

standardization and acceptance based on justice and human rights. Those with potential in considering socio-scientific decisions are in need of considering possible impacts on morality as well [13]. Moral and ethical dimensions are to be a stand point in discussing socio-scientific issues [22].

The aim of this study is to investigate socio-scientific decision making, reported in the literature about socio-scientific decision making concepts. In this context, the following questions were asked:

1. What are the decision making frameworks?
2. What are the methods of analysis?
3. What are the data collection techniques?
4. What kinds of implications have been suggested in the studies?

2. Literature Review

As a result of investigating databases such as ERIC, Springer, EBSCOHOST and ThaiLIS, related to socio-scientific decision making. As a result of the first classification, these studies were found to concentrate on the subjects of teaching socio-scientific issues (SSI), students' reasoning processes in making decisions about SSI, and decision making framework for SSI. Therefore, this paper emphasizes the enhancement of decision making through SSI and related concepts' in the last three decades.

After reviewing related researches, the author found that there was an emphasis on the development of socio-scientific decision making using issue-based approaches, which can be shown below.

Lee [9] cited in his study that there is a great diversity of socio-scientific issues, more work still needs to be done at the classroom level to identify evidence-based pedagogic practices which can enhance a students' decision-making ability. An issue-based approach could be used to guide students towards informed decision-making, by promoting their conceptual understanding, understanding of scientific inquiry, attitudes, values, and their ability to engage in rational arguments. Lee and Grace [10] stated that a decision making framework adapted from the literature was designed to help students tackle the issue from multiple perspectives with due consideration given to relevant scientific knowledge, rational argumentation, and the values underlying the possible options.

Grace [5] suggests that biodiversity conservation is an important socio-scientific issue that is often regarded as a precondition to sustainable development. The foundation for citizens' understanding of conservation issues can be laid down in formal school education. It can focus on decision-making discussions about biological conservation issues among 15–16-year-old students. Findings indicate the positive value of students taking part in these short decision-making

discussions guided by a structured framework and as part of their normal science classroom activities. Students increase their quality of personal reasoning, and modify their solutions to the issues. These issues provide students with a context that encourages active reflection and examination of relevant connections among science, their own lives and the quality of life in their community [23]. Most students relied upon multiple perspectives when making their decisions. It was found that when students used multiple viewpoints, the perspectives were unequally valued, generally relying more on ethical perspectives [6].

Walpuski et al [20] found that decision-making and argumentation are competences concerning decision-making and are highly dependent on how frequently students are given the chance to debate in science classes. The enhancing decision making of students could be implemented in conventional classroom by assigning the decision making framework to the students. This could develop informed decision making based on brain-storming and provide multiple perspectives with peer group by promoting their conceptual understanding, realization of scientific inquiry, attitudes and values, and their ability to engage in rational argumentation.

At present, the management of knowledge derived from issues concerning science and society are considered important in the study of science, making learners realize that their learning is meaningful in relation to their lives. Socio-scientific issues are applied in generating an interest in argument-based learning among learners and a discussion based on scientific knowledge and data [14]; it serves as the best means in stimulating learners to develop skills in using a reason and making a decision in concern with socio-scientific decision making. A current reformation of the study of science tends to support the scientific advancement toward establishing morality and ethics in a scientific dimension, instead of teaching solely a science-based content, diversifying teaching based on learning techniques and scientific concepts, philosophy, history, society, values and ethics. The use of socio-scientific issues responds to these scientific needs [21]. The use of scientific knowledge before applying it to other situations in concern with social and moral context stimulates learners to find truth, opening their mind to the opinions of others and being able to negotiate carefully and systematically based on their rationale. Moreover, it promotes the quality of citizenry and social consciousness [23].

3. Methodology

Within the framework of the research questions posed to examine the decision making frameworks and data collection methods, the following studies were based on an analysis using a matrix, which

consists of two basic elements, i.e. decision making frameworks, data collection methods. The research questions posed to examine the decision making frameworks and data collection methods, the studies were based on an analysis using a matrix, which consists of two basic elements, i.e. decision making frameworks, data collection methods. It can be shown in Table 1 and 2.

Table 1: The examining the decision making frameworks

Research Studies	Decision making frameworks										
	DP	IS	CI	GO	CO	FC	MR	MD	RA	RD	
Kortland (1996)	/			/		/		/	/		
Ratcliffe (1997)			/	/	/	/		/	/		
Campbell et al., (1997)	/	/	/								
Edelson et al., (2006)		/			/	/					
Kaewmuang moon (2008)	/	/	/		/			/			
Lee and Grace (2010)		/		/				/			
Yu, (2010)			/				/		/		
Walpuski et al.,(2012)		/	/						/		
Lee and Grace (2012)		/	/	/	/	/	/	/	/	/	

DP = Defining the problem, IS= Identifying stakeholders, CI =Collecting information, GO =Generating options, CO =Considering pros and cons of options, FC=Formulating criteria for evaluating options, MR=Developing moral reasoning, MD=Making decisions, RA=Reflection among students, RD= Reflection in a different location

Decision making framework serves as a guide for students so that they were able to consider the issue from multiple perspectives.

Table 2. Data collection techniques

Research Studies	Data collection techniques							
	I	C	O	M	F	A	R	U
Kortland (1996)								/
Ratcliffe (1997)					/	/		
Campbell et al., (1997)							/	
Edelson et al., (2006)								/
Kaewmuang moon (2008)			/		/			

Lee and Grace (2010)	/	/	/		/	/		
Yu, (2010)			/					
Walpuski et al.,(2012)			/		/			
Lee and Grace(2012)		/	/	/	/			

I=Interviews, C =Class observation, O =Opened question, M =Multiple choice,F =Free writing, A=Audio-tape discussion, R =Role play, U =unclear

The triangulation of data in researches increases the reliability and validity[3]. Therefore mixed methods are usually preferred [7]. When Table 2 is examined, it can be seen that researchers collected data using interviews, class observation, open ended questions, multiple choice, free writing and role play. Among the studies, 9 were found to include multiple methods of data collection.

The data collection techniques and methods of analysis used in the studies were conducted to determine how socio-scientific issue decision making is enhanced.

4. Findings

The study found that Kortland [8] conducted a study to explore a decision making of students aged 13-14 in the Netherlands, after teaching the students arguments about a decision making situation had improved as far as clarity of the criteria used for evaluating alternatives is concerned. Ratcliffe [15] conducted a study to explore a decision making on environment issues. The result found that the appropriate framework to follow during discussion among small groups of 15 year olds being able to begin to address. However, the written work was examined alongside the audio-taped discussion. Grace [4] and Lee [8] found that the positive value of students taking part in short decision-making discussions was guided by a structured framework as part of their normal science classroom activities. Campbell et al [2] published a student-centered curriculum with provide a model for decision making focused on defining the problem and emphasized identification of values and role play in decision making. Edelson et al [4] created the Stakeholder consequence Decision making (SCDM) for high school students. He found that decision making process was accessible and engaging to a broad range of students. Lee [9] found that data on the outcomes and student feedback were collected from the student worksheets, class observations and student interviews. A group of five students from each class was interviewed after the lesson. Lee and Grace [10] and found that initial and final decisions of the students reveals notable changes in their

reasoning after carrying out the activity. They made less appeal to anthropocentric values and showed a greater inclination toward a perspective of biocentrism. Kaewmuangmoon [19] said that the students could make socio-scientific decision making after the curriculum implementations were significantly different at 0.05 above the cut-off score of the socio-scientific decision ability test. Lee and Grace [11] found that in different contexts, students had shared different perspectives on reasoning, evidence of data collection, decision criteria along with some decision making behavior in solving similar socio-scientific issues. Yu [21] explained that socio-scientific issues could support the learning of science in relation to morality and ethics along with enhancing the student's obvious ability in ethical terms and other elements that influence their lives; such as an export of electronic waste to poor developing countries, etc. This points out that morality has an important role in a student's decision making.

The most important results obtained by the researchers were given in concern with decision making in issues regarding sciences at national and international levels. It was found that one should develop an academic curriculum on a relative quantity emphasizing the development of potential in solving a problem and doing decision making. Sungsewo

[18] discovering that such an ability have been in solving a problem and decision making with points in finding solution and decision making higher than the crossover point. Kaewmuangmoon [19] discovered that students had decided to work on socio-scientific decision making in a higher level than the crossover point of the test of ability in decision making concerning socio-scientific issues. During a process of decision making of secondary high school students regarding nuclear physics, based on the management of scientific, technological and social ideas (STS) Anantasook [1] found that decision making done by individual students had a more consistent pattern because of their experience in group work. Students with different intelligence tended to have different processes of decision making based on a mutual decision in their group. It was indicated that the majority of the mentioned research are based on either qualitative or quantitative data. As a result, the obtained data were not sufficient for analysis and conclusion, undermining reliability. Furthermore, the majority of research, in emphasis of developing curriculum, does not specify or in cases of a study of decision making, each step was independently classified. In an international level of research, there were those who had studied the issues and their related ones. Lee and Grace [9] pointed to an importance in the process of seasoning of students in concern with socio-scientific decision making under a wide variety

of biodiversity under the scope of a particular decision making by stimulating students through brain storming to generate different perspectives. In this process, the teacher has a role in supporting and guiding the student through appropriate solutions, discussing pros and cons, framing criteria in selecting a choice and reflecting a result of their decision. Besides, they would have to develop a scientific concept in tackling relevant issues so that the student could realize it and make use of it as a knowledge base for decision making. It was discovered that the participant students were able to use scientific knowledge more effectively than they used to before joining the experiment. Anthropocentric values are based on the benefits of human beings alone and values of biocentrism feature a mutual win-win between humans and other organisms. Students became more confident in a process of decision making. Besides that, Lee and Grace [10] found that in different contexts, students had shared different perspectives on reasoning, evidence of data collection, decision criteria along with some decision making behavior in solving similar socio-scientific issues. It was discovered that in different contexts, the framing of decision making would be different generating perspectives in reasoning and reflecting different metacognitions. Qualitative discussion would be based on the student's chances in group work. Meanwhile, Yu [21] explains that socio-scientific issues could support the learning of science in relation to morality and ethics along with enhancing the student's obvious ability in ethical terms and other elements that influence their lives; such as an export of electronic trash to poor developing countries, etc. This points out that that morality has an important role in the student's decision making. The study of science in the future should, therefore, emphasize on socio-scientific issues.

5. Conclusions

The results are summarized and presented as follows:

1. Decision making frameworks serve as a guide for students so that they were able to consider the issue from multiple perspectives.
2. Decision making on SSI is important in developing scientific conceptions and clarifying the misconceptions.
3. Conservation issues are a prerequisite to making informed decisions about wider issues of sustainable development.
4. Decision making on SSI consists of conceptual understanding, nature of scientific inquiry, value clarification, and argumentation.
5. Debating serves as a teaching approach to enhance understanding of socio-scientific issues and

to encourage critical thinking leading to better decision-making.

6. Issue-based approaches could be used to guide students towards informed decision-making. It promotes the students' conceptual understanding, understanding of scientific inquiry, attitudes and values, and their ability to engage in rational argumentation.

The need and relevance of emphasizing decision making in science teaching have also been argued by several educators through the last few three decade. Based on the mentioned principles and theories, it was found that lower secondary school students became an important target in developing the ability in socio-scientific decision making. Students learning science this way would not just memorize information, but they would use scientific thinking to make everyday decisions. However, there is no current form of teaching to develop socio-scientific decision making, a future research should be developed to support the style for lower secondary school students in correlation with a reform in the study of science in the future.

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7. References

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