczynski & Cottrell, 2004; Stanovich, 1999). This model involves two distinct modes of thinking, namely the experiential and the analytic. The first includes processes that are automatic, fast, and effortless, whereas the latter relies on conscious, slow, and effortful processes. One analytical model is the weighted additive value model (Birnbaum, 1998). It rests on the premise that, in the absence of a perfect solution, one has to systematically process all available information and undertake tradeoffs in order to identify the optimum solution. In brief, this model involves three components: (a) transformation of the raw data about the possible solutions, so that they are all expressed in a single metric; (b) adjustment for the relative importance of the criteria through the assignment of weights; and (c) calculation of overall, weighted scores for each solution, which provides an indication for the optimum solution.

The targeted version of the optimization strategy should be conceived of as a teaching transformation of the weighted additive value model (Papadouris, 2012) that seeks to adjust the complexity level according to the needs and resources of the target student population. The simplification offers certain advantages for students at this age. The most important of these is that it allows students to better appreciate decision-making as a process that is amenable to systematic elaboration. This important idea can be more effectively portrayed and elaborated in such a simplified context.

Additionally, it is suggested that variations in the scores (weights), proposed by the different members within a group for certain options (or criteria), offer the opportunity to explicitly address the role of values in decision-making (Papadouris & Constantinou, 2010), even though it has not been empirically tested.

The ability to explicitly weight decision criteria or weight trade-offs in a decision-making situation, is according to research (Kolstø, 2006; Seethaler & Linn, 2004), difficult to perform and thus, might only be found at higher levels of ability. Eggert and Bogeholz (2010) found that students' answers fell short when explicitly weighting the trade-offs they presented. The ability to explicitly weight important decision criteria or trade-offs in a decision-making situation seems to pose difficulties for students in general. Several researchers attribute this to the fact that weighting decision criteria or trade-offs includes prioritizing conflicting values (Bogeholz & Barkmann, 2005; Jimenez-Aleixandre, 2002; Kolstø, 2006).

Values and decision-making about the environment

Values are often invoked in discussions about how to develop a more sustainable relationship with the environment. There is a substantial work on values that spans across several disciplines (Brennan & Lo, 2002; Joas, 2000; Schwartz & Bilsky, 1987). In the context of social sciences, Dietz et al. (2005) suggest that values are relatively stable principles that help us make decisions when our preferences are in conflict and convey some sense of what we consider good. When trying to understand the relationship between discussions of values in environmental ethics and the social science tradition, is easier if we keep in mind that the concept of values is often deployed to explain how we make new choices. A general argument, among others, is that environmental decisions often require us to make decisions about things we have not thought much about in the past. Thus, decision making about the environment often concerns an issue of which we have not given much previous thought (Stern, Dietz, Kalof, & Guagnano, 1995). Whether such novel decisions actually reflect our values depends on the context in which we have the opportunity to reflect on our values. In some contexts, a quick decision seems appropriate, and that may lessen the influence of values or bias which values are given weight (Dewey, 1988).

In ethical theory values influence how people make decisions. Ethical theories of value (e.g., Dewey, 1988), point out that people consider not just their immediate wants and desires, but sometimes reflect on deeper concerns about what is important. This emphasis on the role of values in decision-making is consonant with social science theory. Hechter (1994) argued that we make decisions by weighting the alternatives in comparison with our preferences. Therefore, values help us weight our preferences and choose which one is better regarding everything we prefer. That is, values help us make choices when there are trade-offs. For Dewey, values arise because it is common for our preferences to be in conflict during decision-making. Based on the same research can be stated that our values, as an abstract set of principles, allow us to resolve those conflicts by suggesting which preferences are better. This also suggests that values are deployed in a reflective process of self-examination rather than in a quick judgment. Dewey's arguments about the role of values in decision-making suggest that values are invoked when we reflect on difficult choices, especially those involving trade-offs among our preferences. Once a decision becomes routine, we may not consciously reference our values but are more likely to do so for novel decisions (Dietz & Stern, 1995).

Contribution of the study and research questions

The results of the aforementioned studies strengthen the argument that since socio- scientific issues are ill-defined in nature, and there is no absolute solution to these problems, it is important to give more space and respect to students' values in those issues and promote decision-making through inquiry-based learning environments.

The studies so far were focused on secondary and higher education students, ages 14-21. The present study focuses on values and reasoning of upper primary children 11-12 years old and therefore sheds light in the interrelation of values and decisions in younger ages. This age period is important to study because is considered a turning point between childhood and adultness (Crain, 1985). Moreover, the age between 11 and 12 years old is considered by some researchers as the developmental stage where attitudes, values, and emotional motives begin to be formed (Wray-Lake, Flanagan, & Osggod, 2010).

Furthermore, it was revealed that in previous studies dealing with values, the value orientation was supposed by the criteria mentioned by the students. Therefore, values were implicitly and not explicitly characterized. The present study incorporates a decision-making strategy that facilitates the explicit evaluation of criteria in order to capture the values which drive a decision. This was performed by the optimization method in which students were able to account for the relative importance of each criterion and assign different weights.

In addition, most of the aforementioned studies focused on small population samples and therefore, the analysis of the data was mainly qualitative. The present study enabled the systematic recording of the criteria and decisions with amply sample and therefore statistical analysis of the data facilitated the investigation of statistical correlations between the variables.

The present study incorporated the optimization decision making strategy on an authentic socio-scientific issue among 11-12 year-old students, to deal with the aspect of how values are interrelated with decisions and address three research questions:

1. What are the substantive criteria and arguments which drive 11-12 year old students' decisions?
2. How the optimization decision-making strategy helps to the emersion of students' values when dealing with socio-scientific decision-making situations?
3. What relationships emerge among the criteria received the highest weight, the decisions and the arguments supported the decisions? Are there any patterns of decision makers?

METHODOLOGY

Participants

Participants were 51 sixth grade students (11-12 years old) from a suburban elementary school in Cyprus. The participants came from two intact classes (24 and 27 children in each classroom) and were taught by the same teacher. As was reported by their teacher, children did not have any prior experience with decision-making or socio-scientific issues. Regarding prior knowledge on threatened plants, the concept of threatened plants was examined only in one school period during the fourth grade, emphasizing the identification of some local threatened plants, as well as the habitats in which these plants can be found. The concept of threatened plant conservation in the frames of a socio-scientific issue is newly introduced in the science elementary curriculum and the present study is one of the first attempts to design and evaluate material for these concepts employing decision-making procedures in the frame of Cyprus Educational Reformation (Ministry of Education, 2010).

Gender distribution was almost identical with 26 boys and 25 girls. Students were of mixed ability and socioeconomic status and worked in 24 groups of two and one group of three (25 groups) over a period of five weeks. The learning activities were implemented by two of the researchers, once a week, over a period of four meetings of 80 minutes.

Learning environment

The learning environment was designed by the authors for the purpose of this study. The development of the learning environment relied on empirical research in two ways. Firstly, it was informed by a specially designed empirical study of the initial ideas and the corresponding difficulties of students in the target student population (Paraskeva- Hadjichambi, Korfiatis, Hadjichambis, & Arianoutsou, 2012). Secondly, a first version of the learning environment was subjected into a pilot test with a group of students (Paraskeva- Hadjichambi, Korfiatis, Hadjichambis, & Arianoutsou, 2010). This provided preliminary indications concerning the potential effectiveness of the activity sequence and guided its refinement so as to better serve the learning objectives. In addition, the design of the learning environment has been theoretically informed by the literature about learning principles and teaching strategies (Nikolaou, Korfiatis, Evagorou, & Constantinou, 2009; Siegel, 2006).

The finalized learning environment consisted of four web-based activities. In the first activity a motive scenario was given, in which students were challenged through a mission to solve an authentic local problem. The problem was related to conflicts among the inhabitants of a village derived from the need to construct a new road connecting the settlements to a new school building. Students had to consider the multiple aspects of the problem by reading local newspapers and listen to interviews based on inhabitants' opinions.

In the second activity students had to collect information about the several sites of the village (the settlements, the agricultural fields, the ecosystem of a Mediterranean shrubland with several leaving organisms, as well as the plans for a future settlement site) through several digital interactive learning objects (videos, multimedia presentations, interactive booklet etc.). The aim of the activity was to help students to realize that several economic, social and environmental aspects participated in the problem and should bear in mind.

In the third interactive activity students had to collect data about the options for the construction of the road. Four options were presented in the activity. Two of the options caused direct and indirect impact on the ecosystem of a threatened plant population (option C: road through Mediterranean shrubland – causing direct impact on threatened plant population; option B: road through another site of Mediterranean shrubland - causing indirect impact on threatened plant population). The other two options caused direct or indirect impacts on the inhabitants of the village (option A: road through agricultural fields - direct impact on inhabitants, especially health; option D: road through a future settlement site - indirect impact on inhabitants).

In the fourth activity students were asked to complete the optimization table and come up with a decision selecting one of the four options. A concrete explanation should have accompanied their decision in order to help the inhabitants of the village overcome the problem.

The environment provides a navigation frame (left hand column) which presents the learning activities in a flowchart sequence. As the students click on each step in the navigation frame, the main content of that step appears in the main frame window and the main task appears in the right hand site. Within the various activities and their content students were provided with necessary scientific information which allowed for the consideration of the multiple aspects of the problem, the study of the effects of different possible solutions and the formulation and balancing of criteria.

Instructional context and implementation

The implementation of the learning environment lasted four 80-minute sessions, allocated in four consecutive weeks. For the most part, students worked in groups of two, while they also engaged in whole-class discussions organized and facilitated by the teacher. In sum, seven 80-minutes sessions were needed. One session for students' training in the optimization strategy, one session for completing the pre-test, four sessions for the implementation of the learning sequence and a final session for completing the post-test.

Implementation of the optimization strategy

Students applied the optimization strategy for decision-making as an appropriate approach for developing environmental decision-making reasoning (Papadouris, 2012). The optimization strategy involves a process of adjusting relative weights to evaluation criteria and balancing strengths and weaknesses of the various alternative solutions. It is most suitable when dealing with environmental problems where a clear right or wrong choice is not available, and one has to compensate for various factors before selecting the best solution (Anderson, Sweeney, & Williams, 2005). In order to carry out the mission, students had to follow several steps corresponding to the elements of an optimization decision-making strategy (Papadouris, 2012).

- Step 1: Firstly, students had to develop and analyze their own criteria according to which alternative solutions would be evaluated (students were asked to give a mark between 1 and 10 to each alternative option, according to how well it satisfied each criterion. If, for example, students believed that an option is very expensive, they had to give it a low mark on the 'cost' criterion).
- Step 2: Then, they had to rank the alternative solutions with respect to each criterion while accounting for the relative importance of each criterion and assigning different weights (students should decide if some criteria were more important than others and multiply the mark with a higher arithmetic value between 1-5).
- Step 3: Finally, they had to obtain an overall evaluation for each solution by estimating the total sum for all criteria. The solution with the highest score was the optimal one and this was their decision.

Training for the optimization strategy was provided through a specific example according to which a person was trying to decide 'which car is best buying' following the stages of the optimization strategy. Afterwards, students were asked to implement the optimization strategy to the 'road construction problem' on their own and select the optimal solution for the community.

Throughout the learning intervention, students were supported with various scaffolds intended to help them with the implementation of optimization method later on. For instance, in activity two, in order to collect the information of the sites of the village, students were asked to write the criteria that are involved in the case study. In activity three, in order to capture the multiple aspects of each solution, were given tables to record the strengths and weakness of each solution, since according to Ratcliffe (1997) systematically considering advantages and disadvantages can aid reasoning. Finally, in the fourth activity a blank template with the fields of the optimization table was given when implementing the optimization strategy.

Data collection

Students' performance in decision-making procedure was measured through pre- and post-intervention open-ended written test with two tasks. The test required: (Task A) application of the optimization strategy to a situation that was unfamiliar to the students, i.e. the need to select the best place to construct a dump (landfill), thus refer to as the 'dump test' and (Task B) a meta-reflection question regarding their decision, '*Why you selected that place and why you rejected the other two alternatives?*'

According to the information provided on the test, students had to select among three potential places for the construction of a dump - a parking place (A), a field with biological cultivation (B) and a wild forest (C) - taking into account the different number of inhabitants that would benefit from the operation of the dump in each location, the current owning status of the place as well as the current land use. The combination of the three tasks in a new context (construction of a dump) avoided context-dependent and instructionally imposed bias.

Data analysis

Data analysis was based on both qualitative and quantitative methods.

Criteria – Arguments. The analysis of step 1 and step 3 of task A, resulted to the extraction of criteria and decisions and the analysis of Task B resulted to the extraction of the arguments explaining the criteria and decisions.

Each student mentioned several criteria in the first column of the optimization table in order to be taken into account for his / her decision and then explained the decision with elaborated arguments in an open-ended question. The criteria mentioned by the students as well as the content of the open-ended reasoning question were analyzed through content analysis (Krippendorff, 2004). Content analysis constitutes a research technique that permits systematic and quantitative description, not only of content, but also of formal characteristics of messages. It is also extensively used for the analysis of open-ended questions. The criteria mentioned by the students were categorized by the researchers in the three main categories of a socio-scientific issue in the frame of sustainability. Coders first discussed the categories of analysis and then worked independently, processing the whole body of data. Intercoder reliability between the authors was 95%. More specifically criteria related to cost, private / public land, land size, children-excursion and biological cultivation were grouped in the category of Economic criteria. Criteria related to plants, animals, ecosystem and environmental pollution were grouped in the category of Environmental criteria, while criteria related to distance, health and inhabitants were grouped in the category of Social criteria. The categories emerged from the analysis of arguments followed the categorization of criteria i.e. economic, environmental and social.

Upon coding, incidents were given the value score "1". These score were then summed by individual and across groups; analysis was conducted using SPSS with these incidents as discreet data points for the purpose of statistical analysis. Pearson's Rank Order Correlation parametric test was contacted in order to search for significant correlations between criteria and decisions.

Weight given to criteria. The analysis of task A-step 2 resulted to the extraction of the weight given to criteria. In order to handle this data, a coding schema was developed (Table 1). When a criterion from a list of criteria in the optimization table was assigned by a student with the highest value (e.g. health x 5), was ranked by researchers with the value "1". When a criterion was assigned with the second highest value (e.g. inhabitants x 4), was ranked by researcher with the value "2" and so on. Finally, a table with numbers from 1-5 was created for each column of weighted value. The weighted value ranked as first was assumed as the students' decisive value. The decisive value was used for the analysis using SPSS. Pearson's Rank Order Correlation parametric test was contacted in order to search for significant correlations between the criteria given the highest weight and decisions.

Table 1. Application of the coding schema which extracted the decisive value (Example of student's 31 list of criteria)

List of Criteria (example of Student 31)	Weight given to criteria by the student	Weighted value ranked by the researcher	Decisive value revealed
Plants	2	4	
Ecosystem	3	3	
Cost	1	5	
Inhabitants	4	2	
Health	5	1	1

Relationship among the criteria received the highest weight, decisions and arguments - Patterns of decision makers. The criteria which were received the highest weight, the decisions of students as well as students' arguments of justifying their option and rejecting the alternatives, were correlated. The analysis was contacted qualitatively by the researchers.

By this analysis three value driven patterns of decision-makers were emerged: (a) a strong anthropocentric pattern based on economic criteria and utilization arguments (b) a weak anthropocentric pattern based on social criteria and arguments and (c) an ecocentric pattern based on environmental criteria and arguments.

RESULTS

The section is organized in three parts, each corresponding to the research questions of the study.

Substantive criteria and arguments which drive students' decisions

Criteria and decisions. Before the learning intervention social criteria related to the distance of the dump from the settlements and the disturbance of inhabitants were dominant in students' decisions, followed by economic and environmental criteria, which were almost equally important. As showed in Table 2, after the learning intervention, the majority of students (90,2%) emphasized social criteria related to the health of inhabitants while environmental and economic criteria again followed.

As far as it concerns the correlation of decisions with criteria, as can be seen in Table 2, before the learning intervention, the students' decision to build the dump in the biological field (option B) was correlated with utilitarian criteria and especially the "children-excursion" criterion in order to avoid destruction of the forest as a place for excursions as well as a social criterion. Student's decision to make the development in the forest (option C) was correlated to economic criteria and especially to avoid destruction of biological cultivation in option B. Student's decision to make the development in the parking place (option A) was correlated to environmental criteria and especially "ecosystem" and "environmental pollution".

After the learning intervention, the majority of students mentioned much more criteria and few statistically important correlations emerged. Only the students' decision to build the dump in the biological field was correlated to environmental criteria and especially the "animals" and the "ecosystem" criteria.

Table 2. Correlation between criteria and decisions before and after the learning intervention (Pearson's rank order correlation parametric test)

Groups of criteria	Criteria	Students' answers (%)		Decision A Parking place		Decision B Biological field		Decision C Natural forest	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Economic		**56,8**	**62,7**						
Economic-cost	Cost	11,7	49						
Economic-land use	Private / public land	17,6	31,4						
	Land size	5,8	9,8						
	Children-excursion	27,4	11,8			***			
	Organic culltivation	25,4	0					**	
Environmental		**52,9**	**70,5**	**					
	Plants	27,4	64,7						
	Animals	27,4	62,7			**	*		
	Ecosystem	9,8	45,1	*			*		
	Envir. pollution	15,6	27,4	*					
Social		**64,7**	**90,2**			***			
Social - health	Health	23,5	66,7			***			
Social - prosperity	Inhabitants	52,9	62,7			***			
	Distance	33,3	56,9			***			
Optimum		**1,9**	**0**						
No criteria		**13,7**	**0**						

Note. *** p=0.000, ** p=0.001, * p=0.05

As far as it concerns students' decisions, in the pre-test, half of the students (50%) decided to construct the dump in the parking place (Option A), 27% in the biological field (Option B) and 23% in the natural forest (Option C). In the post-test, more than half of the students (57%) decided to construct the dump in the biological field, 35% in the parking place and 8% in the forest.

According to Table 3, students, who selected option A before the learning intervention, were statistically remained in that decision and were also statistically transmitted to option B. Students, who selected option C, presented statistically significant transmission to Option B, while students who selected option B were significantly remained in their decision.

Table 3. Correlation between students' decisions before and after the learning intervention (Pearson's rank order correlation parametric test)

		Pre		
		Decision A	**Decision B**	**Decision C**
		Parking place	**Biological Field**	**Natural Forest**
Post	**Decision A: Parking place**	0.002**	0.055	0.128
	Decision B: Biological Field	0.017*	0.010*	0.011*
	Decision C: Forest	0.327	0.208	0.211

Arguments and decisions. The reasoning of justifying a decision and rejecting the alternative options, in most cases, followed the criteria mentioned. However, a more careful look on students' arguments allow for a deeper understanding of the value-driven reasoning behind a decision. Students' reasoning was much more elaborate after the learning intervention in the post-test. For example before the learning intervention, student S3, selected the parking place for constructing the landfill propounding a societal argument: "this site is very close to the settlements, inhabitants will easily drop waste", while student S1 used a societal argument "this site is very close to the settlements, this not good for inhabitants" to reject the specific alternative. The following quotes in Table 4 provide examples of the societal, economic or environmental reasoning behind the selection or rejection of an alternative before and after the learning intervention.

Table 4. Indicative responses of students' reasoning for selecting or rejecting an alternative before and after the learning intervention

Arguments	
Select Option A – Parking Place	**Reject Option A – Parking Place**
Before the learning intervention	
-"*this site is very close to the settlements, inhabitants will easily drop waste*" S3 – Societal reasoning -"*inhabitants could park their cars in the pavement*" S42 – Societal reasoning	-"*this site is very close to the settlements, this not good for inhabitants*" S1 – Societal reasoning -"*this land is big and id used by many cars*" S35 – Economic reasoning
After the learning intervention	
-"*this site is not important for the environment. There are no animals or plants to lose their home*" S3 – Environmental reasoning -"*this site is a public land and therefore no one will pay*" S4 – Economic reasoning	-"*this site is in the middle of the town and the inhabitants' quality of life will be influenced. Additionally, there will be so many microbes in the town and may create health problems to people*", S1 – Societal reasoning -"*the environment of the town will be polluted and many organisms will suffer*", S2 – Environmental reasoning
Select Option B – Biological cultivation	**Reject Option B – Biological cultivation**
Before the learning intervention	
-"*the land size is big*" S6 – Economic reasoning -"*many inhabitants will be served*" S15 – Societal reasoning	-"*biological products are useful for people, should not be lost*" S1 – Economic reasoning -"*the site is far away from settlements*", S13 – Societal reasoning
After the learning intervention	
-"*this site is far away from the town and therefore inhabitants will not be disturbed*", S6 – Societal reasoning -"*this site is not a natural place, it is better to be destroyed comparing to the forest which is a natural ecosystem*", S6 – Environmental reasoning	-"*we should respect the owner and his labor to raise the plants. Additionally, so many people buy biological products and have healthier lives*", S1 – Societal reasoning -"*this site is a private land and the cost is high for the expropriation*", S4 – Economic reasoning
Select Option C – Natural Forest	**Reject Option C – Natural Forest**
Before the learning intervention	
-"*its is public land*" S8 – Economic reasoning -"*this site is far away from settlements*" S12 – Societal reasoning	-"*there are many animals*", S8 – Environmental reasoning -"*the forest is important for children's school excursion*" S10 – Economic reasoning
After the learning intervention	
-"*is the cheapest solution. Additionally, if the dump take the half place the other part of the forest can also be destroyed and make play-ground for children*" S11 – Economic reasoning -"*this site is far away from settlements and therefore inhabitants will need much time to take their waste*" S12 – Societal reasoning	-"*the forest is a big ecosystem with many plants, animals and other organisms. The life cycle of all those organisms will be destroyed*"S8 – Environmental reasoning -"*the forest provides oxygen to the town and it is important for peoples health*", S9 – Societal reasoning -"*the forest is important for children's school excursion. If it will be destroyed children will not have a park to go*", S10 – Economic reasoning

Optimization decision-making strategy and the emersion of students' values

The second step of the optimization strategy is the evaluation of criteria in order to account for the relative importance of each criterion and assign different weights. Regarding the weight given to each criterion in the pre-test, very few students (5,9%) were able to adjust relative weight to evaluation criteria, since by completing the table of optimization strategy, the column of relative weight was empty in most cases. Probably the majority of students felt unable to decide which criterion deserves more weight. It is worth mentioning that 80% of the students, who adjusted weight they evaluated two criteria the same. From Table 5 we can see that after the learning intervention, students were able to clarify their values and assign weight to decision making criteria. When students balanced the strengths and weaknesses of the various alternatives, social criteria (especially health) were more frequently evaluated (47.1%) as more important. Environmental (39.2%, especially ecosystem) and economic criteria (23.5%, especially cost) followed.

Table 5. Correlation between weight given to criteria and decisions before and after the learning intervention (Pearson's rank order correlation parametric test)

Groups of criteria	Criteria	Weight to criteria		Decision A Parking place		Decision B Biological field		Decision C Natural forest	
		Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Economic		**3,9**	**23,5**						*
Economic-cost	Cost	2,0	23,5						*
Economic-land use	Private / public land	2,0	5,9						
	Land size	0,0	0,0						
	Children-excursion	3,9	7,8						
	Organic culltivation	0,0	0,0						
Environmental		**3,9**	**39,2**				*		
	Plants	0,0	27,5				*		
	Animals	3,9	25,5				**		
	Ecosystem	0,0	31,4				**		
	Envir. pollution	0,0	5,9						
Social		**3,9**	**47,1**		*				
Social - health	Health	3,9	23,5				**		
Social - prosperity	Inhabitants	2,0	15,7						
	Distance	2,0	13,7		***				
Optimum		**2,0**	**0,0**						
No criteria		**94,1**	**5,9**						

Note. **** p=0.000, ** p=0.001, * p=0.05*

Regarding the correlation between the weight of criteria with decisions, before the intervention, in no one case students' decisions were correlated to the weight adjusted to evaluation criteria. However, as can be seen in Table 5, after the learning intervention, students' decision to make the development in the Parking place (option A) was correlated to the weight given to social criteria and especially "distance". Student's decision to build the dump in the biological field (option B) was correlated with the weight adjusted to all environmental criteria as well as to social criteria (health). Students' decision to make the development in the Forest (option C) was correlated to economic criteria.

Relationships among the criteria received the highest weight, decisions and arguments - patterns of decision makers

According to the correlations between 'weight of criteria' in relation to 'decisions' found in Table 5, students, who gave greater weight to economic criteria (cost / utilization), were found to prefer the construction of the dump in the forest (Pearson's r=0.354, p < 0.01). This decision was further supported by substantive arguments which were followed. For example, students of this group explained that 'the forest is not a private land and therefore there is no cost' and 'the forest is useless for the town'. Utilitarian values seemed to drive this decision and therefore as can be seen in Figure 1, a strong anthropocentric-economic pattern was revealed among the decision makers.

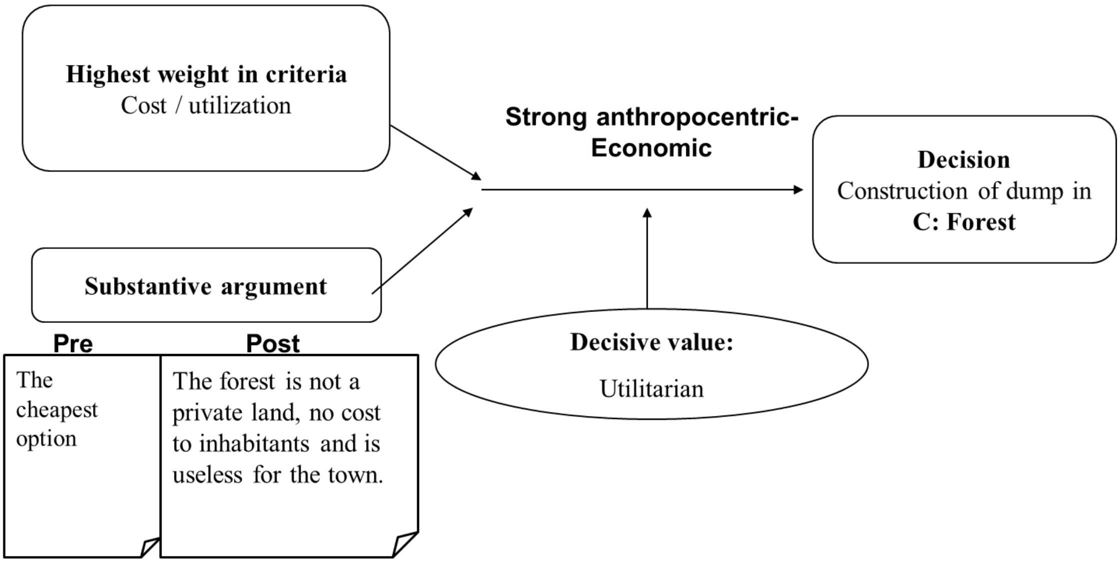

Figure 1. Strong anthropocentric value-driven pattern of decision makers.

Students, who gave greater weight to social criteria (inhabitants, health, and distance), were found to prefer the construction of the dump in the biological field (Pearson's r=0.419, p < 0.001), because 'the dump should be far away from the town in order to avoid health problems' or in the parking place (Pearson's r =0.471, p < 0.000), because 'the dump is in the middle of the town and many inhabitants will be served'. As can be seen in Figure 2, weak anthropocentric values of human health and prosperity seem to drive this decision and therefore a weak anthropocentric-social pattern was revealed among the decision makers.

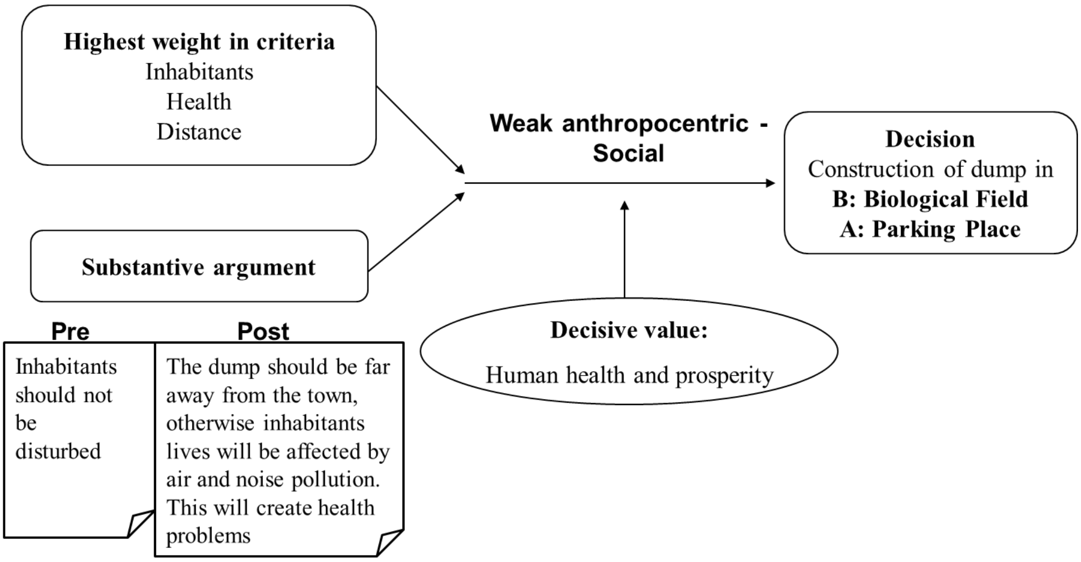

Figure 2. Weak anthropocentric value-driven pattern of decision makers.

As can be seen in Figure 3, students, who gave greater weight to environmental criteria (plants, animals, ecosystem and environment) were found to select the construction of the dump in the biological field (Pearson's r=0.418, $p < 0.001$), because 'the forest ecosystem should be conserved. Ecocentric values of ecological integrity seem to drive this decision and therefore an ecocentric pattern was revealed among the decision makers.

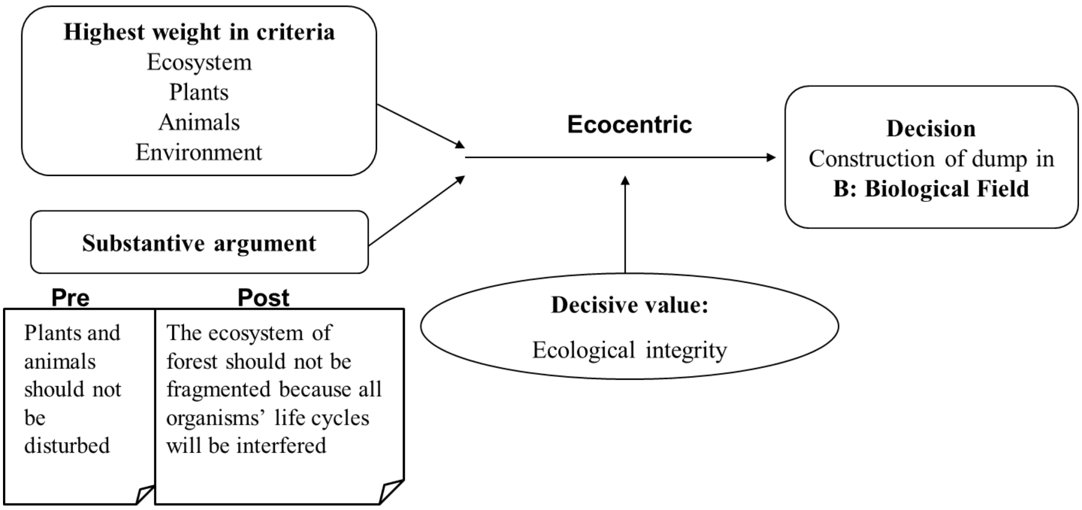

Figure 3. Ecocentric value-driven pattern of decision makers.

DISCUSSION

What are the substantive criteria and arguments that drive 11-12 year old students' decisions?

In the present study, after the learning intervention, almost the two thirds of the participants mentioned criteria from all the three domains of sustainability i.e., economic, societal and ecological. This is in accordance with several studies (Kolstø, 2006) claiming that when students are engaged in a socio-scientific issue, usually maintain combinations of social and scientific orientations, whereas in fewer cases individuals hold strictly social or scientific orientations.

The results of the present study indicated that the social dimension of the socio-scientific issue dominated in students' criteria. Health of people and the number of inhabitants served, were important criteria for most participants' decision. This finding is consistent with other studies which support that knowledge of the social world, as opposed to the physical world, is the most important determinant of students' reasoning in socio-scientific decisions (e.g. Fleming, 1986) and that students are concerned with the evidence and data associated with different positions as well as the social consequences of the positions (e.g. Sadler & Zeidler, 2004).

The ecological reasoning of participants was also developed through the learning intervention. It is worth mentioning that the independent parts of plants and animals, which were presented before the learning intervention, were re-organized in a more holistic representation which is the ecosystem that acted as an organizing principle. The criterion "ecosystem" was statistically significant correlated with plants, animals as well as the environment.

The development of reasoning, which was revealed through the more elaborated arguments in post-tests, is an important outcome of the present study. We suggest that the controversy behind each socio-scientific issue corroborates that there is a need of improvement in the thinking skills used by decision-makers and citizens in their daily affairs (McTighe & Schollenberger, 1991). Environmental education does not advocate a particular solution or action, but instead facilitates a student's ability to draw on and synthesize knowledge and skills from a variety of subject areas to conduct inquiries, solve problems, and make decisions that lead to informed and responsible actions (UNESCO, 1998). In the light of increasingly complex societal challenges the goal of improving critical thinking is fundamental to environmental educators' efforts to create an environmentally literate citizenry, instead of guiding youth towards a specific sustainability domain.

How the optimization decision-making strategy help to the explicit emersion of students' values when dealing with socio-scientific decision-making situations?

This study has also provided encouraging indications as to the extent to which specially designed learning environments and decision-making frameworks can help to the explicit emersion of students' values when dealing with socio-scientific decision-making situations. The majority of students in our study reported many criteria from all aspects of an SSI. After the learning intervention students were able to realize that the SSI which they had to solve was a complex issue involving several advantages and disadvantages and with many conflicting interests and multiple solutions. Their decision would be a compromise between competitive criteria and in order to come up with an unambiguous decision, students had to prioritize these criteria. This was not an easy task since it has been pinpointed by other researchers that students face difficulties in prioritizing 'conflicting' criteria (Bogeholz, 2009) probably because weighting decision criteria or trade-offs includes prioritizing conflicting values (Bogeholz & Barkmann, 2005; Jimenez-Aleixandre, 2002; Kolstø, 2006). One explanation for this inefficiency may be attributed to the fact that students find it hard to explicitly weigh the criteria given in decision-making situations, because they represent different ecological, social and economic dimensions of the problem. Another explanation is that individuals in general do not explicitly weight criteria, but do this rather implicitly or give equal weight to the presented criteria (Payne, Bettmann, & Luce, 1998).

However, the participants in the present study were scaffolded by the learning environment and prompted by the optimization decision making framework to clarify their values and therefore 80% of them were able to explicitly assign weight to evaluation criteria in the post test. The present study highlights that the development of the ability of assigning weight in conflicting criteria is a cornerstone for the emersion of how values are interrelated with decisions and that by clarifying values young people are able to decide how to think about a choice and what to do by giving priority to preferences. The training in the optimization decision-making as well as of the implementation of the strategy in two different socio-scientific contexts contributed to the development of that ability.

We believe that equipping young people with such skills is fundamental objective, especially for environmental education, since dilemmas concerning environmental problems are common place for consumers, voters, or any active citizen. The effective confrontation of vital everyday issues, such as energy consumption habits, or recycling routines, demands not just conceptual understanding of the relevant topic, but also skills of making choices with impact on both the quality of life and the environment. Therefore, school curricula should seek the development of problem-solving and decision making skills.

What relationships can be seen among the criteria received the highest weight, decisions and arguments? Are there any patterns of decision makers?

The relationships among the criteria received the highest weight, the decisions and the arguments highlight that the participants reacted in a specific way and it suggests that there are several tendencies among the young decision makers. The prioritized criteria along with the elaborated reasoning seem to drive the decision towards a specific direction, based on the value system of each individual. In the case of participants who assigned greater weight to environmental criteria their decision found to be driven by ecocentric values of ecological integrity. According to that group the new development should not disturb the natural environment; therefore the optimum solution should result only to economic or social impacts. In the case of students who gave greater weight to social criteria their decision found to be driven by weak anthropocentric values of human health and prosperity. According to that pattern the optimum option would be the one that safeguards inhabitants' health or maximizes the number of inhabitants served. From the other hand, participants who gave greater weight to economic criteria their decision seemed to be driven by economic and utilitarian values since the optimum option would be the one which increases human profit and wouldn't threaten economic or social interests.

The three value-driven patterns of decision makers help us understand the relationship between values and how we make new choices. The results of the present study empirically revealed that values arise when our preferences are in conflict during decision-making and that we make decisions by weighting alternatives in comparison to our preferences. Actually, we agree with the theories of Dewey (1988) and Hechter (1994) suggesting that values give weight to competing preferences and when faced with a decision, people simply apply the weight to the alternative options.

However, the weight given to various elements of our values are not always fixed since may depend on the role we are in when we are making a decision. Cues about the context and thus the role to be taken can shift individuals from one value weight to another. Some people have little range in the weight they assign to their values, where others change weight much more with contexts. Additionally, over one's life, communication with other individuals shapes and reshapes the emphasis we place on values (Dewey, 1988). Our sense of identity and the values to which we give greatest weight are developed by interactions with others whose views we respect.

Limitations of the study

From a methodological point of view, the relatively small sample imposes some limitations on our ability to generalize from the study. Additionally, the study's sample size was most likely suffered from a certain degree of self-selection bias, since it becomes from only one school of the country, however some fairly detailed exploration of a relatively small sample of children's views can reveal some of the possibilities inherent in broader issues that are raised.

IMPLICATIONS AND CONCLUSIONS

Situations of the sustainable development of our environment are typically characterized by the existence of inherent conflicts that cannot be resolved easily. Consequently, students have to learn to develop solutions that represent a compromise between economic, ecological, and socioeconomic dimensions, which includes establishing a value hierarchy. The ability to weigh decision criteria and to disclose underlying value considerations may be an elaborate way to work with these multifaceted situations. Even though there is a skepticism whether it might be useful in teaching specific reasoning strategies for the comparison of possible solutions in decision-making situations (Beyth-Marom, Novik, & Sloan, 1987; Ratcliffe, 1997), however, the present study reveals empirical evidence that the optimization strategy is appropriate for sixth graders since was proved to help students shift toward a more informed and analytic stance when processing data for the selection among competing solutions in the upper grades of the elementary school.

Another highlight of the present study is that children at the age of 10-12 years old, have the necessary cognitive apparatus to cope with environmental protection tasks. Children at that age not only start to take account of "the bigger picture," they also develop a capacity to reason and work things out (Berk, 1994; Vosniadou, 2002). They are able to solve concrete (hands-on) problems in a logical fashion. They can talk about concepts and possibilities, form hypotheses and conclusions and use rules to solve abstract problems. Therefore socio-scientific issues related to sustainability, could be incorporated in Science Curriculum of the upper primary school.

Finally, clarifying the value-patterns students follow as they confront controversial dilemmas will aid in the development of appropriate socio-scientific curricula and pedagogical strategies for enhancing scientific literacy and critical thinking skills. These will better prepare students to evaluate environmental issues and make informed decisions regarding the stewardship of the planet.

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