Students' reasoning processes in making decisions about an authentic, local socio-scientific issue: bat conservation

Authors

Yeung Chung LEE
Assistant Professor in Department of Mathematics, Science, Social Sciences and Technology, Hong Kong Institute of Education, Hong Kong SAR, The People's Republic of China

Postal address: Department of Mathematics, Science, Social Sciences and Technology, Hong Kong Institute of Education,10 Lo Ping Road, Taipo, Hong Kong
***Telephone No.*:** (852) 2948 7658
***Fax. No.*:** (852) 2948 7726
***Email address*:** yclee@ied.edu.hk

Marcus GRACE
Senior Lecturer in the School of Education, University of Southampton, UK
Postal address: School of Education, Building 32, University of Southampton, Southampton SO17 1BJ, UK
***Telephone No.*:** (44) 23 8059 3213
***Fax. No.*:** (44) 23 8059 3556
***Email address*:** M.M.Grace@soton.ac.uk

***Keywords*:** conservation, biodiversity, decision making, scientific literacy

Students' reasoning processes in making decisions about an authentic, local socio-scientific issue: bat conservation

Abstract

Education for scientific literacy entails the development of scientific knowledge and the ability to apply this knowledge and value judgments to decisions about real-life issues. This paper reports an attempt to involve secondary level biology students in making decisions about an authentic socio-scientific issue - that of bat conservation - through a classroom activity. A decision making framework adapted from the literature was designed to help students to tackle the issue from multiple perspectives with due consideration given to relevant scientific knowledge, rational argumentation, and the values underlying the possible options. An evaluation of the results showed that there were considerable changes in the students' decisions before and after the activity, thus reflecting a change in values from an anthropocentric viewpoint to an eclectic perspective that emphasizes both utilitarian and biocentric values.

Background

Socio-scientific issues (SSIs) have been used to provide the necessary contexts for students to connect personal, scientific, and social dimensions to make informed decisions, and are widely regarded as contributing to scientific literacy (Zeidler and Keefer, 2003). The study of SSIs is to be distinguished from the traditional Science-Technology-Society (STS) approach in that the latter tends to emphasize the impact of science and technology on society, whereas the former focuses on the moral and ethical implications underlying these issues (Sadler and Zeidler, 2005). However, many studies have revealed that students' reasoning about SSIs is more complex than their reasoning about pure scientific issues (Braund et al., 2007). Among the factors found to influence students' decision making about SSIs are personal values (Bell and Lederman, 2003), prior beliefs, personal consequences (Sadler and Zeidler, 2004), and cultural standpoints (Braund et al., 2007). However, it seems to be uncommon for students to consider multiple perspectives in making decisions about these issues (Sadler and Zeidler, 2004).

Various pedagogic practices have been suggested to promote the ability of students to make informed decisions about SSIs, including the use of argumentation to promote understanding and decision making (Patronis et al, 1999; Simon et al, 2006; Simon and Maloney, 2007); the utilization of metacognitive strategies such as reflective thinking to integrate multiple perspectives (e.g. Zeidler et al, 2002); the integration of scientific knowledge, argumentation, and personal value identification (Lee 2007); and

confronting students with opposing arguments through class discussions to clarify their thoughts (Simmonneaux, 2001).

All of these approaches indicate the necessity of challenging students to consider multiple perspectives in approaching SSIs. This involves the application of relevant knowledge, critical reflection on evidence, values, and cultural standpoints, and the integration of all of these into logical arguments. Researchers have further reported that peer group discussion can enhance students' knowledge base and their awareness of values related to SSIs (Ratcliffe, 1997; Grace, 2009). This kind of collective decision making falls within the constructivist paradigm, and is also in accord with the Vygotskian view that underscores the importance of social interactions in intellectual development. The effectiveness of this form of collective decision making appears to hinge on two important premises. First, a clear framework should be put in place to guide students to approach the issue from multiple perspectives and to reason through the issue in a logical and rational way. Second, this framework should encourage interactions between students to stimulate discussion and reflection on the views and perspectives of others so that they make an informed collective decision. The latter premise is presumed to be of great importance to any society that emphasizes pluralistic thinking and democratic decision making.

This research explores whether a prescribed decision-making framework that is underpinned by these two premises could stimulate Hong Kong biology students to make decisions about a socio-ecological issue relevant to the conservation of biodiversity. Biodiversity conservation is of particular importance in the contemporary world, as many wild species are over-exploited for food and their habitats are destroyed to pave the way for agricultural or economic development. Wildlife conservation has long been regarded by many scientists as a precondition for sustainable development (Solbrig, 1991). However, this raises the question of whether we are prepared to pay the price for conserving biodiversity by compromising our rate of economic development, and whether we are willing to coexist with wildlife by sharing with it some of "our" resources. These are questions that can be put to secondary level biology students to develop their ability to make decisions about biodiversity conservation. Based on the aforementioned premises regarding collective decision making, a framework was designed drawing on the one developed by Ratcliffe and Grace (2003) .The framework used in this study was supported by empirical findings gathered from research on the utility of the analysis of scientific and normative evidence (Zeidler, Sadler, Applebaum and Callahan, 2009), argumentation from different perspectives (Patronis, Potari and Spiliotopoulou, 1999; Wu and Tsai, 2007; Zeidler, Osborne, Erduran, Simon and Monk,

2003; Zeidler, Sadler, Applebaum and Callahan, 2009), and consideration of values (Grace, 2009; Lee, 2007) in developing students' capability of decision making on SSIs.

Fig, 1 (To be inserted here)

The framework, which comprises three key stages, is set out in figure 1. The first stage encourages students to explore through brainstorming as many perspectives as possible that might be held by the stakeholders affected by the issue in question. This is to prevent students from adopting tunnel vision and focusing overly on preconceived views without considering other perspectives. It also helps students to identify and read through the information or scientific evidence that is needed to gain a deeper understanding of the issue and the perspectives identified in the first stage. This paves the way for students to coordinate their own perspective, others' perspectives and external evidence in subsequent argument evaluation (Kuhn, 2005). Based on the outcomes of the first stage, students are asked to identify possible solutions to the problem at stage two and are encouraged to come up with at least two options to keep their minds relatively open to feasible solutions. This is followed by argumentation, in which students articulate the pros and cons of each option in groups by interacting with their peers. They are also asked to identify and reflect on the values underlying each option that are implicit in the relevant arguments and counterarguments. The aim of this process is to engage students in thinking in an in-depth and metacognitive way. At stage three, the students are asked to consider the main differences between the arguments and values underlying the various options, and to deliberate on the criteria that they would employ to choose between the options. Each group is then asked to make a final decision and to provide full justification for it. This requires students to revisit their criteria to ensure that they have made a consistent judgment and to reflect on these criteria if necessary. The groups take turns to present their decisions and justifications to the whole class. Following this, the students in each group are asked to discuss and reflect on their group's decision, drawing on the decisions and arguments of the other groups.

The study examines the reasoning process that the students used to make decisions about a socio-ecological issue under the guidance of the prescribed framework. The reasoning process includes the perspectives considered and the way in which the

students arrived at the various options and weighed the importance of the underlying concepts and values. The study is based on the following research questions.

Research questions

How did the prescribed decision-making framework help to guide 15- to 16-year-old secondary level biology students to resolve a local socio-ecological problem?
What were the characteristics of the reasoning process that they use to make a decision?

Methodology

The study involved an intact class of 31 secondary students (aged 15-16) attending a local co-educational secondary school in Hong Kong. The trial was conducted during a two-hour lesson. A socio-ecological case, "Bat Intruders," was presented to the class in the form of a video clip. Details of the issue are described in the next section. This particular issue was chosen because people have many pre-conceptions about bats, for example, that they transmit disease and suck blood. Chinese people have mixed feelings about bats. The Chinese word for "bat" is similar to that for "good fortune" and the pronunciation of the two words is exactly the same. For this reason, bats have long been regarded as a symbol of good fortune, as demonstrated by their appearance in many Chinese folk art designs. The students were divided into six groups, each comprising four to seven students. At the beginning of the lesson, the students were asked to suggest their personal solution to the issue and their justifications for their decision, and to record it on a specially designed worksheet. This was treated as the pre-test. The students then engaged in a decision making exercise through group discussion guided by the prescribed decision making framework. Due to the limited class time available for the activity, once the students had identified the information that they required the teacher distributed reading materials to them, rather than letting them search for information on their own. The materials covered the following aspects about bats.

Characteristics and habits of bats (e.g., life span, food, activity, roosting sites)
Roles of bats in the ecosystem (e.g., pollination, seed dispersal, mosquito control)
How likely it is that bats transmit diseases
Blood-sucking bats
A simple taxonomy of bats
Bat reproduction
Bat predators
Influence of human activities on bats
Bats and Chinese culture

Use of bat guano (bat droppings)
Legislation to protect bats in Hong Kong

(Source: Kadoorie Farm and Botanic Garden (KFBG) (2007). A teacher's guide to the world of bats. Hong Kong: KFBG.)

Each group recorded the outcome of their discussion at each stage on their worksheet. After the groups had made their final decision, individual students were asked whether they agreed with the decision of their group. If the answer was affirmative, then the group's decision was recorded as the member's decision, and if not, then the student was required to give his or her own viewpoint with justification. This was treated as the post-test. The lessons were conducted by the first author and the class biology teacher. After the lessons, one student from each group was selected to participate in a focus group interview conducted by the first author to collect their feedback on the decision making process. The development of the students' reasoning in the decision making process was traced by analyzing their written record during the classwork. In the analysis, the responses provided by the students at each stage for each specific task were categorized. The students' initial decision in the pre-test and their final decision were further categorized using two parameters, namely, the types of actions that the students suggested should be taken, and the values underlying these actions. The results of the pre-test and post-test were compared to reveal the impact of the group discussion on the students' decisions about the issue. The interview data was then analyzed to elicit the perceptions of the students of how the framework guided them to make an informed decision.

Presentation of the socio-ecological issue

The case presented to the students was an authentic incident that had occurred in a small village in a rural part of Hong Kong. A colony of bats was using a small house in a village as a roosting site. The house belonged to an old woman. The house had two compartments: one had been abandoned for years and was being occupied by the bats and the other was the ancestral home of the woman where she worshipped her ancestors, a cultural tradition in rural Chinese communities in Hong Kong. The owner was annoyed by the bats because they flew in and out of the house leaving droppings on the ground. She also worried that the bats might spread disease and attack her grandchildren. She was particularly concerned that the bats might move into her ancestral home sooner or later. Her neighbors had also complained about the odor of the bat droppings. The case was presented to the students through a video provided by Kadoorie Farm and Botanical Garden (KFBG), a local non-governmental organization dedicated to wildlife conservation. At the beginning of the lesson, only the introductory

part of the video depicting the occupation of the bats in the house was shown to the students. The remaining part, which described the remedial actions taken by the KFBG conservation officers, was withheld until the end of the lesson.

Results

Students' perceived views of the stakeholders involved in the issue

The number of stakeholders cited by each group varied from three to five. Table 2 shows the range of stakeholders or people affected by the issue identified by the students in descending order of frequency.

Stakeholders involved or persons affected	No of groups (N = 6)	Stakeholder viewpoints (Predicted by the students)
Villagers/neighbors/residents of other places	5	Afraid that the bats might spread to other houses in the village. Wary of hygienic problems.
Owner of the house	5	Finds the bats a nuisance, afraid of being attacked by bats, is emotionally disturbed by the bats.
Ecologists/environmentalists/ bat experts	5	Need to investigate the reasons why bats moved into the village house and to manage the issue to avoid interfering with the life of the bats. Need to devise methods to prevent the same thing from recurring. Need to identify the bats and their habits to assess the potential hazards before coming up with a resolution.
Agricultural and Fisheries Department of the government/	2	Will advise the owner not to attack the bats.
Bats	2	Already adapted to the environment of the village house, difficult for them to migrate elsewhere.
Animals Protection Group	1	Concerned about how the villagers handle the bats and wish to avoid the bats from being hurt.
Other animals including insects	1	Loss of original habitat.
Ancestors	1	Unhappy about this; somehow

		affected; could bring misfortune to the village.

Table 2: Stakeholders and their views as perceived by students

Among the most frequently cited stakeholders were the owner of the house, the other villagers, and ecologists or environmentalists. The identification of the ecologists as stakeholders implied that the students were concerned with the ecological implications of the issue. Interestingly, although the students were asked to identify the stakeholders or persons involved, some groups mentioned the bats and even other insects, presumably those preyed upon or driven away by the bats. Even more surprising was that one group identified ancestors as stakeholders, reflecting a cultural perspective in analyzing the issue. This also indicates the influence of traditional superstitions on at least some of the students. Taking these perspectives together, the students seemed to be thinking quite extensively of the different views of a sufficiently wide range of stakeholders.

Knowledge and information sought by the students

Table 3 shows the types of information and knowledge that the students thought would be useful for a more in-depth discussion of the issue leading to the resolution of the problem.

Information/knowledge	No. of responses by the student groups
Habits of bats, e.g., food, feeding methods, and other requirements for survival	10
Reasons for bats moving into the village; the surrounding environment, landscape and ecology of the areas and changes in these in recent years	8
Impact of bats on humans and other wildlife (including potential hazards to humans)	8
The architecture of the village house	2
Taxonomy of bats	2
Legislation about bats	2

Views of the villagers	1
Weaknesses of bats, e.g., the things that they are afraid of, including predators	3
Samples of bat droppings (to check whether they were harmed by humans)	1
Agencies that protect bats	1
Methods for removing bats or preventing them from entering houses	2

Table 3: Types of information or knowledge thought to be useful by the students

The type of information required by the students reflects their stance and approaches to resolving the issue. Information about the habits of bats, the surrounding ecological environment, the taxonomy of bats, and the reasons why bats moved into the village is general, but could serve as background and contextual information for the further discussion of possible strategies. Other information, such as methods for removing bats, the weaknesses of bats, and the agencies that protect bats, reflects the intention of some of the students to either get rid of or protect the bats. Some students sought to clarify some common myths about bats, such as whether bats are disease carriers or blood-suckers, and whether there is any legislation to protect bats, which indicates a relatively neutral or objective stance. There were relatively fewer concerns about the legal implications of the issue. This may reflect the students' general lack of awareness of the need to protect bats and of the measures in place to protect bats in Hong Kong. This is probably due to their lack of understanding about bats and the rationale behind protecting these seemingly harmful animals. One group wanted to seek the views of the villagers, which reflects their respect for the views of the main stakeholders in the issue.

Possible options suggested by the students

The number of options identified by each student group ranged from three to six. These options can be categorized into five main types of action as shown in the following (the frequency in number of groups is cited in brackets).

1. Driving the bats away from the house with no regard for their fate (5)
2. Leaving experts to decide what to do (4)
3. Protecting and restoring bat habitats (5)
4. Allowing the bats to stay (3)
5. Making use of the bats for specific purposes (3)

Various ways to drive away the bats were suggested by the student groups, such as using noise or predators such as cats, or asking bat experts to catch them. A more radical suggestion was to re-plan and re-build the whole village as a measure to completely wipe out the bats and to avoid any future access by them. To protect and restore bat habitats, the students suggested a variety of long-term and ecologically sustainable options. These included attracting the bats to another suitable habitat, reducing the exploitation of the surrounding environment, reducing light pollution in that area, building a "bat park" for conservation purposes, asking the government to purchase the village house to convert it and the surrounding area into a bat conservation area, and restoring the original habitat of the bats and guiding them to migrate back to that site. Suggestions for the last type of action (making use of the bats for specific purposes) included rearing the bats to attract tourists and collecting bat guano for profit.

A number of arguments and counterarguments and their underlying values were put forward by the groups for each of the options that they proposed. Table 4 shows some examples of the options for each of the five types of action, together with their respective arguments, counterarguments, and underlying values as suggested by the student groups.

Option (frequency in brackets)	Arguments	Counterarguments	Underlying values
Action type 1: Driving away the bats from the house without regard for their fate			
Using noise (1)	Effective	Annoying to villagers	-
Using cats (3)	Practical and effective	May hurt the bats. Some bats might not be frightened off. May drive bats to other houses. Bats may lose their habitat.	Human safety and interest. Fair to humans but not bats. Humans are more important than bats. Selfishness.
Action type 2: Leaving the experts to decide what to do			
Calling in experts from government authorities (4)	Help would be obtained from professionals. The experts would take milder actions	Relatively time consuming. Villagers may not welcome the final solution.	Human safety and interest. More comprehensive considerations.

	to drive away the bats without causing them injury.		
Action type 3: Protecting or restoring bat habitats			
Moving or attracting the bats to another habitat or restoring their original habitat (3)	Effective in the long term. Beneficial to both humans and bats.	Wastes money and manpower. The new habitat may be destroyed once again. Difficulty in finding a new habitat for the bats.	Humans should compensate for their wrong-doing. Takes care of the interests of both humans and bats.
Building a "Bat Park" for conservation purposes at the original site or in the vicinity (3)	Bats would have a stable habitat. Balances the ecosystem. Could educate the public on bats. Bats could be bred for use.	Space limitations. Financial problems. Bats may proliferate and cause disease. Need to take villagers' views into account as it might inconvenience them.	Humans and bats can live peacefully together as both are life forms on Earth. Humans should not deprive other animals of their rights.
Action type 4: Allowing the bats to stay			
Educating the villagers that bats and humans can live together harmoniously (2)	Relieves the villagers' fear of bats. Bats need not be driven out.	The problem is not solved completely. Bats will keep proliferating. Villagers are likely to object.	Values the right of bats to survive while relieving villagers' fear. Saving bats from extinction. Equality between humans and bats.
Finding another place for the ancestral home of the villager (1)	Bats can stay without disturbing the ancestors	Not easy to persuade the house owner to make such a change. May not be appropriate for bats and humans to live so close together.	Bats' interests should come first.
Action type 5: Making use of the bats for specific purposes			
Allowing the bats to stay and organizing	The public would get to know more about bats.	Could be turned into a commercial activity.	Practical.

bat-watching tours (1)			
Collecting the bat guano as manure, making a profit from it (2)	Using natural fertilizers causes less pollution to the environment. Free manure available. Profit.	Too much guano. May attract even more bats to the village. Bats may reproduce at a fast pace and could threaten the safety of the house owners. The smell of bat guano is disgusting.	Human interest. Full exploitation of living organisms. Monetary reward. Humans and bats are both animals; both have the right to exist.

Table 4: Examples of the options, arguments, counterarguments, and underlying values put forward by the students

Students' criteria for choosing between the options

The criteria chosen by the six groups are presented in Table 5.

Group	Criteria for choosing between the options
1	Humanitarian Different organisms should live in harmony Humans are dependent on nature for survival
2	Abiding by the law Life of villagers Maintaining a hygienic environment Concern for personal safety
3	No harm caused to the interest of humans and bats
4	Both sides gain benefits
5	Both sides gain benefits
6	Respect for the bats

Table 5: Criteria adopted by the student groups in making their final decision

From the data presented in Table 5, students were able to state explicit criteria for making decisions on the issue. Groups 1, 3, 4 and 5 emphasized that the decision should be beneficial to both humans and bats. Group 2 was most concerned with the impact of the issue on the villagers and also with abiding by the law. In contrast, Group 6 was more concerned with the well-being of the bats. Thus most groups appeared to adopt a 'win-win' approach to resolve the problem. This approach is consistent with the values

underlying students' justifications for their final decision (reported later in this paper), which reflect an emphasis on the well-being of both humans and bats.

Comparison of the students' decisions before and after the activity

The students' decisions in the pre-test and post-test were categorized into the five main types of actions shown in Table 4, and compared to reveal any change in their views after carrying out the activity. Figure 2 shows that the majority of students (84%) changed their decision between the pre-test and the post-test.

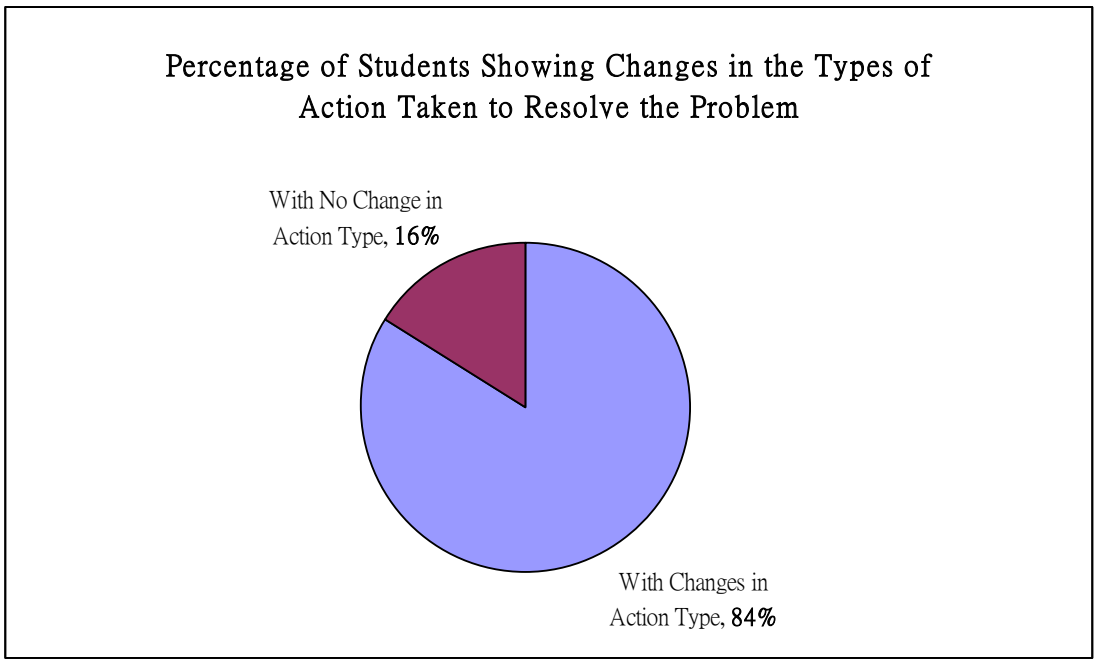

Figure 2: Percentage of students showing changes in the types of action from pre-test to post-test

Table 6 shows a more detailed comparison of the pre- and post- test results highlighting the trend in the changes.

Type of action	Pre-test (N = 31)		Post-test (N = 31)	
	No. of students	Percentage	No. of students	Percentage
1.Driving the bats away or catching them	13	42%	1	3%
2. Leaving the experts to	11	36%	3	10%

decide what to do				
3. Protecting or restoring bat habitats	4	13%	19	61%
4. Allowing the bats to stay or taking no action	2	7%	4	13%
5. Making use of the bats for specific purposes	1	3%	4	13%

Table 6: Comparison of the frequency that the types of action were suggested by students between the pre-test and the post-test

As shown in Table 6, the dominant view in the pre-test was to force the bats out of the house (42%), which reflects an intuitive or emotive type of reasoning described by Sadler and Zeidler (2005). This also implies that students possessed a rather negative attitude towards bats before the activity. The second most dominant view was to leave the matter to the discretion of experts (36%). However, in the post-test the students tended to adopt a more tolerant attitude toward the bats. Viewing this together with the findings presented in Table 5, the change in the students' dominant view was most probably a result of an increased understanding of the ecological importance of bats. Students' change in their stance on the issue is consistent with the research finding of Prokop and Tunnicliffe (2008) that fewer alternative conceptions of bats resulted in less negative attitudes towards them. Although leaving the matter to the decision of experts was still a legitimate option for the students, they tended to form their own views after the activity based on reasoning with both scientific-oriented and social-oriented information, the two reasoning modes identified by Yang and Anderson (2003).

Comparison of the students' values between the pre-test and the post-test

The values underlying the students' options were inferred from the justifications that they provided. The categorization of the students' values drew on the dichotomy suggested by Callicott (1997), who divided values related to the conservation of biodiversity into two main types: the anthropocentric (with a utilitarian value for

humans) and the biocentric (with an intrinsic or ethical value in itself). Analysis of the students' justifications for their decisions in the pre-test and post-test resulted in the generation of four value categories. The four categories, the frequency distribution of the students across the categories in the two tests, and examples of the students' justifications are shown in Table 7.

Type of value	Frequency (Percentage of students)		Students' justifications exemplifying the value
	Pre-test	Post-test	
No clear value	29	0	I don't know what to do. Let's ask the experts and see whether we should drive the bats away or take other action.
Anthropocentric	52	23	The bats disrupt normal living. They are terrifying. I am afraid that we will be attacked. We need to study whether bats will bring benefit or harm to humans. The house belongs to the old woman, therefore we should make the bats move away from the house. It is very difficult to handle bat droppings. Bats are annoying.
Biocentric	19	36	Both bats and humans have the right to live. We should respect bats.
Eclectic (both anthropocentric and biocentric)	0	42	Nature is important to us all. We can find a new habitat for the bats so that the villager's life will not be affected any more. Both humans and bats should be fairly treated. We should avoid conflict between humans and bats.

Table 7: Comparison of the values adopted by the students in the pre-test and post-test

There was a tendency for the students to abandon a purely anthropocentric view and there was an increase in the proportion of students adopting a purely biocentric view in the post-test. Of particular interest is the finding that a fairly large proportion of students (42%) adopted an eclectic view that emphasized the needs of both humans and bats, which was not obvious in the students before the activity. In contrast with the pre-test, all of the students based their decision on some type of value in the post-test. Overall, 77% of the students changed their values after the activity (Figure 3).

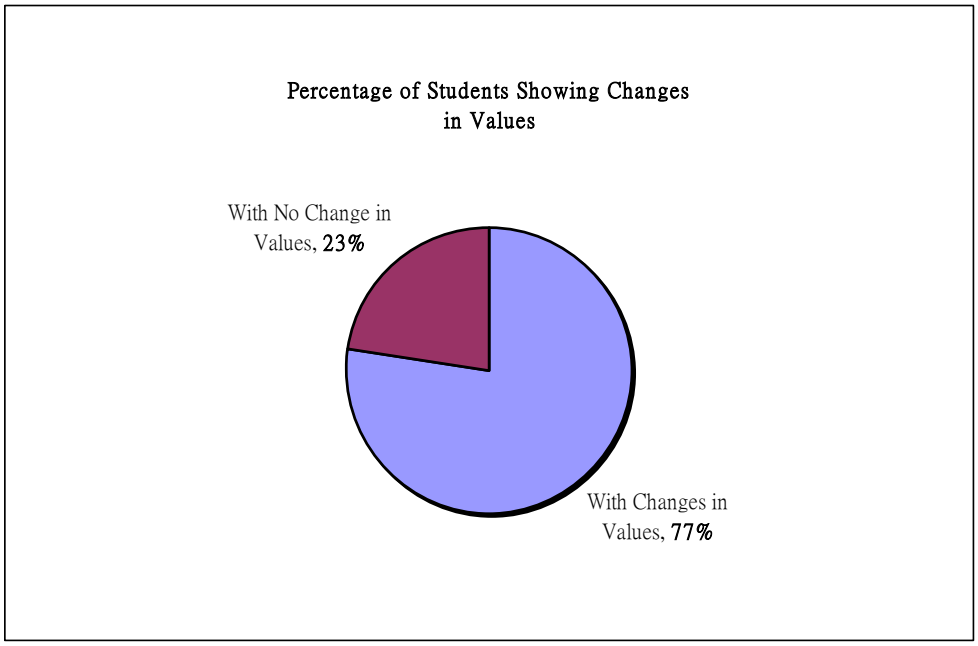

Figure 3: Percentage of students showing changes in value from pre-test to post-test

Discussion

An analysis of the findings shows that with the prescribed decision making framework as a guide the students were able to consider the issue from multiple perspectives, as evidenced by the range of stakeholder views elicited by the students at Stage 1. The provision of knowledge in the form of reading materials at Stage 2 was also important in developing scientific conceptions about bats and clarifying the misconceptions that the students had about these animals. The importance of developing this knowledge base for subsequent decision making was underscored by the following comments made by two students in the focus group interview.

S1: The information mentioned that the role played by bats in nature is particularly important.

S2: The reading materials described that vampire bats can be found in South America. This reminded me of the things happening in Brazil, where there are a lot of human

activities that lead to the destruction of the environment. This could lead to bats losing their habitat.

Both the perspectives and understanding of bats developed by the students seemed to have contributed to their formulation of a wide range of options at stage 3. These options provided the necessary basis for them to develop their argumentation at stage 4, which is a crucial step toward informed decision making. The students appeared to have taken into consideration the stakeholder views that they had identified and the information about bats including the scientific, legal, health, economic and cultural aspects that they had acquired from the reading materials in formulating arguments for and counterarguments against each option. As a consequence, these aspects of knowledge about bats were reflected in their arguments and counterarguments. At the beginning, it was not easy for the students to explore the values underlying the various options, as they seemed to have difficulty in concretizing the notion of value in this particular context. However, with some prompting from the facilitator they were able to propose some relevant values underlying the various options. In fact, some of the values that the students identified were fundamental, such as equality between humans and bats, and fairness in considering the interest of humans and bats.

An analysis of the initial and final decisions of the students reveals notable changes in their reasoning after carrying out the activity. The justifications provided by the students in the post-test were also better informed by scientific knowledge. They made less appeal to anthropocentric values and showed a greater inclination toward a biocentric perspective, and displayed more confidence in making their own decision rather than relying solely on expert opinion.

The use of group discussion for collective decision making made an important contribution to broadening the students' perspectives. The audiotaped record of the group discussion captured the nuances of the students' reasoning throughout the decision making process. The following exchange in one of the groups illustrates how the students engaged in argumentation regarding two options for handling the bats, which led them to the awareness that any option was bound to have pros and cons.

Transcript 1
S1: Even if we used a cat to drive them [the bats] away, they would still fly back. So we still need to settle them somehow.
S2: You should not be too perfect. Our world is not that perfect.
S1: So we need to think of a better method. Could we use smoke to drive them out?

S2: But that would hurt them even more.
S3: Or we could find another place for them to live in.
S1: How do you find a place to settle them in?
S3: So that solution has both pros and cons.
S4: Each method must have both pros and cons.

This exchange shows that the students were capable of reasoning through interactions with their peers. Guiding students to weigh the pros and cons of the options helped them to appreciate the complexity of the issue and the need to approach it from multiple perspectives.

The following is another exchange in the same group that demonstrates how the students argued for and against the third option, raising conflicting values in the process.

S1: Our third option is to resettle the villagers [Laughter].
S2: The old lady could be persuaded to give up her ancestral home.
S3: But how could we move an ancestral home? That is a taboo in Chinese society!
S2: But the place seems no longer suitable for that purpose.
S3: So what you actually mean is that we humans should compromise.
S4: Yes, this implies respecting the rights of bats.
S1: What are the cons of this option?
S2: The old lady will not be willing to give it up.
S5: You don't feel that this option will cost lots of money?
S2: I think the standpoint of the old lady is more important.
S1: We could be seen as being irresponsible to our ancestors.

The following extract from the transcript illustrates how the students in another group took the views of the main stakeholder – the owner of the house – into consideration, while at the same time applying their new understanding of bats to tackle the issue.

S1: Anyway, we must care about the rights of the villagers. We should not give up humans for the sake of bats. The villagers will surely not agree to that.
S2: Uuh. In fact, bats do not interfere with humans' daily lives very much, because they are nocturnal animals. In rural areas, there are only very few people going out at night. The major impact is that bats leave droppings that need to be handled. From the information we read just now, they can be used as fertilizer. Maybe we can encourage the villagers to collect bat droppings.

S1: Human feces are useful as well.
S2: Why not have an additional source?
S3: That means we are going to utilize the bats?
S2: We just let them stay.
S4: More bats may fly in then.
S2: Yes, that is a disadvantage.

The benefits gained by the students from this kind of collective decision making through group discussion is exemplified by a remark made by one of the students in the focus group interview.

The insight that I got is that we should go through a process in making a decision. I could not just do anything I wished; I had to listen to others' views before making the decision. That made the final decision better.

Both the exchanges among students and the interview data demonstrated that the prescribed decision making framework could help to guide students to more informed decision making by encouraging them to consider viewpoints from multiple perspectives, identify the pros and cons of different options, and evaluate the values underlying each option. As indicated by the criteria developed by the groups for making their final decisions, many students seemed to be convinced that taking care of the interests of both humans and bats was the best approach. That is to say, they tended to chart a middle course between a purely anthropocentric and a purely biocentric view. This reasoning was made explicit by one of the students in the focus group interview.

We cannot emphasize only personal interest. We must strike a balance between both sides. Bats that enter our homes are just passing by. They will only stay temporarily. We should not attack them or drive them away. We should find a peaceful way out, for example, by seeking help from the Agriculture, Fisheries and Conservation Department. We need not be afraid just because we do not know how to handle them.

This eclectic approach seems to represent a pragmatic way of managing the issue, showing that the students were able to negotiate among themselves to arrive at a reasonable solution . A similar approach to resolving the issue was in fact adopted by the KFBG conservation officers in handling the issue. At the end of the lesson, students watched the remaining part of the video depicting the decision of the conservationists. They decided that as bats are protected species in Hong Kong, they had to let them stay in the village house. However, they helped the villager to build a new transparent

skylight in the rooftop of her ancestral home to prevent the bats from flying into it. They also collected the bat guano for composting. The compost was sold as plant fertilizer and the profit returned to the villager. They also put sawdust onto the floor of the house to reduce the odor from the accumulated droppings.

Implications

The discussion of socio-scientific issues through case studies provides an authentic context for students not only to learn scientific concepts, but also to develop their decision making skills to handle controversial ecological issues. Although the study of bats is not specifically covered in the secondary biology curriculum, it certainly helps to illustrate a number of key biological concepts that students need to learn at this level, such as the important role played by animals in plant pollination and seed dispersal, the interrelationships between different organisms including humans, and the importance of these relationships in maintaining balanced ecosystems. Students are better motivated to learn new concepts from authentic contexts than from textbooks, which too often explain concepts out of context. This is particularly true when students are given a chance to apply their newly acquired knowledge to solve problems based on the prescribed framework, as occurred in this study. In this study, the students were provided with information about bats including bat ecology, positive and negative impacts of bats on humans, and how they are protected in Hong Kong. It could be argued that the information provided might have predisposed the students to a particular standpoint or attitude towards resolving the issue. It may be worthwhile to turn this class activity into a project-based task in which students search for information relevant to the issue by themselves. This self-directed type of learning has the added value of developing students' inquiry skills, notably searching for and evaluating information and evidence to clarify their understanding about bats, thereby assuming greater ownership of their learning.

The findings of this study have several implications for teachers, the first being the need to develop their pedagogical content knowledge to improve students' decision making skills in the context of biological or environmental education. The inclusion of the SSI approach in the biology curriculum means that students would be expected to consider wider perspectives in tackling biological issues in addition to applying scientific knowledge. As such, teachers would need to readjust their roles to lead students to study these issues, with the aim of developing both the scientific knowledge of students and a wide range of other skills, including reasoning, argumentation, and decision making. Ratcliffe and Grace (2003) proposed some roles that teachers could take in

managing group discussions, such as taking the "neutral chair" approach or the "balanced approach" (p. 129). This study indicates that there are other aspects of socio-scientific issues in addition to scientific knowledge and pedagogy that demand teachers' attention, including legal and ethical factors. The students participating in the study seemed not to have sufficient awareness of the current legislation protecting wildlife and the rationale behind its enactment. Teachers thus need to be vigilant in ensuring that students consider this aspect. Teachers also need to be aware of the multiple values underlying an issue and the potential conflicts between them. Such awareness would help teachers to engage students in more meaningful and in-depth discussion of the value aspect of an issue, which often underpins their final decision.

The posing of issues about conservation of biodiversity highlights the dilemma between human needs and the survival of wild animals. On the one hand, this encourages students to reflect on the dominance of humans in the global ecosystem and how this dominance, if left unchecked, could affect other organisms, which might in turn affect humans in the long term. On the other hand, students also need to consider the "price" that humans must pay in conserving wildlife, as evidenced by the case study. There are numerous local and global cases illustrating this conservation dilemma that could be used for classroom discussion to develop students' ability to make informed decisions and to further their understanding of the biological concepts and values behind biodiversity. Examples of local cases are the invasion of wild boar into local farms, the proliferation of monkeys in local country parks and the potential hazard for visitors, and the felling of old trees in urban areas to make room for urban renewal. Issues that are more global in scope include large-scale whaling by some countries and the destruction of rainforests to fuel the economic growth of developing countries.

There are three main constraints that might make teachers hesitant about discussing more complex global SSIs with their students. The first is that it seems unrealistic to ask secondary students to provide solutions to issues that even experts have difficulty in managing. The second is that teachers may not feel sufficiently confident or well equipped pedagogically to handle the non-scientific aspects of biodiversity education. These two constraints were pointed out explicitly by Gayford (2000) from his research findings with focus groups of teachers. The third constraint is that it is uncertain whether students are able to transfer decision making skills developed in the classroom to real life settings. In response to the first constraint, it is reasonable to assume that average citizens as well as experts have the right to voice their views on SSIs, and they certainly have an important role to play in deciding whether to put any recommendations or resolutions into action. The second constraint could be overcome

by professional development that is geared toward helping biology teachers to master the relevant pedagogic repertoire, thus enabling them to contribute more to school education by assisting students to connect with different types of knowledge, skills, and values. In response to the third constraint, it is a reasonable expectation that the classroom experiences that students have gathered – such as the other learning experiences that they obtain at school – will prepare them to meet real challenges in the future in their capacity as global citizens.

Acknowledgements

The authors would like to express thanks to Kadoorie Farm and Botanic Garden for providing the video and materials, and to the teacher who participated in the study.

References

Bell R. L. and Lederman N. G. (2003). Understandings of the nature of science and decision making on science and technology based issues. *Science Education*, 87, 352-377.

Bingle, W. H., & Gasket, P. J. (1994). Scientific literacy for decision-making and the social construction of scientific knowledge. *Science Education,* 78(2), 185-200.

Braund, M., Lubben, F., Scholtz, Z., Sadeck, M., and Hodges, M. (2007). Comparing the effect of scientific and socio-scientific argumentation tasks: lessons from South Africa. *School Science Review*, 88(324), 67-76.

Callicott, J. B. (1997). Conservation values and ethics, in G. K. Meffe and C. R. Carroll (eds) *Principles of conservation biology*. Sunderland, MA: Sinauer.

Gayford, C. (2000). Biodiversity education: a teacher's perspective. *Environmental Education,* 6(4), 347-361.

Grace, M. (2009). Developing high quality decision-making discussions about biological conservation in a normal classroom setting. *International Journal of Science Education*, 31(4), 551-570.

Kadoorie Farm and Botanic Garden (KFBG) (2007). A teacher's guide to the world of bats. Hong Kong: KFBG.

Kuhn, D. (2005). Education for thinking. Cambridge, Massachusetts: Harvard University Press.

Lee, Y. C. (2007). Developing decision-making skills for socio-scientific issues. *Journal of Biological Education*, 41(4), 170-177.

Patronis, T., Polari, D. & Spiliotopoulou, V. (1999) Students' argumentation in decision-making on a socio-scientific issue: implications for teaching. *International Journal of Science Education*, 21(7), 745-754.

Prokop, P., & Tunnicliffe, S. D. (2008). "Disgusting" animals: Primary school children's attitudes and myths of bats and spiders. *Eurasia Journal of Mathematics, Science and Technology Education,* 2008, 4(2), 87-97.

Ratcliffe, M. (1997). Student decision-making about socio-scientific issues within the science curriculum. *International Journal of Science Education*, 19(2), 167-182.

Ratcliffe, M, & Grace, M. (2003). *Science education for citizenship*. Maidenhead, Philadelphia: Open University Press.

Sadler, T. D., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Education,* 26(4), 387-409.

Sadler, T. D., & Zeidler, D. L. (2005). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching,* 42(1), 112-138.

Simon, S., Erduran, S., and Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education*, 28 (2-3), 235-260.

Simon, S., and Maloney, J. (2007). Activities for promoting small-group discussion and argumentation. *School Science Review*, 88(324), 49-57.

Simonneaux, L. (2001). Role-play or debate to promote students' argumentation and justification on an issue in animal transgenesis. *International Journal of Science Education,* 23(9), 903-927.

Solbrig, O. T. (1991) The roots of the biodiversity crisis. *Biology International*, 23, 5-13 (International Union of Biological Sciences)

Yang, F. Y., & Anderson, O. R. (2003). Senior high school students' perference and reasoning modes about nuclear energy use. International Journal of Science Education, 25(2), 221-244.

Wu, Y.-T. & Tsai, C.-C. (2007). High school students' informal reasoning on a socioscientific issue: Qualitative and quantitative analyses. *International Journal of Science Education*, 29(9), 1163-1187.

Zeidler, D. L., & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education. Philosophical, psychological and pedagogical considerations. In D. L. Zeidler (Ed.). *The Role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education* (pp. 7-38). Netherlands: Kluwer Academic Publisher.

Zeidler, D. L., & Osborne, J., Erduran, S., Simon, S., & Monk, M. (2003). The role of argument during discourse about socioscientific issues. In D. L. Zeidler (Ed.). *The Role*

of Moral Reasoning on Socioscientific Issues and Discourse in Science Education (pp. 97-116). Netherlands: Kluwer Academic Publisher.

Zeidler, D. L., Sadler, T. D., Applebaum, S. & Callahan, B. E. (2009). Advancing reflective judgment through socioscientific issues. *Journal of Research in Science Teaching*, 46(1), 74-101.

Zeidler, D., L., Walker, K. A., Ackett, W. A., and Simmons, M. L. (2002). Tangled up in views: beliefs in the nature of science and responses to socioscientific dilemmas. *Science Education*, 86, 343-367.