STUDENTS’ UNDERSTANDING IN MAKING DECISION ON A SOCIOSCIENTIFIC ISSUE WITHIN A CO-CURRICULAR CONTEXT

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ABSTRACT

The issue of the gap in research on the socioscientific issues and co-curricular context exists internationally. In global and Malaysian perspectives, socioscientific issues are difficult to solve; thus, it is important that students are exposed to informal learning circumstances through the co-curricular context. The co-curricular context as a learning environment is identified as a less explored area. Consequently, it possesses inadequate structure and guidelines that hinder its proper implementation, development, and significance. Therefore, this study aimed to explore the students' understanding in making a decision on global warming issue within co-curricular context using a generic research paradigm. The participants were chosen based on the purposive sampling technique. This study involved 30 students (7^{th} – 9^{th} grades) of the Science and Mathematics Society from a Fully Residential School located in Selangor. It was conducted for six months. The related documents, interviews and observations were utilised as data collection techniques. The primary document used in this study is the Persuasive Graphic Organiser (PGO). It was developed by the researcher to explore students' understanding in making decisions on the global warming issue. The PGO provides an appropriate visualised method for students in the aspects of understanding and performing decision-making skills on the socioscientific issues. The PGO evaluation process involved professional reviews from socioscientific and qualitative experts and orderly administered to students aged 13-15. The data were analysed using the constant comparative method. Four categories emerged when exploring the students' understanding of global warming issue. The findings describe the students' ability in 1) defining the global warming phenomena in terms of temperature and Green House Gasses (GHG) emissions, 2) identifying anthropogenic and natural factors affecting global warming, 3) clarifying the global warming effects in the aspects of health, ecological system and climate change, and 4) providing alternative solutions for the global warming phenomena in the aspect of sustainable development. This goes beyond formal curricular specification where students were traced as having sophisticated understanding in the global warming issue. The understanding is important for the students to draw conclusions using scientific and social considerations. The considerations of the students' decision-making were grounded from the dimensions of environment, technological advancements, medical, economy, politics and religion. The study also reveals four factors which explain the influences of the co-curricular context towards promoting the students' understanding in making decisions related to global warming issue. They are learning flexibility, socioscientific instructional materials, integrative activities and student readiness. Three conclusions can be drawn from the study. First, socioscientific understanding can be identified through the students' ability in recognising relevant science knowledge. Second, socioscientific decisions can be drawn upon multi-dimensional considerations according to the specificity of context. Finally, the co-curricular setting can be used to complement socioscientific learning. Practical and methodological implications regarding the integration of socioscientific issues in the co-curricular context are also discussed.

PEMAHAMAN MURID DALAM MEMBUAT KEPUTUSAN TERHADAP ISU SOSIOSAINTIFIK DALAM KONTEKS KO-KURIKULUM

ABSTRAK

Isu jurang penyelidikan mengenai isu-isu sosiosaintifik dan konteks ko-kurikulum wujud di persada antarabangsa. Dalam perspektif global dan di Malaysia, isu-isu sosiosaintifik adalah sukar untuk diselesaikan; maka ini menjadi bermakna jika murid didedahkan dengan keadaan pembelajaran tidak formal melalui konteks ko-kurikulum. Konteks ko-kurikulum dikenal pasti sebagai persekitaran yang kurang diterokai. Kesannya, ia mempunyai struktur dan garis panduan yang tidak mencukupi seterusnya menyukarkan pelaksanaan, pembangunan, dan kepentingannya. Oleh itu, kajian ini bertujuan meneroka pemahaman murid-murid dalam membuat keputusan terhadap isu pemanasan global dalam konteks ko-kurikulum menggunakan paradigma kajian kualitatif generik. Para peserta dipilih berdasarkan teknik persampelan bertujuan. Kajian ini melibatkan 30 orang murid (gred 7-9) dari Persatuan Sains dan Matematik di sebuah Sekolah Berasrama Penuh yang terletak di Selangor. Ia dijalankan selama enam bulan. Dokumen, temu bual dan pemerhatian telah digunakan sebagai teknik pengumpulan data. Dokumen utama yang digunakan dalam kajian ini adalah "Persuasive Graphic Organiser" (PGO). Ia telah dibangunkan oleh penyelidik untuk meneroka pemahaman murid dalam membuat keputusan mengenai isu pemanasan global. PGO menyediakan kaedah visualisasi yang sesuai untuk murid dalam aspek pemahaman dan kemahiran membuat keputusan mengenai isu-isu sosiosaintifik. Proses penilaian PGO melibatkan ulasan profesional daripada pakar-pakar sosiosaintifik dan kualitatif, juga diedarkan dengan teratur dalam kalangan murid berumur 13 – 15 tahun. Data telah dianalisis menggunakan kaedah perbandingan yang berterusan. Empat kategori muncul ketika meneroka pemahaman

murid terhadap isu pemanasan global. Dapatan menggambarkan keupayaan murid dalam 1) mendefinisikan fenomena pemanasan global dari segi suhu dan pelepasan Gas Rumah Hijau (GHG) 2) mengenal pasti faktor-faktor antropogenik dan semula jadi yang menjadi punca kepada pemanasan global 3) menjelaskan kesan pemanasan global dalam aspek kesihatan, sistem ekologi dan perubahan iklim 4) menyediakan penyelesaian alternatif untuk fenomena pemanasan global dalam aspek pembangunan mampan. Pemahaman ini melampaui spesifikasi kurikulum formal di mana murid telah dikesan mempunyai pemahaman yang sofistikated terhadap isu pemanasan global. Pemahaman ini adalah penting bagi murid untuk membuat rumusan menggunakan pertimbangan saintifik dan sosial. Pertimbangan murid dalam membuat keputusan boleh dijelaskan melalui dimensi persekitaran, kemajuan teknologi, perubatan, ekonomi, politik dan agama. Kajian juga mendapati empat faktor bagaimana ko-kurikulum mempengaruhi pemahaman murid dalam membuat keputusan berkaitan dengan isu pemanasan global. Faktor tersebut adalah pembelajaran fleksibel, bahan pengajaran berkaitan isu sosiosaintifik, aktiviti bersepadu dan kesediaan murid. Tiga kesimpulan boleh dibuat daripada kajian ini. Pertama, pemahaman sosiosaintifik boleh dikenal pasti melalui keupayaan murid dalam mengiktiraf pengetahuan sains yang berkaitan. Kedua, keputusan untuk isu sosiosaintifik boleh diambil berdasarkan pertimbangan pelbagai dimensi mengikut spesifikasi konteks. Akhir sekali, platform ko-kurikulum boleh digunakan untuk melengkapkan pembelajaran isu sosiosaintifik. Implikasi praktikal dan metodologi mengenai pengintegrasian isu-isu sosiosainifik dalam konteks ko-kurikulum telah dibincangkan.

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Table of Contents

Chapter 3 Methodology

Chapter 4 Findings

List of Figures

List of Tables

List of Symbols and Abbreviations

DOE	Department of Environment
GHG	Greenhouse Gasses
GO	Graphic Organiser
MKO	More Knowledgeable Other
PGO	Persuasive Graphic Organiser
SSI	Socioscientific Issues
ZPD	Zone of Proximal Development

List of Appendices

Chapter 1 Introduction

Background

Science may be hard to learn (Soh & Meerah, 2013) and may not be able to stand on its own to let students make the decisions which affect human lives and environment (Castano, 2008). The acquisition of science information throughout a student's life is dependent on the student's construction of understanding scientific knowledge and information. It is parallel with the empowerment of students as citizens; the recognition of science as an institution and the processes by which scientific knowledge is produced. Holbrook and Rannikmae (2009) emphasised two primary roots that should be viewed in defining scientific literacy which are "those that advocate a central role for the knowledge of science and those who see scientific literacy referring to a society usefulness" (p. 278). For this to happen, the relevance of science education must be scrutinised; the role of teaching materials, the struggle towards the enrichment of scientific literacy, the deep consideration on a societal frame, the introduction of science concept as a stimuli to know basis and to encircle the socioscientific situation that represents the relevance for the empowerment of responsible citizenship (Holbrook & Rannikmae, 2009).

However, the need for scientific literacy is not purely stagnant at the knowledge level and the relation of daily life usefulness. It takes a narrow space for integrating higher order thinking that appropriately blends science and social elements, hence enables the students to reflect on the underlying information on the issues (Zeidler, Sadler, Simmons, & Howes, 2005). Recent developments in the field of science education have led to a new interest in introducing socioscientific issues (SSI), the issues that possess a conceptual foundation in science, but consists of societal, political and ethical dimensions of human lives (Ekborg, Ideland, & Malberg, 2009). The SSI directly exposes students to view science in a realistic way, including knowledge and ethics in making a decision about societal issues related to science. The SSI is known as controversial in nature, requiring students to engage in informal discussions, debates, and argumentative thinking. It is considered as the main part in exposing students to utilise information in facing personal and societal relevant context (Zeidler, Sadler, Applebaum & Callahan 2009). There are a variety of social issues that have been integrated into socioscientific instructions such as animal transgenesis and stem cell matters that are compatible for students and promoting them in solving scientific problems, hence preparing students to use argumentative thinking (Reis & Galvão, 2009; Simonneaux, 2001).

If the goal of scientific literacy is to encourage students to understand complex scientific issues and make a decision according to their knowledge, then it is imperative to expose the students with SSI within an informal learning environment (Walker & Zeidler, 2007). A few studies have acknowledged that formal learning is necessary but not sufficient enough to support scientific literacy. Hence, it requires the additional demands of alternative learning environments and approaches (Falk, Storksdieck, & Dierking, 2007). Through the informal learning environment, students will be exposed to other meaningful ways of gaining knowledge that allows students to explain science in the appropriate angle. In conjunction with that, informal learning is believed to be able to strengthen the formal learning and assist students to learn and understand more (Braund & Reiss 2006).

Hofstein and Rosenfeld (1996) stated that “future research in science education should focus on how to effectively blend learning experiences in formal and informal learning in order to significantly enhance the learning of science" (p. 107). The present study undertakes to explore the integration of informal learning via a co-curricular context that can be used as a platform to increase students' science learning (Jarman, 2005). It is in line with the Malaysian co-curricular context, as a complementary medium of the curriculum in which it provides numerous opportunities for students to develop, measure and practice the skills, knowledge, and values gained from the classroom (BSSK, 2009).

The goal in working with SSI is to make science appropriate and usable outside the classroom. Therefore, students have the opportunity to engage themselves with community needs in a general discourse which comprises the science and social issues rather than focusing on a rigid science discourse. The use of informal discussions using SSI exposes students to the moral and ethical problems and diverging viewpoints, creating a richer experience for the students (Zeidler, Applebaum & Sadler, 2011; Zeidler et.al 2009). Thus, students are encouraged to get involved in socioscientific related activities to refine their knowledge while being a part of the community outside the school.

Co-Curriculum in Malaysian Education Context

The National Curriculum is an educational programme consisting of curricular and co-curricular activities which encompass all aspects of knowledge, skills, norms, values, cultural elements and beliefs to fully develop an individual with respect to the physical, spiritual, mental and emotional and instil moral values. Co-curriculum is precisely linkable and well known as a complementary medium of the curriculum in which it provides numerous opportunities for students to develop, measure and practise the skills, knowledge, and values gained from the classroom (MOE, 2009).

Initially, co-curriculum in Malaysia is defined as 'group activities' or '*kegiatan kumpulan*' (Warta Kerajaan, 1967). The definition has been changed to the form of study which occurs outside of the classroom within an informal learning environment (DBP, 1984). After that, it has been acknowledged as programmes or activities conducted out of the classroom, but it is a part of the formal curriculum (DBP, 2002).

The objectives of co-curriculum are parallel with the National Philosophy of Education which is an ongoing effort towards the further development of the potential of individuals in a holistic and integrated manner, so as to produce individuals who are intellectually, spiritually, emotionally and physically balanced and harmonious. Thus, the implementation of the co-curricular activities may indirectly aid in achieving the goal of National Philosophy of Education (MOE, 2007).

This philosophy is a guide for all educational activities that clearly expresses the purposes, goals, principles and values that underlie the basic form of the Malaysian education system. To achieve the aspiration, the school organisation has the authority in forming activity clubs related to the available subjects offered in that particular school as stated in *Peraturan-Peraturan Pendidikan Kurikulum Kebangsaan 1997* (Akta Pendidikan, 1996). Such efforts are designed to produce Malaysian citizens who are knowledgeable and competent, who possess high moral standards and who are responsible and capable of achieving a high level of personal well-being as well as being able to contribute to the betterment of society and the nation at large (MOE, 2002 p.7). This National Philosophy of Education becomes the kernel and the root of national education system; as such, all of the educational programmes and activities are the reflections of the principles and values of the philosophy.

Contradictory to the philosophy above, informal learning via co-curriculum in schools seem to be underplayed. Burley (1990) emphasised that many students who are active in the co-curricular activities did not transfer and apply their experience in co-curriculum into formal curricular fields or vice versa. Therefore, co-curriculum in school should be acknowledged as a suitable medium for spreading knowledge and skill to make it inter-related to the formal curriculum. Hundal et al. (2014) and Jarman (2005) asserted that the co-curricular setting is strongly suggested to be an enrichment platform as this learning experience draws a continuum spanning from the formal to the informal in respect of assessment and curriculum.

It is important to note that the Ministry of Education (MOE) actively plays a major role in placing informal learning within the formal curriculum, hence supporting the formal curriculum. The exposure of informal activities via co-curriculum emphasise a particular potential upon informal learning, where it is only the process and not the outcome which becomes necessary. In 1996, the Informal Education team was formed within the Co-Curricular Activities Branch which was responsible for six states in Malaysia (Md Amin, 2011). It has helped and guided Malaysian schools to support the implementation of the informal learning as a supplement to the classroom learning. The ongoing collaboration between the MOE and other ministries or agencies such as the Ministry of Science, Technology and Innovation (MOSTI), the Department of Environment (DOE) and the Ministry of Health (MOH) seems to be an essential foundation in accordance to support informal education. However, until now, there is a lack of explicit structures and guidelines that can be utilised by school organisations emphasising on the integration of informal learning agencies and school content-related learning, especially within the co-curricular environment. Bozdogan and Yalcin (2009) stated that the strategic collaboration between schools and other organisations should be designed meaningfully, as an effort to optimise the contribution of this informal education institution and support formal learning in schools.

Parallel with this context of the present study, a systematic plan and coordination suggested in the literature review are integrated within informal science learning to make sure that informal learning via co-curriculum plays its role as a complement of formal learning. The integration of co-curricular learning into academic courses will improve out-of-class learning. This is the space for the exploration of how to enhance the quality intentionally as well as improve the impact and assessment of co-curricular learning context specifically. This atmosphere will reveal some values and surely its effectiveness could be realised as a supplement for formal learning. It will bring about a change and provide a new atmosphere for formal and informal learning to get synchronised together (Coombs, 1976; Rahmat, Sharil, Ahmad, Ishak, & Salimin, 2017; Zeldin, Krauss, Kim, Collura, & Abdullah, 2016). The support of informal learning via co-curricular activities are more likely to have a positive impact on students' understanding depending on the institution's educational purposes and values (Kuh, 2000).

Statement of the Problem

Science education has been an important part of the school setting in many countries across the world because it is regarded as an essential move in linking knowledge, skill and daily phenomena application (MOE, 2011). The United Nations Educational, Scientific, and Cultural Organization (UNESCO) recommends science to be taught in schools, as the teaching and learning have a direct influence on how students think logically about the daily phenomena and how they make decision to solve daily problems. This recommendation is parallel with the Malaysian context; particular concerns are given on the acquisition of scientific knowledge, mastery of scientific and thinking skills, inculcation of moral values concurring with the premise that man is entrusted with the responsibility of managing his own and daily social life. This goal will enable students to understand and appreciate the role of science and its application in everyday life together with moral and ethical values concerns (MOE, 2011).

However, the obvious lack in the science curriculum is the student's inadequate opportunities to apply science concepts and process skills they have learned to overcome the problems they encountered (Hughes, 2000). Hofstein, Eilks and Bybee (2011) emphasised that one common theme arising in the current reports regarding science education is about the content of formal science education and its related pedagogical approach, and this is poorly aligned with the requirements of students and society. In other words, there is a lack of relevancy, and the gap exists between what students are taught in the science classroom and what is happening in the real world (Dahlan, 2008; Wahibi, 2004). The capability of explaining daily life comprising scientific and social values requires sound knowledge and critical thinking such as arguing about specific socio-science-related content. Accordingly, science education has often been given fewer concerns on deriving formal socio-science constructs, building knowledge and engaging students via discussion (Leitao, 2000) and discourse within formal science classroom. Consequently, the majority of the students are ineffectual to participate in socioscientific discussions which comprise science and its relation to the daily application (Hofstein, Eilks, & Bybee, 2011). The circumvention of socioscientific discussion is highly contradicted with the concept of the ability to explain natural phenomena and everyday life as a hallmark of scientific understanding (Abrams & Southerland, 2001).

Assertions that SSI build an essential component of scientific literacy demands a further exploration on how these issues can be meaningfully incorporated into the science curriculum (American Academy for the Advancement of Science, 1993; Nuangchalerm, 2010; Siebert & Mcintosh, 2001). When encountering SSI, every decision a person makes could bring a large impact on his or her daily life and the environment (Grace, 2009; Spangenburg & Moser, 2006). Furthermore, working with the SSI is said to be a vehicle for promoting generic skills such as teamwork and problem-solving (Ratcliffe & Grace, 2003). Decision-making and argumentation are also the elements that can be contributed from working with SSI. Research has revealed that SSI can also challenge students' intellectual, social and emotional skills (Sadler, 2004). Specifically, the approach of using SSI could enrich a student's knowledge of critical thinking which is extremely required in connecting students to daily social life. By reviewing the international research conducted previously (Callahan, Zeidler, & Orasky, 2011; Chung, Yoo, Kim, Lee, & Zeidler, 2014; Jho, Yoon, & Kim, 2014; Keskin, Samanci, & Yaman, 2013), it is time to disclose this fundamental part in exposing students to interconnect science and daily life via SSI approach.

Unfortunately, an overcrowded secondary school's science curriculum often leaves little opportunity to argue, collaborate and communicate about specific science knowledge related to SSI in face-to-face classrooms (Levinson, 2006). The fact that a science classroom is a place where SSI can be posed as model activities for students face challenges in various concerns such as scientific knowledge, technological creativity, environmental situation and social concerns (Nuangchalerm, 2010; Zeidler et al., 2011). The previous findings indicated that students' understanding is naive (Khishfe, 2015; Walker & Zeidler, 2007), it also lacks the knowledge and employment of scientific-based lenses to frame a decision (Chang & Chiu 2008; Uskola et.al., 2010). Moreover, a previous study indicated that students fail to utilise and connect their science knowledge to draw their decisions (Zohar & Nemet, 2002).

Dealing with SSI confronts students with decision-making situations which require factual and ethical complexities (Sadler & Zeidler, 2005). Contrary to the routine of the decision process, students have to engage with argumentation or diversified reasoning before reaching the actual preference. In other words, they have to generate options, evaluate relevant information and weigh the generated options to make a choice (Eggert & Bögeholz, 2010; Grace, 2009; Uskola, Maguregi, & Jimenez-Aleixandre, 2010).

Regarding decision-making skills, ideally, students must possess the ability to use 'trade-off', which is characterised by the capacity to consider and distinguish the advantages and disadvantages of the options taken. It can be described as a compensatory decision-making strategy where the students face the consideration zone of positive and negative aspects that can be compensated (Böttcher & Meisert, 2013). Contradictory from the characteristic above, Ractliffe (1997) demonstrated that students could distinguish the options given but failed to follow the systematic way of the decision-making process. In conjunction with this issue, the majority of the students did not apply the trade-offs for options comparison and only focused on a limited number of decision-making structures, hence establishing the option cut-offs through the elimination process (Hong & Chang, 2004). According to Jungerman (2004), this strategy is described as a non-compensatory strategy for decision-making. The failure of weighing the important criteria or approaching a non-compensatory strategy in a decision-making situation leads to the difficulties for students in general (Böttcher & Meisert, 2013; Eggert & Bögeholz, 2010). These situations have become conflicting values that need to be addressed (Grace, 2009; Jime´nez-Aleixandre, 2002).

It is imperative to mention that the common use of questionnaires and persuasive essays in decision-making assessments revealed that students are facing difficulties in visualising the structural complexity and in sequencing persuasive ideas to make a decision related to SSI (Jho et al., 2014; Zohar & Nemet, 2002). Instead of contributing useful ideas, students are unable to make a clear decision about the issues and failed to reach a final determination (Grace, 2009). Aikenhead (1985) pointed out that this is not necessarily a problematic issue and highlighted that the quality of the decision-making process is more important than the quality of the decision itself.

Considering the aforementioned problematic area in making decisions, this current study considers that teaching strategies about multifaceted issues should be directed to promoting students' understanding of the nature of the decision-making processes and to the consolidation of skills needed in each phase of the process (Böttcher & Meisert, 2013; Hong & Chang, 2004). Bottcher and Meisert (2011) added that the indirect instruction of decision-making skills especially for SSIs must not be undervalued and it significantly influenced students to foster decision-making skills.

Therefore, the visualisation method on the structure of decision-making is pertinent to explore the students' performance accompanied by the understanding of the processes that precede a decision. The socioscientific tasks would be sophisticated if the students are given clear visualisation and framework about the structural complexity that needs to be considered in the decision-making process (Grace, 2009; Ratcliffe, 1997; Uskola et al., 2010).

Engaging students to connect science in a meaningful way through formal learning experiences with socioscientific understanding and decision-making has become a big challenge in science education (Grace, 2009; Jho et al., 2014). Teachers are always making a judgement on how well a student's response aligns with the textbook's answer because it is simpler to compare an idea on a textbook's answer than to analyse the reasoning that supports the ideas (Russ, Coffey, Hammer, & Hutchison, 2009). The stagnant styles of gaining knowledge are not appropriate in conducting SSI-based education because it requires a dynamic learning style and experience for every issue that requires justifications. Encouraging the integration of thinking skills in the classroom instruction is required so students will not rely on the textbook's answer. With that, there is much need to explore students' experiences that occur outside the classroom which correlates with developing understanding socioscientific based-issues holistically. A different learning environment such as informal learning can be a good way in developing students to gain certain outcomes that cannot be readily achieved in the formal learning environment. Such intellectual and scientific skills are stagnantly nurtured at formal settings; it would be valuable if the students are exposed to the informal setting as this science setting could informally foster students' understanding and decision-making, being well-equipped with meeting socioscientific requirements (UNESCO, 2010). However, informal learning is not strongly related to the knowledge platform in facilitating learning (Falk & Storksdieck, 2010).

Livingstone (1999) pointed out that informal learning can be defined as "any activity involving the pursuit of understanding, knowledge or skill which occurs outside the curricula of educational institutions, or the courses or workshops offered by educational or social agencies" (p.2). The category of informal learning includes all learning that occurs outside of the curriculum of formal and non-formal educational institutions and programmes. Referring to the above definition, working with students outside the classroom through co-curricular clubs activities are considered as informal learning in schools. However, informal learning option through co-curricular activities tends to be underplayed (Burley, 1990; Jarman, 2005). Burley (1990) added that this informal learning environment provides abundant opportunities in introducing core concepts of specific scientific issues through appropriate and well-designed activities.

Co-curriculum in Malaysian context is a complementary medium of the curriculum in which it provides numerous opportunities for students to develop, measure and practise the skills, knowledge, and values gained from the classroom. Regrettably, the co-curriculum that involves informal learning activities is mainly restricted to relating science to the social medium and to develop a practical science activity already undertaken in the classroom (Griffin & Symington, 1997; Pereira, Ismail, & Othman, 2013; Zeldin et al., 2016).

From my experience of twelve years in teaching, there were no organised activities related to SSI prompted in an informal learning setting. Taking a co-curricular activity as an example, the routine is likely to let students stand alone and participate in the activities designed by the teacher. The designed activities are plain with no connection to what students have experienced in the formal classroom. It is also rarely evaluated whether the activities within the co-curricular context contributes to the scientific knowledge and the skills gained by the students. The above mentioned phenomena is also acknowledged by the Co-Curricular and Arts Division, Ministry of Education Malaysia, as there are no specific outcomes and guideline that have been documented specifically for the co-academic category (MOE, 2009, 2016). Ideally, co-curricular must be viewed as a paradigm that possesses a significant potential to support formal learning (Winter & Cotton, 2012) especially in enhancing students' learning effectiveness and providing positive effects on the academic performance (Leung, Chan, & Ng, 2011; Paul & Baskey, 2012).

Previous research has clearly demonstrated that informal learning programmes through co-curricular activities benefit the students as a whole, specifically in assisting students to gain new knowledge and skills (Manaf & Fauzee, 2002). It has also been observed that co-curricular activities help reduce academic stress and tension, helping students to become more alert and productive in their learning (Arip & Yusof, 2002; Jamalis & Omar Fauzee, 2007). Students who are productive will indirectly have a better thinking skill and directly able to interpret the knowledge in science, technology, and social context. A well-planned informal learning through co-curricular activities can develop positive outcomes in scientific knowledge and skills.

The SSI coupled with informal learning experiences have the ability to create scientifically literate citizens by enhancing students' understanding of how science works outside of the classroom. Placing emphasis on the quality of educational experience leads to the improvement of life quality in our society (Zeidler & Sadler, 2009). If the aim of scientific literacy is about the understanding of complex scientific issues and decision according to their knowledge, then it means that they are influenced by SSI within informal learning circumstances (Walker & Zeidler, 2007).

It is imperative to note that most studies in an informal learning environment have been focusing on the use of museum and science centre exhibits as aids in learning science. However, very few have been looking at the co-curricular context particularly about its potentials as a learning platform (Burley, 1990; Jarman, 2005) and its translation of students' understanding especially in the SSI area (DeWitt & Hohenstein, 2010). Parallel with these issues, the co-curriculum in Malaysia possesses inadequate structure and guidelines, limiting its proper implementation, development, and significance and avoid any desirable contact especially in science learning (Pereira et al., 2013). Pereira, et.al (2013) highlight that the lack of structure and guideline of the co-curricular setting involves the corpora of relevancy, time frame, applicability, the presence of an important person and challenging on-going activities.

Since there are less organised and systematic activities within the co-curricular context, the skills of gaining knowledge towards making a decision which incorporated SSI should be included in the frame of a research. It is important to note here that there is a lack of research investigating the use of SSI within the informal setting via co-curricular meetings. The following Figure 1.1 illustrates a conceptualising framework which frames this study. The conceptualising framework is derived from the appropriate literatures ranging from the fields of SSI, learning environment, learning theory and model.

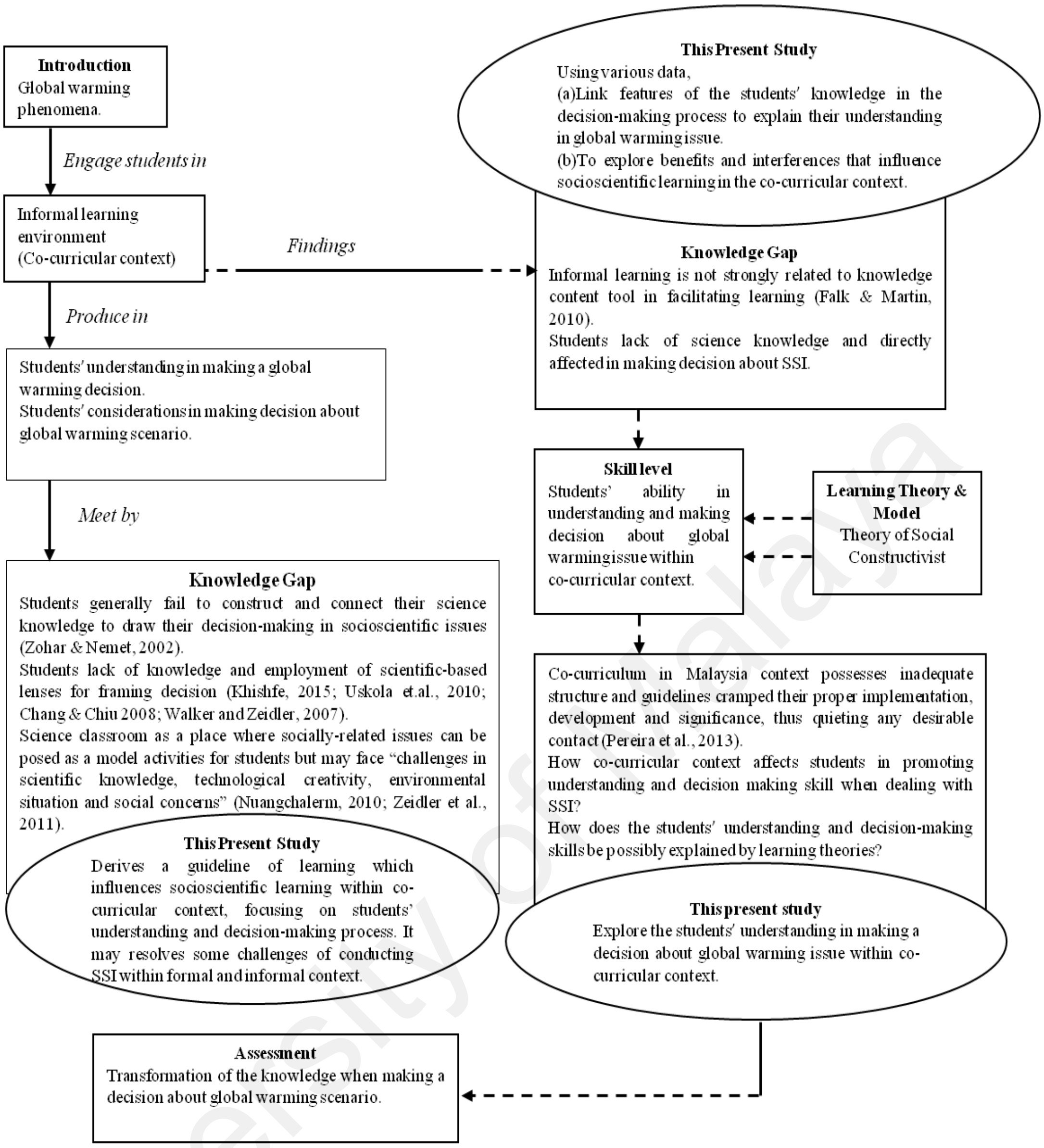


Figure 1.1. Conceptualising framework of the present study

Therefore, the present study attempts to focus on exploring students' understanding in making decisions on a socioscientific issue of global warming within a co-curricular context. This study also tries to develop a visualised method namely Persuasive Graphic Organizer (PGO) to assist students' learning as they are dealing with the controversial issue.

Objectives of the Study

This research focus is concentrated on three overarching and interconnected objectives:

1. To investigate the students' understanding of the global warming issue within the co-curricular context.
2. To investigate the students' considerations when making a decision about the global warming issue within the co-curricular context.
3. To determine the factors for conducting SSI within the co-curricular context which influence students' understanding in making a decision about the global warming issue.

Research Questions

Specifically, this study is designed to answer these main research questions:

1. What is the students' understanding of the global warming issue conducted within the co-curricular context?
2. What are the students' considerations in making a decision on the global warming issue conducted within the co-curricular context?
3. While conducting SSI within the co-curricular context, what are the factors and how do these factors influence students' understanding in making decision about the global warming issue?

Significance of the Study

The present study attempts to contribute the potential for the practical and methodological significance within the field, not only informal science education but formal science education as well. It contributes the framework for the designed quality programmes conducted within the co-curricular setting as a relevant way to promote students' understanding and decision-making skills, particularly in the reflection of SSI. This study contributes to the existing body of knowledge and experience concerning controversial SSI. The present study has a view of making available to students, teachers, administrators and policy makers the information which would enable them to implement systematic activities within the co-curricular context, as well as utilise effective educational opportunities offered by informal learning platforms.

Integrating socioscientific case-based issues that could be used during the science co-curricular experience is the primary practical outcome, particularly in reducing the gap present between the formal classroom and the informal environment through the co-curricular context. By investigating students' learning as they engage with SSI conducted in the informal learning environment and with their perception of the co-curricular programmes as learning programmes, the findings may shed some light onto the co-curricular activities as a platform for learning. Theoretically, this exposure enables students to relate old and new scientific knowledge, leading to knowledge map construction (Vygotsky, 1967).

To date, there are limited studies conducted in Malaysia in providing opportunities for students to learn about SSI, particularly within the co-curricular platform. This strategy enables teachers to reflect on how students construct their understanding and developing decision-making skills when dealing with SSI. To be specific, this present study attempts to provide a relevant and linkable content-related learning between the existing formal curriculum (Foong & Daniel, 2013; Heng, Surif, & Seng, 2015) and co-curriculum, focusing on translating students' understanding in making a socioscientific decision.

The incorporation of SSI enables the students to think and become concerned about the significances of using relevant knowledge in making the decision to these problems. This research offers the potential on how students draw their understanding and make a decision to an ill-structured issue, particularly regarding global warming. The importance of socioscientific integration has been proved effective in contributing the development in critical thinking (Zeidler et al., 2005; Zohar & Nemet, 2002), parallel with the current Malaysian science curriculum's emphasis on the importance of higher order thinking skills in the teaching and learning of science in Malaysian classrooms.

Regarding methodological significance, this study may benefit teachers and students in utilising the Persuasive Graphic Organiser (PGO) which is developed to tackle students' understanding as well as decision-making skills when dealing with socioscientific tasks. The use of the PGO template may also be applied on other subjects that require persuasive ideas in the teaching and learning tasks.

Importantly, the integration of SSI in the co-curricular context implies the cross-cutting concepts in the global framework of science education (K-12) by addressing related topics at any particular grade level without any explicit prior knowledge and instruction. As such,it is considered timely to consider that science can also be learned outside of the formal classroom. These significances are in line with the suggestion of "rather than relying on a single-hulled vessel, the metaphor change to that of a catamaran: the twin hulls of the formal and the informal platforms contributing what they do best to move science education forward" (Stocklmayer, Rennie, & Gilbert, 2010).

Limitations of the Study

This study is confined with its own limitations. The employment of qualitative criterion involves the small sample size, thus, the findings are not intended to be generalised to individuals or site. In fact, the essentiality of this research is to explore an in-depth understanding of the process in which students experience socioscientific learning within the co-curricular context.

Limitations are also recognised in the learning environment. Due to the nature of informal learning environment, it should be reaffirmed that I hold the perspective that learning is often gradual, incremental and assimilative in nature. Accordingly, learning science in a casual setting occurs not only within this co-curricular setting but it is also dynamically interpreted in the subsequent life experience of days, weeks, months and years after the experience (Griffin & Symington, 1997).

The involvement of informal learning education from DOE leads the lower secondary school students to break down the complex frames to make a decision on the global warming aspect scenario. Thus, it is likely that the data obtained from this study might only be applicable to this topic and similar groups and thus the data may not be generalised.

Finally, this study is only focused on the students' understanding in making a decision on the global warming issue within a co-curricular context. The global warming issue is selected as a controversial issue because it is recognised as an "environmental health' problem which is connected to the secondary level students and linkable to the formal curricular. Importantly, the choice of global warming issue is compatible with the Malaysian Form One and Form Two science curriculum (Table 1.1 and Table 1.2).

Table 1.1

Themes and Learning Areas in the Malaysian Form One Science Curriculum

Theme	Learning Area	Relevant Socioscientific Issues
Introducing Science	Introduction to science	Not found
Man and The Variety of Living Things	Cell as a unit of life	Not found
Matter in Nature	Matter	Not found
	The variety of resources on earth	Not found
	The air around us	Air Pollution Health
Energy	Sources of energy Heat	Not found

Table 1.2

Themes and Learning Areas in the Malaysian Form Two Science Curriculum

Theme	Learning Area	Relevant Socioscientific Issues
Management and Continuity of Life	The world through our senses	Not found
	Nutrition	Health
Man and the Variety of Living Things	Biodiversity	Not found
	Interdependence among living organisms and the environment	Not found
Matter in Nature	Water and Solution	Water Pollution Health
	Air pressure	Not found
Force and Motion	Dynamics Support and moment	Not found Not found

The incorporation of these contexts (environment and health) that surround global warming is significant as it enables to the creation of a frame for some of these concepts to be applied at the present time and in the future. The use of ‘contexts’ is a fundamental area for the topic, and therefore concept and choice (Gilbert, 2006) circumnavigates the controversy between the separate topics and enables some of these issues to be addressed. In this framework of the study, the above mentioned limitations are set. Thereby, other problems or issues beyond this frame of study are not taken into reflection in the research findings.

Definition of Terms

There are some definitions that need to be clarified to avoid any perplexity in understanding the context of the present study. The terms used in this study are:

Socioscientific issues (SSI). The SSI is usually controversial in nature but has an added element requiring a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at a decision (Dolan, Nichols, & Zeidler, 2009). The decision-making made by students could involve human life and environment beyond an expected extent (Dawson & Venville, 2009). In this context of the study, the global warming issue is deemed to be appropriate for discussions among the lower secondary students (Form 1 and Form 2).

Informal learning. Informal learning is a complementary and reinforcement of learning gained from the formal curricular and it can be transformative and additive (Burley, 1990). Informal learning is also recognized as any activity that occurs in the formal environment or outside the classroom environment via informal ways. In this framework of the study, informal learning is conducted within the co-curricular setting through the Science and Mathematics Society involving students from different ages, gender and grade levels. It is in line with the Malaysian context by acknowledging the co-curricular activities as the platform to develop relevant knowledge and skills outside the classroom.

Co-curricular context. The co-curricular context is a complementary medium in which it provides numerous opportunities for students to develop, measure and practise the skills, knowledge and values gained from the formal classroom (MOE, 2007).

Experience. Experience is knowledge or mastery that the lower secondary school students gain through their involvement in socioscientific instruction within the co-curricular context. In this particular study, the socioscientific instruction is integrated with four activities pertaining to the global warming issue. The activities include the introduction phase, reading posters and internet exploration, science talk and closure phase.

Understanding. Understanding can be conceptualised as the ability of students to appropriately reason, relate and connect content knowledge in making the meaning of the SSI such as global warming (Klosterman & Sadler, 2010). It includes the content knowledge of global warming. This study explores the students' understanding based on the global warming scenario entitle 'Global Warming: A Silent Killer'.

Socioscientific decision-making. A socioscientific decision-making typically confronts students with science, moral and ethically complex issues (Zeidler, Applebaum & Sadler, 2011), requiring them to generate options, develop criteria, clarify the information evaluate the options, making choices and reviewing the decision-making process (Ratcliffe, 1997). In this particular study, I have developed a visualisation tool for decision-making consolidated on the seven elements of the decision-making structure namely the PGO. This was done due to the students' inability in visualising the structural complexities when dealing with socioscientific decision-making (Grace, 2009; Jime´nez-Aleixandre, 2002; Ratcliffe, 1997).

Persuasive Graphic Organiser (PGO). The PGO is a visualised decision-making method that has been developed by the researcher aimed at assisting students in monitoring their decision-making process. It can be utilised to represent organised knowledge and information when making a socioscientific decision. The

PGO layout contains two components, namely the ‘scenario’ and the ‘decision-making graphical organiser’ (refer Appendix D).

Decision-making considerations. In this research, the decision-making consideration is defined as a careful thought that induces students to enter into the final decision. It goes beyond content knowledge but still confined within the relevancy of the global warming scenario presented.

Chapter Summary

This chapter has outlined the potential of integrating socioscientific issue within the co-curricular context. The major educational problem is that students are given less opportunities to learn and make decisions on the SSI due to several constraints in the formal classroom. This challenges may indicate that students are often reluctant to deal with SSI within the formal and conventional science pedagogy. Therefore, the co-curricular platform is used as a complementary in learning SSI. The rationale for choosing the co-curricular context has touched on the “less-explored” context of learning, especially for SSI.

For the present study, I have suggested how this problem could be minimised. Accordingly, the research objectives, significances, and limitations of the study have been put forward. Towards the end, this chapter has stressed the detailed definition of terms used in this research.

Chapter 2 Literature Review

Introduction

The purpose of this study is to explore students' understanding in making a decision about SSI within the co-curricular context. This study was guided by the following research questions: (1) What is the students' understanding of the global warming issue conducted within the co-curricular context?, (2) What are the students' considerations when making a decision on the global warming issue conducted within the co-curricular context?, and (3) While conducting SSI within the co-curricular context, what are the factors and how do these factors influence students' understanding in making decision about the global warming issue? This chapter reviews previous research on the SSI particularly in students' understanding in the decision-making domain, learning environments, methodological aspects and related learning theories. Figure 2.1 demonstrates the outline of literature review, which navigates further understanding about the frame of this present study.

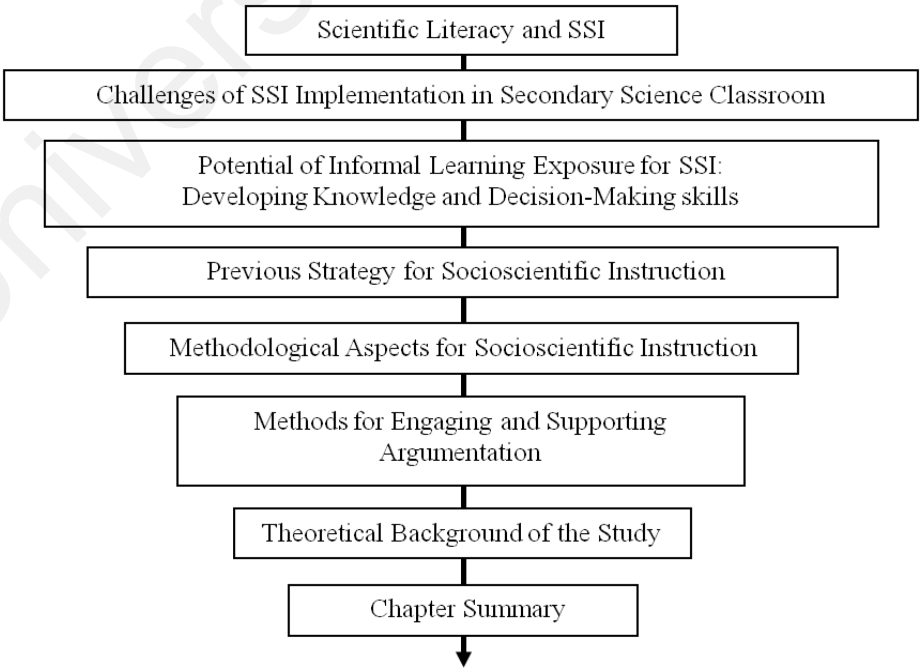


Figure 2.1. Outline of the Literature Review

Scientific Literacy and Socioscientific Issues

The development of scientifically literate citizens is about the willingness of the individual to engage in science-related issues, capable in applying scientific ideas and making a conclusion about scientific issues (Sadler, 2004; Tytler, 2007). This development is in line with a new trend in current science education which encourages the well-crafted inclusion of SSI in order to promote a functional scientific literacy (Zeidler et al., 2005). The SSI movement primarily emphasises on empowering students to be rational in connecting science-based issues and the decisions made, requires them to focus and reflect on the moral principles and the qualities of their lives, as well as the physical and social worlds around them (Zeidler et al., 2005). Ratcliffe and Grace (2003) have described SSI as the controversial issues that possess a basic in science and have a potentially large impact on society. It comes to the main vision of SSI education as one of the pedagogic approaches to engage the students actively with the construction of moral judgements regarding scientific issues via social interaction and discourse.

Zeidler, Sadler, Simon and Howes (2005) have identified an overview of four pedagogical frameworks that should be presented in order to conduct research relevant to socioscientific exploration in the context of science education. The four pedagogical issues include 1) the nature of science issues 2) classroom discourse issues 3) cultural issues and 4) case-based issues. These four issues provide a tentative thematic understanding for its foundation and interdependent, linkable to each domain of SSI. Figure 2.2 illustrates the socioscientific elements of functional scientific literacy.

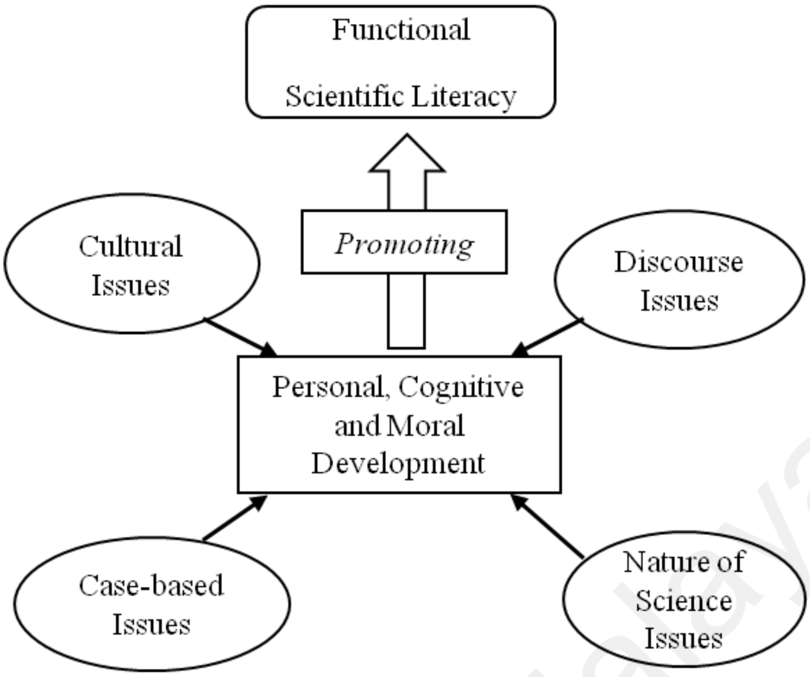


Figure 2.2. Socioscientific elements for functional scientific literacy
(Reference: Zeidler et al. (2005))

In general, these issues can be categorised as an entry point for science curriculum, which can promote students' personal cognitive and moral development; hence, it acknowledges science education in promoting functional scientific literacy. "An individual who achieves functional scientific literacy, therefore, is one who possesses command of a science lexicon, and also be able to converse, read and write coherently, using such science terms in perhaps a non-technical but nevertheless meaningful context" (Shamos, 1995 p.8).

By working with socioscientific context, students will develop critical thinking such as reasoning, arguing and the ability to discuss particular science issues that are needed when they have to make choices and take standpoints in daily life (Zohar & Nemet, 2002). This teaching approach is pointed out as a medium to encourage students to use basic knowledge of science in overcoming societal problems (Sjoberg, Svein, & Schreiner, 2005). The exposure of engaging students with SSI involves students' skills in scientific reasoning and analysing the relevance and validity of information and evidence. This learning process is aimed to provide students with a space to develop their understanding in various factors affecting the issues. The discussions of SSI provide healthy experiences for students to share their different viewpoints of moral and ethical issues connected to science (Zeidler et al., 2011).

The involvement of conflict in the issues discussed reveals the different personal views and understandings among the students. Students will indirectly become concerned on certain issues and it is admitted that SSI can be recognised as a means to provide communities of practices (Lave & Wenger, 1991). To become communities of practices, students should be exposed to opportunities to openly discuss a specific issue in a professional way. It is one of the practices which focus on the view that science is driven by debate and disagreement, and therefore it is a foundational part of learning science (Simonneaux, 2001). This offers the students to take a critical approach to reason and argue about scientific issues intellectually.

Argumentation is essential in decision-making process; it has been identified as a ‘core epistemic practice’ of science and should be applied in scientific discourse in order to master a specific scientific concept (Bricker & Bell, 2008). Furthermore, students must be familiar with the general skills of how to engage in scientific discourse accordingly. This exposure will assist students in developing their understanding; at the same time enrich their experiences about dealing with SSI. From the above explanation, there is a connecting power which exists between SSI and scientific literacy, hence this is the time to overcome some challenges of implementing it in science classroom learning.

Informal Learning via Co-curricular: A Place in the School Curriculum

People's perceptions of informal learning may vary broadly. Informal learning can exist in schools with varying intention and context (Burley, 1990). It provides a significant contribution to the curricular development and it depends on the informal method and contexts used. Integrating informal learning into formal curriculum offers schools the space to inject more relevant knowledge, skills and values within the existing formal curriculum.

Informal learning is a complementary to and a reinforcement of learning gained from the formal curriculum, which can be transformative and additive (Burley, 1990). Transformative learning refers to a comprehensive and complex description of how learners construct, validate and reformulate the process of meaning-making through their experience. Additive learning is defined as an addition to knowledge, skills and the development of values that alter, improve and strengthen the existing components respectively. Simultaneously, it refers to the learning experiences that radically change the existing knowledge and approaches, thus encourages the students to challenge their assumptions. In other words, informal learning can also occur in the regular school curriculum via informal ways. The simple analogy that can represent the condition is like one student realising that he is learning Mathematics (knowledge 'A') through formal curricular, without realising that he is learning discourse skills (knowledge 'B').

Combining informal learning within the mainstream curriculum offers a variety of responses and outcomes. Burley (1990) added that informal learning would provide new opportunities for students to get closer and work with them from different ages across curricular boundaries. This significant extension gives way for students to construct knowledge, hence strengthening understanding through the greater fulfilment of the activities given. Furthermore, the informal learning setting builds up the character of students to be a self-directed learner. It makes them feel recognised for their effort in controlling their pace as well as the learning process. It can be recognised as a catalyst where it is a platform to gain more of everyday experience. The platform offers the students to try a new thing and enrich their experiences beyond the stagnant environment of the formal classroom.

Co-curricular or after-school programs are prevalent across the world, but there is a paucity of research that examines quality within the setting of learning platforms (Zeldin et al., 2016) especially for science education (Birmingham & Calabrese Barton, 2014). Jarman (2005) has investigated an informal learning environment through understudied contexts for science learning through scouting. This study explored the informal learning field, by examining ten scouts in the United Kingdom. The methods that were undertaken in this study involved in-depth interviews, email survey and students' unscripted role play. The results revealed that the students' responses were related to cognitive and affective domains. The students were able to recall their prior knowledge when it comes to the topic already taught in the formal classroom. The ability to illustrate the knowledge from formal learning is possibly taking place. Indeed, some of the students revealed that their conceptual understandings became exclusive to their Scout experiences and remained memorable over a considerable amount of time. The evidence derived from this study offers wide opportunities for young people to learn science through the co-curricular context. Hundal, Levin and Keselman (2014) and Jarman (2005) asserted that informal learning through co-curricular setting is strongly suggested as an enrichment platform as this learning experience has drawn a continuous spanning from the formal to the informal context in respect of assessment and curriculum.

There are some recent studies related to co-curricular programs in Malaysian context; however, there are no specific studies which relate co-curricular and SSI. For instance, a higher education study conducted by Rahmat, et., al (2017) aimed at identifying the role of co-curricular courses for the Bachelor of Education students (n = 881) of Sultan Idris Education University. The quantitative research design was used and the findings showed that the co-curricular courses were very beneficial to the students in guiding them to implement co-curricular activities during the teaching practice in schools. Nevertheless, the practitioners should always be ready to provide beneficial courses, experienced educators, sufficient facilities and teaching aids to achieve the intended purposes.

Zeldin, et., al (2016) carried out a study on youth-adult partnership (207 youth aged 15-17) in Malaysian after-school, co-curricular programs. The study examined hypothesized pathways between the experience of youth-adult partnership (youth voice in decision-making; supportive adult relationships), the mediators of program safety and engagement, and the developmental outcomes of youth empowerment (leadership competence, policy control) and community connectedness (community connections, school attachment). The general findings indicated that the two core components of youth which are the adult partnership-youth voice and supportive adult relationships, may operate through different, yet complementary, pathways of program quality to predict developmental outcomes. For reasons of youth development and youth rights, the immediate challenge is to create opportunities for youth to speak on issues of the program concerned and to elevate those students who are able and willing to help youth exercise their voice.

Challenges in SSI Implementation in Secondary Science Classrooms

This subsection addresses the challenges in implementing SSI-based instructions in the secondary school's science classrooms. Teachers and students have been introduced to several numbers of problems when dealing with SSI issues in their classrooms. The dynamics of SSI-based instructions in science education seem to challenge the usual science classroom routines. It has been proven, when such controversial issues are introduced, teachers and students are becoming reluctant and know the difficulties and uncertainties in their classroom strategy (Zeidler et al., 2011).

The SSI-based education is often circumvented within formal science pedagogy because it requires students and teachers to critically examine the issues beyond the formal science content (Hughes, 2000). For instance, if the teacher intends to explore about human cloning, he or she is not confined to teach the scientific knowledge primarily but must consider the impact of health, social, economic and environmental aspects of the issues. In other words, teaching SSI-based subjects needs a wider interdisciplinary view, where the inclusion of scientific and social aspects must be acknowledged and discussed.

Simonneaux (2007) has pointed out that many teachers are reluctant to conduct a discourse or informal discussion dealing with SSI because it forces them to try new things beyond their comfort zone. This indicated that the teachers had an average level of knowledge and practices on SSI (Yakob, Yunus, & May, 2015). Thus, they are accustomed to the traditional way of learning science, which deals with the memorisation of facts and theory (Hodson, 2003) rather than connecting science knowledge with daily life issues. Introducing activities that need argumentation into science learning become a signal for teachers to believe in the essentials of discourse as a medium of spreading science knowledge (Kuhn, 2010). However, there are some perspectives from the teachers who work on SSI; they tend to keep their old habits, act as dispensers of knowledge and to deliver science content as facts (Ratcliffe & Grace 2003). Also, they seem to practise their socioscientific assignment like teaching scientific facts (Ekborg, Nyström, & Ottander 2009).

This situation directly contributes difficulties for students when learning with SSI-based instructions. It may also be caused by the infrequent practices of connecting knowledge for making a decision about SSI in the classroom. Students easily feel distracted when working with SSI as the answer is often not clear (Zeidler et al., 2005). Thus, there is an appropriate action to integrate SSI in science learning to ensure that students would be able to relate science and SSI (Dawson, 2015; Sadler & Zeidler, 2005).

Hughes (2000) has highlighted that the incorporation of SSI gives rise to the perception of science as 'soft science', while the science with no social problem aspect is often considered as 'hard science'. This perception of 'hard science' remains unbeatable and it indirectly forms a barrier and challenges the students' opportunity to discuss, debate, reason and make a new decision regarding socially-related issues in science (Simms, 2011). This situation is parallel with my teaching experience where students have failed to make the connection between scientific knowledge and social issues when they are required to deal with application questions.

An over-crowded curricular content and having large class sizes are some of the challenges encountered by secondary school teachers who are adopting classroom discourse as an approach to teaching science (Hughes, 2000). Large class sizes restrict the students from communicating and speaking their opinions. It minimises the opportunity for the students to discuss and exchange their views even though they have been encouraged by the teacher to do so (Levinson, 2006). The difficulties discussed above are in line with Levinson (2006) who has stated that there are common reasons why SSI is challenging: lack of interest and motivation, confusion about the importance of this matter and irrelevance of connecting school context with the issue happening in the outside world.

These challenges may give negative impacts on teachers and students as a whole. Reis and Galvao (2009) has suggested that the implementation of SSI-based education must consider the professional development opportunities where teachers need new guides, experience and approaches under an expert's supervision. Furthermore, the teaching and learning approaches must not be restricted to formal learning that follows the school syllabus, but it requires more synergistic assistance from various sources of knowledge. Therefore, the current study attempts to explore the influence of co-curricular platform in promoting socioscientific learning. The structural tensions and potential of learning SSI within informal learning via the co-curricular context may benefit students' learning particularly in the aspects of students' understanding and decision-making skills.

Potential of Informal Learning Exposure for Socioscientific Case-Based Issues: Developing Understanding and Decision-Making Skills

The potential value of using SSI to explore students' understanding and decision-making skills cannot be undervalued. Rose and Barton (2012) have demonstrated that students must be able to recognise the multi-dimensional matter and propose complex decisions in line with their knowledge and experiences gained. They have added that the acquisition of context knowledge and informal learning experiences are needed to maximise socioscientific learning.

The importance of informal exposure supports the consensus that learning science formally is not enough in producing well-equipped citizens to solve ill-structured problems (Nisbet & Scheufele, 2009; Sadler & Zeidler, 2009). It is because learning SSI goes beyond formal content knowledge which comprises science, technology and society with an addition of moral and ethical elements.

The importance of Science, Technology and Society (STS) has been stressed by Yager (2007) as follows:

> "Science, Technology and Society (STS) is superior in developing a better understanding and use of the skills used by scientists as they seek new understandings of the natural world. Furthermore, it results in more creative skills and more positive attitudes - which are sometimes called the two enabling domains". (Yager, 2007, p.390)

Unfortunately, STS issues contribute some problem when the curriculum is studying various issues that are not relevant or meaningful for students (e.g. nuclear power) because they are isolated from their daily personal experiences (Shamos, 1995). He also added that STS does not pay special attention to the ethical issues nor does consider the moral development of students. According to the post-modern analysis of reform curriculum, Hughes (2000) has acknowledged a few reasons why STS education is out of context with students; leaving them ill-prepared to deal with science and technological controversial issues. She has admitted that STS neglects the socioscientific materials, which directly permit students to develop values and characteristics within contextualised orientation.

Indeed, the Malaysian Ministry of Education (MOE) acknowledges the importance of contextual learning in the science curriculum as an approach of integrating science, technology and society, hence enhancing students' understanding and cognitive skills. It has been incorporated into the curriculum and suggests that contextual learning through investigation and discussion are the suitable alternatives that can take place (MOE, 2002). In the contextual approach such as socioscientific case-based issues, scientific knowledge is supposed to be learned with the application of scientific principles and technology and their impact on society. To note, the science curriculum has added SSI focus as a general expectation of National Science Education Philosophy. For instances, it reveals the importance of contextual learning as an approach that associates learning with daily experiences of students. In this way, students are able to appreciate the relevance of science learning on their lives.

Making connections between science and daily life provide the context for developing the related science process skills in science. In conjunction to develop understanding related to contextual learning, science process skills are simultaneously required in the process of making a decision in a systematic manner. It is a mental process that promotes critical, creative, analytical and systematic thinking. The mastery of science process skills and the possession of suitable attitudes and knowledge enable students to think effectively (MOE, 2011 p.7).

By exposing SSI into the informal learning environment, students are expected to engage in the real world of problem-solving. The knowledge and thinking strategy are brought into the particular atmosphere, which enables them to share ideas on how to make a decision about an issue. Figure 2.3 indicates the relationship between thinking skills and thinking strategy that is required in making a decision about SSI.

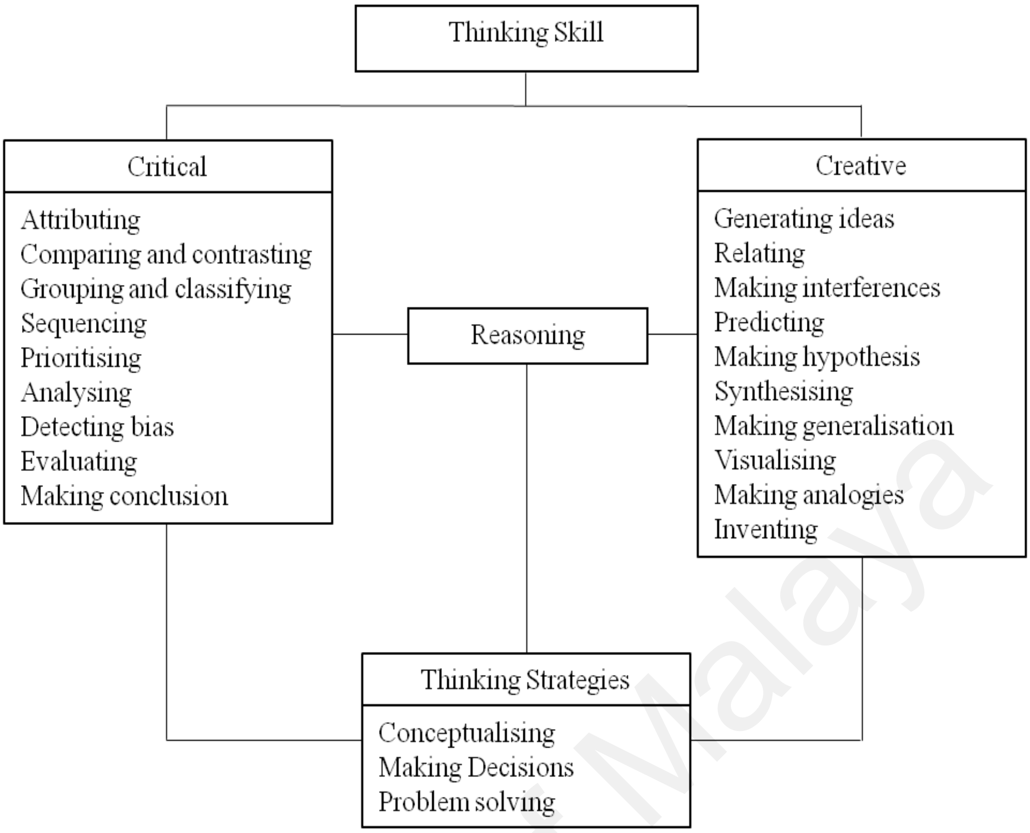


Figure 2.3. Relationship between thinking skills and thinking strategy

(Reference: TSTS Model, MOE (2002)

Integrating socioscientific case-based issues in the science curriculum may produce students capable of using multiple thinking strategies, which in turn develop the students' cognitive thinking skills. When dealing with these ill-structured issues, students will employ critical and creative thinking skills such as analysing, relating and evaluating before making a decision.

The use of SSI in science learning can provide students with cognitive thinking skills towards understanding the issues (Liu, Lin, & Tsai, 2011; Yager, 2007). Students are observed to be superior in using multiple processes skills, creative thinking skills and possess a potential in connecting ideas to different situations. In addition, students are identified as progressive in developing a better understanding of the history and nature of science. For instance, Yager (2007) found that there was a big difference when he compared the traditional classroom with the classroom that integrated STS in science learning. He consolidated the comparison and the details as the following:

> "Traditional classes resulted in practically no students questions; in contrast, STS classrooms were characterised as being structured by student questions. Furthermore, student questions outnumbered teacher questions. Student questions in the STS classrooms were 'higher level ones'". (Yager, 2007, p.388).

Students that have been exposed to socioscientific learning approaches develop a stable understanding in addition to other cognitive skills. The reality that students' questions outnumbered their teacher's responses indicates that the SSI stimulate their curiosity, thus further improving their cognitive skills in order to continue to explore the issues before making the decision.

Recent investigations related to the advantages of learning SSI has demonstrated that informal learning can enhance scientific understanding, promote critical thinking and active learning behaviours (Dolan et al., 2009; Hundal, Levin, & Keselman, 2014; Marrero & Mensah, 2011). A previous report has also indicated that the students showed progressive understanding towards the richness of science concepts and were able to integrate the multidimensional perspective in order to reach their decision related to their lives and the environments they encountered (Dolan et al., 2009).

Additionally, Marrero and Mensah (2010) have stated that students truly internalised the information learned during their study of the existing Signals of Spring (ACES) curriculum which involves hands-on informal learning, thus enabling them to make their personal and societal decisions easily. A recent study by Hundal et al. (2014) has also demonstrated that students must be encouraged to find the resources of SSI that can deepen their science understanding and enrich their critical thinking such as reasoning and decision-making skills.

In the context of the current research, students are exposed to deal with SSI within the co-curricular context. This research focuses on the global warming issue that integrates science and society problems. It is acknowledged as argumentative in nature, multidisciplinary and subjected to different perspectives. Surely, it demands students' collective social values as indicated by their sensitivity in adding social justice elements. There are no easy solutions for students to face the complex issue and make informed decisions related to such a topic. Yet, the values consideration, ethics and morality are acknowledged as the essentials in developing students' understanding and decision-making skills (Zeidler,& Sadler, 2008). Therefore, it demands extra strategies for socioscientific instructions.

Strategies and Contexts for Socioscientific Issues Instruction

Teaching and learning strategies are the most effective when they are applied in the positive environments where students' potential can be developed. The instructions for SSI in a well-known multidisciplinary context demands varying strategies including formal and informal learning exposure. In the past, a number of studies investigated the use of SSI within a formal learning environment (Callahan et al., 2011; Ideland, Malmberg, & Winberg, 2011; Jho et al., 2014; Keskin et al., 2013; Lewis & Leach, 2006). On the other hand, other studies have focused on informal learning environment as an approach to develop students' understanding and decision-making skills (Hundal et al., 2014; Rose & Barton, 2012). The next section discusses the details of strategies and contexts of formal and informal learning exposures used for socioscientific instructions.

Formal learning exposure. Lewis and Leach (2006) have demonstrated that the requisite basic scientific knowledge is relatively modest and can be taught effectively through teaching instructions that are well designed and contextualised. This study was conducted primarily in understanding the relationship between scientific knowledge or understanding and the ability to discuss genetic engineering among 200 school students aged 14-16, within the formal classroom environment. Overall, it indicated that the requirement of specific context knowledge is needed for individuals' understanding as a way for them to identify key scientific ideas. It also confirmed that the ability of students to engage in reasoned discussions depended on the specificity of the context knowledge, not only the content knowledge. In other words, students must not be restricted with content knowledge in the formal classroom learning, but require simultaneous additional exposure related to the context knowledge, especially when dealing with SSI.

Nuangchalerm and Kwuanthong (2010) have carried out a study to investigate the effective teaching criterion and effectiveness index of SSI instructions within a formal classroom setting. This study involved comparing analytical thinking of students before and after they went through SSI learning activities and how they discovered the learning satisfaction through SSI instructions. The findings indicated that SSI instruction possessed a high potential in comprehending knowledge. The use of SSI instructions within a formal classroom contributed to the cognitive development and learning satisfaction. However, the understanding of these outcomes is still inconclusive as the study was only conducted quantitatively using questionnaire without carrying out any in-depth investigations.

On the other hand, Uskola et al. (2010) conducted a study to understand the criteria constructed by the students while making a decision and the meanings that students construct their knowledge regarding environmental concepts. The participants comprised twenty-five university students with ages ranging from 18 – 23-years old. They engaged in a formal classroom discussion through an elective course of existing ‘Environmental and Informal Education’ in the social education degree education programme. In the knowledge construction aspects, students tended to use sustainability rather than renewable concepts and these concepts were dominant in considering their justification of option. Other than that, the rare use of this scientific concept indicates that the students lacked the knowledge and employment of scientific-based lenses to frame decision. Furthermore, students did not relate the decrement of resources to the economic impacts. The findings of oral discussions revealed that students used both explicit and implicit multiple criteria to support their options even though they are facing difficulty in demonstrating the disadvantages of the option chosen. In terms of the quality of decision-making, the students used a variety of criteria especially about environmental and sustainable concepts in explaining the meanings of knowledge construction. Seven categories emerged from the use of criteria of decision-making and these were in the ascending order: economic, pollution, pragmatism, resources, comfort, sustainability, and others.

A separate study by Klosterman and Sadler (2010) have explored the impact of socioscientific case based issues on students’ content knowledge conducted among 108 students from formal classes of Environmental and Chemistry Science. This three-week curricular intervention was conducted in two different schools from a south-eastern United States town. The data from the quantitative analysis (standards-aligned test and Curriculum-aligned test) revealed that the post-test scores were significantly different from the pre-test. On the other hand, the qualitative analysis indicates that students range from average, express more accurate, detailed and sophisticated understanding of the issues undertaken. The combination of quantitative and qualitative results proved that socioscientific case-based issues are an important approach in supporting students' understanding especially in the context of science education.

Another study conducted by Callahan et al., (2011) sought to explore the relationship between SSI and the students' understanding of nature of science conducted within a formal learning environment. This study proved that a semester long treatment that did not integrate explicit socioscientific instruction managed to increase some students' understanding. Some reasons interrupted the students' Nature of Science (NOS) understanding discussed in this paper. The researcher has emphasised that in order to integrate SSI in science learning, students must not be confined within formal learning as its characteristics and movement are about the open-endless, can be controversial in nature and surrounded by moral and ethical reasoning (Zeidler et al., 2005).

The characteristics of bioethics education, which are slightly similar to SSI, has become a medium in integrating SSI as the argumentation is based on science education. It also represents the knowledge cross-cutting concept, which requires the applications of ethical consensus. A recent study conducted by Keskin et al. (2013) used the existing Framework for Teaching Bioethics which had been implemented within the formal setting as a basic guide in tackling the ethical issues regarding Genetic Screening Tests (GST) and Genetically Modified Organisms (GMOs). The research questions were constructed to understand the relationship between the individual's content knowledge or understanding and argumentation quality, the significant effect of the framework on the individual's argumentation quality and the effect of the framework on the individual's decision-making about SSI. This study denoted that the formal learning with integrated SSI had improved students' understanding, questioning, knowledge researching, problem-solving and decision-making skills.

Jho, Yoon and Kim (2014) investigated the relationship of students' understanding of scientific knowledge, attitude and decision-making on SSI, focusing on the nuclear energy issues in Korea. The socioscientific instruction had been implemented in a formal classroom to stimulate students' science knowledge, attitude and decision-making about nuclear energy, a controversial issue in the current society. The results revealed that the students' science knowledge had significantly improved as well as their attitude and decision-making skills on the issues. Based on the relationship between the three domains, attitude had a significant relationship with decision-making whereas scientific knowledge had an insignificant relationship to decision-making.

According to the aforementioned research concerning SSI, informal exposure seems to be appropriate for socioscientific instruction. Lewis and Leach (2006) have emphasised that students must possess some experience to articulate their views within a science context. This goes beyond formal learning and content knowledge; thus it requires the inclusion of informal context knowledge that supports the development of students' ability to engage in reasoned discussions of such issues. Furthermore, the students' ability in articulating ideas about SSI must be based on relevancy and experiences which are linked to the understanding of the context undertaken (Lewis & Leach, 2006). Callahan, Brendon and Zeidler (2011) added that some reasons limit students' understanding, especially when dealing with these controversial issues. They stressed that students possessed the right to explore knowledge via informal learning exposure such as using information technology and build up group dynamics, particularly with the students who faced difficulty in basic concepts in the past.

Formal learning and informal learning exposure. Dolan, Nicols and Zeidler (2009) have conducted a research to investigate 5th grade students' experiences and understanding of scientific knowledge through the infusion of socioscientific case based-issues involving classroom and hands-on activities conducted outside of the classroom. Before implementing the SSI and activities in science learning, the instructor ensured that the students possessed a fundamental science concept that will be discussed. This blended approach combining formal and informal hands-on activities of advanced socioscientific instruction enhanced students' understanding of a scientific concept, directly provide a meaningful link between theoretical and practical exposure.

The study by Marrero and Mensah (2010) used the existing focused curriculum approach in teaching students in socioscientific decision-making. The method explores the way students engage in ocean literacy where it draws upon scientific concepts of the ocean when considering personal and societal decision related to it. The focused curriculum, ACES, comprising earth and ocean science, has become the core concept of ocean literacy. It combines formal classroom learning and outdoor activities as a supplement for students to maximise their learning. The outcome was a result contradictory to the previous literature where students were not fully dependent on their formal classroom learning when making decisions. The ability of students to apply scientific concepts in the given SSI revealed that they had connected their biological and physical sciences knowledge to complete societal decision-making tasks. According to the findings, the students were strongly empowered by the knowledge acquired through this informal activity from ACES curriculum and the infusion of SSI might be a helpful channel to help students to achieve ocean literacy.

The strategy of blending formal and informal learning exposure improves students' understanding in making a decision on SSI. The scientific and social dilemma contribute personal relevance and provide context, directly avoiding students' formal learning from being disconnected from their everyday experiences (Duit & Treagust, 1998).

Informal learning exposure. There are various components of informal science contexts that can be coordinated to maximise students' learning (Schugurensky, 2000). Interestingly, one study focusing on how two youths navigate SSI contributed a wide lens in understanding how students stabilise their understanding before making a decision (Rose & Barton, 2012). The study sought to understand the ways they navigate the complex issues including the resources they leveraged in defining the problem and the stances toward the issues. This study had focused on an after school club as a context for informal learning. The findings indicated that students had applied the knowledge gained from informal context, thus this contributed to the solid understanding before making a decision about the particular issue. However, their knowledge was deeply influenced by personal and public discourses when defining the issue that mattered to them.

When discussing environmental health issues, one particular study involved a group of four middle school teachers collaborating on co-designing an environmental health after school club curriculum that would facilitate students' understanding, their use of electronic resources and argumentation skill (Hundal et al., 2014b). These three objectives are well known as a core domain in navigating SSI. Results indicated that the SSI pertaining to environmental health was appropriate to the middle school students. It possessed a high potential to improve the understanding and argumentation skills during the after school programme. The after school club is claimed to be an important space for supporting formal learning as it is influenced by time, pressure and logistic constrains.

For further improvement, it is suggested that when posing SSI within an informal learning environment, students must view the issues as relevant to their daily lives, linkable to the existing curriculum (formal learning), vital for informed citizenship and able to stimulate their interest (Hundal et al., 2014b). This present study attempts to explore informal learning via a co-curricular context, providing relevant and linkable issues to the existing formal curricular. A summary of strategies and contexts for SSI instruction is shown in Table 2.1.

Table 2.1

Multiple Strategies and Contexts for SSI Instruction

Author	**Strategy** Formal Learning	Formal Learning and Informal Learning	Informal Learning
Lewis and Leach (2006)	Formal classroom		
Dolan et al. (2009)		Formal classroom and outdoor activities	
Marrero and Mensah (2010)		Formal classroom and outdoor activities	
Nuangchalerm, Prasart and Kwuantong (2010)	Formal classroom		
Uskola et al. (2010)	Formal classroom		
Klosterman and Sadler (2010)	Formal classroom		
Callahan et al. (2011)	Formal classroom		
Rose and Barton (2012)			After school club
Keskin et al. (2013)	Formal classroom		
Hundal et al. (2014)			After school club
Jho and Mijung (2014)	Formal classroom		
Dawson (2015)	Formal classroom		
Current study			Co-curricular context (Science & Mathematics Society)

Methodological Aspects of SSI Instruction

This section focuses on the methodological aspects of SSI instruction. The methodological aspects involve the description of research design, the selection of site and participants, the data collection techniques and the procedure that preceded previous studies.

A mixed method research conducted by Lewis and Leach (2006) was divided into two phases, aimed to investigate the role of formal scientific knowledge played in discussions. The researchers used questionnaire and interviews with questions prompts as the main evidence in answering the state of students' understanding. The first phase of the study was designed using paired and small group discussions and seven sets of questions covering a wide range of the issues on genetic engineering. The 60-minute task for the first phase indicated that students who worked in pairs had a limited understanding of scientific knowledge and had difficulties to engage in discussion. On the other hand, the students in small group discussion performed better and could identify key issues with the help of peers. During phase two, students were given 10 minutes of video show as additional information related to the issues and the findings exhibited an increase in students' understanding.

Dolan et al. (2009) selected a qualitative method by infusing three SSI involving earth, life and physical sciences. Instead of conducting formal classroom learning, students were instructed to do plenty of hands-on and inquiry-based activities. Debates and continuous dialogue were conducted to invoke students' understanding and critical thinking. These activities moved formal content knowledge and provided practice for science process skills. The data was collected through students' documents, debates and dialogues and analysed with qualitative analysis.

Marrero and Mensah (2010) also conducted a qualitative case study using focus group interviews, students' documents and decision-making task as sources of decision-making evidence. Two school visits with six full school days were conducted to understand how students handled the teaching and learning process on the existing curriculum in the northern California. The pre-interview was conducted initially with the aim to understand their prior knowledge including what they considered important and interesting about the sources they believed. For the post-interview, the researchers were trying to focus more on the students' personal behaviours, which they believed was important to achieve ocean literacy. The data were analysed using the constant comparative method where the data triangulation was used to comprehend the students' decision-making related to personal, societal and ocean literacy.

There was another study conducted in Asian region indicated that socioscientific issues-based instruction helps in promoting students' development in terms of cognitive abilities such as analytical thinking (Nuangchalerm & Kwuanthong, 2010). The study involved 24 5th grade Thai students learning global warming issues during the first semester of the 2009 academic year. The quantitative study comprised of 30 items in the achievement test, 30 items in the analytical thinking test and 15 item questionnaires on learning satisfactions.

Another qualitative case study by Uskola et al. (2010) focused on the process of completing argumentative tasks among three groups of university students when making a decision upon a heating system, confined on economic and ecological concepts. The case study took place in the four 90-minute discussion sessions that were audio-recorded. The first three discussions sessions lead students to work cooperatively in a small group and the last session leads students to share their result.

The authors had developed 23-page dossier containing information about the characteristics of different energy sources, environmental problems and multiple data regarding economic and ecological aspects, and six articles that provided extensive information about the issues under study.

Klosterman and Sadler (2010) investigated the impact of using socioscientific curricular on students' content knowledge development among108 students from 9th – 12th grade. This mixed method study used a multi-level assessment to explore the effect of the formal curricular instruction, measuring students' knowledge gains before and after the three-week unit instruction on global warming and the related controversies surrounding it. The distal and proximal assessment were analysed by using a Standard-Aligned Test (SAT) and Curriculum-Aligned Test (CAT), respectively, to measure students' content knowledge gains. The SAT was modified quantitatively following the standardised test from the Trends in International Mathematics and Science Study (TIMMS) and the National Assessment of Educational Progress (NAEP), containing four areas of science such as climate and temperature, greenhouse effects and climate change, chemical principles and processes and graphing and graph analysis. The CAT, on the other hand, was developed to measure students' content knowledge, comprising five open-ended items about the definitions of the global warming and the greenhouse effects, the relationship between the two issues, controversies associated with global warming and how challenging the global warming problem is. The data from SAT was analysed using descriptive and inferential statistics packages in Microsoft Excel and Statistical Package for Social Sciences (SPSS) while the data from CAT was measured qualitatively as a second layer of understanding students' content knowledge

Callahan, Zeidler and Orasky (2011) also conducted a mixed method approach and it involved six Biology classes from the Tampa Bay in the central part of Florida.

Three classes were taught in a 6-month semester long SSI based curriculum, while the comparison classes were taught following their conventional teaching and learning manner. Both Views of Science and Education quantitative survey (VOSE) and Views of Nature of Science qualitative survey (VNOS-B interview protocol) methods were utilised to examine the differences of both classes and individuals between the initial and the end of the semester. Surprisingly, the quantitative findings showed that the classes that did not receive explicit SSI instruction had an increase in the students' NOS understanding. However, the small number of sample size did not allow statistical significance to be generalised in this developmental model.

Rose and Barton (2012) selected two middle-school aged students as the sample for the case study and the programme was conducted within thirteen weeks during an after school programme. The programme was focused on green energy technologies, to reflect on the students' stance on whether their city should build a new power plant. The data was extracted through position surveys, weekly thinking prompts, students artefacts, interviews and video transcripts. The results gained from "before", "during" and "after" the visit to the electric company indicated that the knowledge that students used in dealing with the issues was influenced by the course of investigation during after school programme.

In the following year, Keskin et al. (2013) investigated the argumentation-based bioethics education on thirty-eight prospective teachers at the School of Education of a university in Ankara. The Framework for Teaching Bioethics was used as a basic guide to discuss the ethical issues related to Genetic Screening Tests (GST) and Genetically Modified Organisms (GMOs). This quasi-experimental research method adopted Achievement Test (AT) and Bioethical Values Inventory (BVI) questionnaires in answering the research questions. Twelve participants with acceptable AT scores were interviewed to look at their advanced position about the dilemmas. The findings revealed that there was no difference between the control and treatment groups as far as argumentation quality was concerned. This could explain that content knowledge was not a significant factor for prediction of argumentation quality. Instead of infusing argumentation in science education, this study showed the importance of SSI in improving students' questioning, knowledge researching, problem-solving and decision-making skills.

Hundal et al. (2014) selected the qualitative research design, which focused on the effective design of socioscientific learning conducted within an informal learning setting. The data analysis was collected based on research objective driven and data driven approaches. Observations and interview methods were used to fully understand the teachers' perspectives on the effectiveness of addressing environmental health issues within the after school club.

Jho and Mijung (2014) on the other hand had applied a quantitative approach in exploring the relationship between students' understanding and decision-making. Students were exposed to 1-hour lecture and 1-hour discussion each week and it took over 4 weeks period to conduct this study. The pre- and post-questionnaires were distributed to 89 students to understand their scientific knowledge (content and context knowledge); attitude and decision-making about the lifetime extension of nuclear power plant. Although this study attempted to understand how scientific knowledge was related to socioscientific decision-making, it only considered decision-making as choosing alternatives or preference without taking into account the dimension of understanding, as well as the process of decision-making.

More recently, Dawson (2015) aimed to examine students' understanding and misconceptions of the climate change and the greenhouse effect using a mixed method approach. A questionnaire designed for the study was completed by 483 Western Australian students aged 14 – 15-years old. Twenty of the students were selected and were interviewed further. The findings showed that the students understood different characteristics of the climate change and the greenhouse effect. Further five themes of alternative concepts were identified. A summary of methodological aspects for socioscientific instruction is detailed in Table 2.2.

Table 2.2

Summary of Methodological Aspects for Socioscientific Instruction

Author	Methodology	
	Design	**Focus**
Lewis and Leach (2006)	Mixed method Questionnaires and Interviews	- Discussions on understanding genetic engineering among 100 school students aged 14 – 16-years old. - Paired and group work
Dolan et al. (2009)	Qualitative method Documents	Applying discussion on earth and physical sciences among 5th grade students - Group work
Marrero and Mensah (2010)	Qualitative -case study Interviews Documents Observations	- Applying discussion on ocean literacy which included in the existing curriculum - ACES - Involved two schools of 7th grade students - Group work
Nuangchalerm et al. (2010)	Quantitative method Questionnaire	- Discussions on global warming among 24 5th grade students. - Individual
Uskola et al. (2010)	Qualitative Case study Observations Transcribed discussions	- Applying discussion on deciding upon heating system based on economic and ecological criteria. - Involved 25 university students aged 18 – 23-years old - Small group work
Klosterman and Sadler (2010)	Mixed method SAT –quantitative CAT-open ended for qualitative *SAT-modified from TIMSS and NAEP	Exploring students' understanding and content knowledge regarding global warming, climate change and its controversies - Involved 108 students (9th – 12th grade) from Chemistry and Environmental Science formal classes - Individual

Table 2.2

Summary of Methodological Aspects for Socioscientific Instruction (cont.)

Author	Methodology	
	Design	**Focus**
Callahan et al. (2011)	Mixed method Questionnaires Interviews	- Exploring students' understanding about NOS from 3 heterogeneous classes of 10^{th} – 11^{th} grade students. - Individual and group dynamic
Rose and Barton (2012)	Qualitative method -case study Interviews Documents Observations	- Focused on the interaction between 2 youths' experiences in an after school programme, their scientific knowledge, and set frames to which they were exposed in understanding green energy technologies - Individual
Keskin et al. (2013)	Mixed method Questionnaires Interviews	- Exploring argumentation and understanding about genetically modified organisms (GMOs) and genetic screening test (GST) among 380 prospective teachers - Individual
Hundal et al. (2014)	Qualitative method - Research objective and data driven approaches - Interviews - Observations	- Exploring on the need of students' understanding about environmental health issues. - Involved researcher and 4 collaborating middle – school teachers from social and science fields - Individual
Jho and Mijung (2014)	Quantitative method Questionnaires	- Applying discussion and debate on the issues on nuclear power plant to study the relationship between knowledge, attitude and decision-making among 89 students. - Individual

Table 2.2

Summary of Methodological Aspects for Socioscientific Instruction (cont.)

Author	Methodology	
	Design	**Focus**
Dawson (2015)	Mixed method Questionnaires Interviews	- Examining students' understanding as well as misconception of climate change and greenhouse effect. - Conducting among 438 students aged 14-15 in Perth, Australia.
Current study	Qualitative method Interviews Observations Documents - PGO - Diary	- Exploring students' understanding and socioscientific decision-making. - Focusing on content-related issues (global warming) for students from different grade levels (Grade 7-9) via co-curricular context. - Group work - Students

Approaches for Engaging and Supporting Decision-Making for Socioscientific Issues

According to the previous literature reviews, there is a wide range of approaches used in engaging and supporting critical thinking through SSI. The important characteristics which need to be emphasised are; 1) to ensure that the learning environments engage meaningful and argumentative learning tasks , 2) are provided in a form of project-based or problem-based learning environments, 3) they require legitimate alternatives and 4) they contain ill-structured scenarios that the students must resolve (Jonassen & Kim, 2010). In order to fit the aforementioned requirements, various approaches were used for socioscientific instruction in the previous literature. These approaches include scenarios (Dolan et al., 2009; Jho et al., 2014; Keskin et al., 2013; Marrero & Mensah, 2011; Sadler & Zeidler, 2005), debates (Callahan et al., 2011; Dolan et al., 2009; Jho et al., 2014), jigsaw discussions (Hundal et al., 2014; Ideland et al., 2011; Jho et al., 2014; Lewis & Leach, 2006), written tasks (Keskin et al., 2013; Marrero & Mensah, 2011) and oral presentations (Ideland et al., 2011).

The scenario is initially presented with the general purpose of contextualising the issues and engaging decision-making process. The scenario is given to stimulate students' interest and connect them with the issues studied. Based on the literature reviews, the scenarios were presented following the appropriateness of the context of the study. Some studies in the literature apply the term 'scenario' to 'best-guess' or forecast types of projections or future development of a particular issue. Jigsaw discussion, on the other hand, is a strategy in learning the course material through a cooperative learning style. This strategy promotes interaction among all students and encourages them to share and appreciate each other as contributors to their common tasks.

Other than that, question prompt is one of the favourite approaches that have been used to engage argumentation. Question prompt is a set of directions for constructing arguments (Jonassen & Kim, 2010). Based on the studies that utilised question prompts, students were motivated to apply argumentation by asking controversial questions through interviews and written task such as argumentative essays. Stab and Gurevych (2014) described persuasive essay writing as a form of writing that includes persuasive and well-defined arguments that attempt to persuade the reader. The persuasive essay genre requires the student to write about a controversial issue in which one party agrees or refuses to adopt a particular point of view. Importantly, the art of persuasion entails skill in sequencing the student's thought (Silver, 2003; Stab & Gurevych, 2014).

The students enjoy writing and drafting persuasive essays with peers to generate ideas for their drafts. However, most of the students admit that they are unable to evaluate their work with respect to its structural complexity of persuasion, such as substantiating their ideas with supportive evidence (Giridharan & Robson, 2011). Moreover, the students are more inclined to use stance indicators and make a few errors when sequencing their ideas in persuasive essays (Anwardeen, Luyee, Gabriel, & Kalajahi, 2013).

Visual Models in Socioscientific Decision-Making

Visualisation is deemed appropriate in enhancing students' understanding and memory. It facilitates them to explain complex information clearly (Rakes, 1999), reduce cognitive load and connect between information sources (Neumann, Gräber, & Tergan, 2005). Keys (1997) highlighted that a visual model enables students to visualise the physical structure and relationship and interpret the meaning of the structure when dealing with the decision-making process, as well as argumentation.

Following the routine of the decision-making process, students are encouraged to engage in argumentation before reaching a preference. It is imperative to highlight that there is a complimentary requirement between decision-making and argumentation skills. Decision-making skills refer to the thought process of selecting a logical choice from the available options while argumentation is defined as a logical way of discussing or debating an idea. The background of decision-making contains various visual models including normative and descriptive models that mainly correspond to various disciplinary interests. According to the most general normative standards, an individual who is encountering problem tasks should know how to make a decision and consider cognitive skills for the decision-making process. It requires reasoning skills, referring to cognitive abilities, including the evaluation of probability and the employment of abstract thinking in the decision-making process (Beyth-Marom, Fischhoff, Quadrel, & Furby, 1991).

The descriptive principle of decision-making stresses the preference of choosing and conveying the task that provides an understanding for students to intuitively approach decision-making tasks (Beyth-Marom, Fischhoff, Jacobs, & Furby, 1989). It also highlights the interaction of students in social dynamics involving cognitive skills (Hirokawa & Johnston, 1989). Given these principles, students are required to use their cognitive skills thereby directly moving forward from their current state to one that is more sophisticated.

Ratcliffe (1997) studied how 15-years old students worked within a decision-making structure using this combined model in a formal classroom. This approach resulted in well-reasoned decisions. The employment of framework could also improve the level of personal reasoning in a short period (Grace, 2009). In another study, Eggert et. al. (2010) demonstrated that the students' decision-making competency had increased through the use of framework, although the second group that received meta-cognitive training did not show improvement in the decision process.

Toulmin's Argument and Lakatos' visual models are well-known models used in the field of socioscientific argumentation. According to the visual Model of Toulmin's Argument Model (1956), argumentation skills involve six elements of the structure (epistemic criteria): the claim, grounds, warrant, backing, qualifier and rebuttal. For the Lakatos' visual model, there are four components involved: hardcore

(HC), protective belt (PB), negative heuristic (NH) and positive heuristic (PH) (Lakatos, 1970). HC is the core of the theory, and it possesses the unalterable features, while PB consists of auxiliary hypotheses to avoid HC from being attacked. In other words, the students must be able to make a claim supported by one or more reasons. NH and PH are both strategies rooted in the model with separate purposes to evaluate and to expand theory. Additionally, PB function is to adjust the auxiliary hypotheses when the theory encounters the anomaly and could absorb the anomaly via NH and PH.

Osborne, Erduran, and Simon (2004) conducted a study to investigate the progression of argumentation using a framework developed from Toulmin's argument pattern (TAP). Results showed improvement in the quality of 8th grade students' argumentation. The improvement was up to the extent to which students had made use of data, claims, warrants, backings and qualifiers to support their arguments. They also engaged in claiming, elaborating, reinforcing or opposing the arguments of each other. The structure of TAP functions as the foundation of rational thoughts, thus enabling the process of argumentation to be assisted and its quality to be determined. Additionally, it serves as an indicator of quality and quantity of argumentation. Moreover, the TAP mapping technique enables students to evaluate evidence for possible options and judge the sufficiency of proof for the satisfactory and rejected conclusions (Maloney & Simon, 2006). It acts as a beneficial foundation for communicating the meaning of argument and evaluating students' outcome.

A methodology for supporting argumentation among eighty-four 8th grade students through a personally-seeded on-line discussion system was outlined by Clark and Sampson (2005). The results suggested that the structured methodology could effectively scaffold student's participation in the discourse. It included the epistemic operation (grounds, and content normativity) and the overall argumentation structure of the oppositional episodes.

The introduction of a new assessment framework consisting of a low degree complexity and exemplifying students' written argumentation on genetically modified organism (GMO) issue was developed recently (Christenson & Chang Rundgren, 2015). The simplified framework in the structural and justifications aspects could be operated as a tool or template for identifying quality indicators that could serve as the basis for grading. Lakatos' visual model can also act as an alternative means that benefits students to practise their decision-making and argumentation skills (Chang, 2007; Chang & Chiu, 2008).

Duschl (2007) has proposed that the skills of decision-making must involve an evaluation component on the examination of evidence or argument. Therefore, the development of epistemic criteria that students use to identify the reasons for beliefs, judgements, and actions they put for the decision must be addressed (Clark & Sampson, 2008; Duschl, 2007).

Dilemmas in Quantitative Versus Qualitative Instruments for Socioscientific Understanding and Decision-Making Skills

There are no denials on the prioritisation of scientific ideas for decision-making process (Klosterman & Sadler, 2010). Zeidler and Nicols (2009), highlighted that socioscientific approach requires the use of evidence-based decisions and contextualised scenario for understanding scientific information. The rationale is because it ought to be the furtherance of the scientific concept and processes, thus, develop a sound understanding of the particular dilemmas (Dawson, 2015; Sadler & Zeidler, 2009; Zeidler et al., 2005). Sadler and Zeidler (2009) emphasised that students must be drawn up with sound knowledge and formalisms as well as the skills and processes required within sciences. These include the ability in conceptualising the relevant key issues which are in agreement with scientific knowledge as well as decision-making skills. With that so, it is beneficial to gauge students' understanding so that they can make a sound decision regarding the socioscientific dilemma.

In this regard, the biggest problem uncovered is the students' revelation that they had difficulties in visualising structural complexities for the decision-making process (Ratcliffe, 1997; Zohar & Nemet, 2002). As a result from this complication, they were unable to evaluate scientific evidence, hence, they treated scientific information as uncertain and intolerable (Fleming, 1986). They were also unable to make decisions about the issues and failed to reach a final determination (Grace, 2009).

The importance of developing instructional materials for SSI should be improved to promote students' understanding as well as decision-making skills (Choi, Hand, & Norton-Meier, 2014; Jho et al., 2014; Klosterman & Sadler, 2010; Ratcliffe, 1997; Sakschewski, Eggert, Schneider, & Bögeholz, 2014). It will be beneficial if the students are provided with decision-making framework (Acar, Turkmen, & Roychoudhury, 2010; Grace, 2009; Ratcliffe, 1997) to avoid vague directions in constituting scientific evidence and formulating sound understanding (Walker & Zeidler, 2007).

Previous studies show that the use of questionnaires, for instance, restricted students to prioritise knowledge criteria based on their personal experiences and values because the selection of construct has already been arranged (Gresch, Hasselhorn, & Bögeholz, 2013). Consequently, students have a tendency to delimit their offers to provide more solutions as a further explanation of the finalised preference. Furthermore, Callahan, Zeidler, and Orasky (2011), utilised the VOSE to investigate the relationship between SSI with scientific understanding. The results indicate that students were approximately halfway between conventional and contemporary of science views even after a semester-long socioscientific treatment. The statistical insignificance might arise from the two possibilities of using VOSE questionnaire. It highlighted the poor detection power of VOSE in discriminating between naïve and sophisticated understanding. In addition, there was the problem of revisiting the same survey because of the students' demotivation parameters. Additionally, Zohar and Nemet (2002) examined the influences of teaching argumentation skills in the context of human genetics on the acquisition of content knowledge among 9th grade students in Israel. The study was promising regarding large samples used as well as the positive after effect. However, the main emphases were on argumentation skills as the students' ability to recognise the key issues of science knowledge was unclear.

Recently, Dawson (2015) studied on students' understanding of climate change and the greenhouse effect using a designed questionnaire. The questionnaire was completed by 438 students from year 10 students of selected six schools in Perth, Western Australia. The interview was carried out among 20 students to explore more about their understanding. The findings demonstrated that the students knew different features of both climate change and the greenhouse effect, although not necessarily all of them and the relationships between. It was emphasised that the use of clear consequences and solutions for these issues were unclear because the sciences of climate change, greenhouse effect or global warming were subject to change. For instance, the public can hold and oppose views regarding the sciences of factors and consequences. In addition, Khishfe (2015) investigated the 10th grade students' understanding of genetically modified food, and river fluoridation using a pre-, post- and delayed post-test. Results showed that the majority of students reverted to their earlier naive understanding even after they had been exposed to a four-month socioscientific instruction.

In response to the quantitative methods dilemmas, Choi et al. (2014) suggest the employment of a qualitative method such as using the Science Writing Heuristic (SWH) approach in the decision-making process. This method resulted in a very satisfactory outcome for students' socioscientific understanding.

Walker and Zeidler (2007) conducted an inquiry-based curricular unit to promote socioscientific learning among thirty-six 9^{th} – 12^{th} grade students in the south east of the United States. The researchers utilised an on-line and interview questions to examine the features of argumentation and discourse as they reached the final decision on genetically modified foods. Results showed that students did not divulge much of their understanding when making a socioscientific decision. They also not specifically directed in applying their nature of scientific understanding. The worst condition is that they were most likely to utilise more factual-based content that leads to numerous examples of flawed reasoning and personal attack. The findings recommended a socioscientific approach to exploring aspects of scientific knowledge that represented the scientific concepts to be applied within a decision-making context.

Furthermore, the ongoing debate of contradictory validity and reliability issues related to the quantitative and qualitative instruments for decision-making are earnestly discussed among researchers, especially in the field of SSI. For instance, the dilemma related to the use of a quantitative approach requires further explanation of the reliability of the decision-making questionnaire. Although decision-making scale is reliable for a decision-making task, any given socioscientific context includes preferred options that are either inadequate or limited. Taking one clarified example from the previous development of the quantitative study (Gresch et al., 2013), a computer-based programme was developed to train secondary school students (11th – 13th grade) in decision-making strategy. Specifically, the programme investigated whether the application of decision-making strategies and meta-decisions help students' decision-making competence by using a pre-post-follow-up design for the control group. The result showed that decision training led to a significant improvement. However, students possessed a limited freedom to prioritise criteria based on their personal experiences and values because the prioritisation was already arranged according to the construct questionnaire selection.

According to Sakschewski et al. (2014), the quantitative instrument possessed an average power of detection in the aspects of indicating the decision-making strategy used by the 850 students in 6th – 12th grades. They deduced that the utilisation of this developed quantitative instrument led students to spontaneously use the cut-offs (non-compensatory strategy) instead of the trade-offs (compensatory strategy) before opting for the choice. Additionally, they revealed that the assumption of using the compensatory decision-making strategy was more difficult because the students preferred to use the non-compensatory strategy in finalising their decision. With respect to the aspect of differentiating the levels of reasoning, this paper suggested that more items needed to be developed to address the variety of components of cut-off use. The application of a traditional Likert scale and Rasch credit model, for instance, resulted in the students' inability to identify and analyse the drawbacks that were integrated into the demonstrated decision-making strategy, their inability to suggest improvements, and their inability to formulate arguments and counter arguments (Eggert & Bögeholz, 2010).

Conversely, in a qualitative approach, utilising techniques such as question prompts, students were engaged to apply argumentation for decision-making by asking controversial questions through interviews and written tasks such as argumentative or persuasive essays. Choi et al. (2014) employed a qualitative research to examine 5th grade students' argument-based inquiry using the SWH approach in an on-line environment. The results indicated that the students who actively participated in an on-line discussion offered more evidence, supporting claims, and critiquing and negotiating evidence in making a decision about plant and human health investigation. In addition, they challenged the evidence of both reliability and validity. In general, the SWH approach emphasised the importance of decision-making in linking questions, claims, and evidence. However, only the on-line postings data sources were recognised as a limitation of the study in which the value of an argument-based inquiry approach was considered insufficient. Therefore, the interview about students' perspectives on the argumentation process, especially in the face-to-face learning environment, provided rich information for comparison purposes.

Dawson and Venille (2010) found that the use of writing frames played a significant role in developing students' argumentation skills. The writing frames provided guiding questions. These questions were drafted to scaffold students' thinking, acting as a mental prompt for students to convey their arguments about the issues. This approach might be especially useful for students who worked individually, thus enabling them to provide 'data', 'claims', 'warrants', 'backings' and 'rebuttals' in an eloquent manner. The use of this argumentation structure is necessary because it is vital for tracking students' understanding (Walker & Zeidler, 2007), importantly symbolising high-quality skill in decision-making (Toulmin, 2003).

Considering the aforementioned problematic area in understanding and decision-making, this present study suggests that teaching strategies about multifaceted issues should be directed towards not only promoting students' understanding of the nature of decision-making processes but also consolidating the skills needed in each phase of the process (Böttcher & Meisert, 2013; Hong & Chang, 2004; Keys, 1997). A qualitative inquiry that represents a theoretical background is welcomed (Lederman & Lederman, 2015; Marshall & Rossman, 2014), thus, to design a specific instrument that functions as an appropriately visualised tool for the decision-making process. Specifically, the visualisation instrument in the decision-making structure is appropriate to explore students' knowledge, accompanied by an understanding of the processes that precede a decision. This will be beneficial if students are provided with an explicit visualisation method (Jonassen & Kim, 2010) and framework of the structural complexity that must be considered in a decision-making process (Grace, 2009; Ratcliffe, 1997; Uskola et al., 2010).

Framing the concept of Graphic Organisers as a visualisation tool for socioscientific decision-making.

Addressing SSI such as global warming demands a high level of cognitive processing that requires students to reason, argue, and make appropriate decisions (Grace, 2009; Osborne, Erduran, & Simon, 2004; Ratcliffe, 1997; Zohar & Nemet, 2002). Moreover, students must contextualise, integrate, and organise conceptual knowledge and persuasive information to make decisions. With respect to these requirements, one methodological tool could be useful for students to address various types of scientific and social information to make good decisions. Similarly, graphic organisers (GO) are visual aids that afford students with a tool, language, and information organiser for accomplishing many objectives and outcomes (Gallavan & Kottler, 2007). Its educational effectiveness has been broadly tested in a variety of contexts (Moore & Readence, 1984; Phillips & Nagy, 2014; Robinson, 1997).

Although GO is acknowledged as a beneficial learning tool for students, there is a lack of consensus on rules and guidelines for GO construction. The main weaknesses, as described by previous GO studies, are as follows: the unspecified format of GO, a single GO type with an inconsistent text length, and an inability to measure the relationship between knowledge and ideas (Robinson, 1997). These limitations of GO effectiveness have resulted in ineffective pedagogical practices (Phillips & Nagy, 2014).

The eight types of proposed GOs can be utilised for empowering students in social (Gallavan & Kottler, 2007) and science education studies (Lenz & Willcox, 2012). However, the often-used single-type organiser does not fit students' needs, thus decreasing its actual effectiveness. Considering the suggestions above, the current study adopts the specific format 'combine and create' GO (Gallavan & Kottler, 2007) in which each section of the newly generated GO recognises a concept, structure or function for a particular purpose of the decision-making process. For the benefits of reaching optimal fulfilment and appropriate decision-making skills, students are encouraged to construct their own GO by using the 'combine and create' type of GO driven by the contextualised global warming scenario. Accordingly, using this category of GO is an alternative and is deemed to be a suitable tool that gives students indirect spaces of freedom in which to express their ideas through individualised or grouped approaches before making a decision.

For the decision-making structure, the "decision-making models from sociology and psychology seem to hold little promise in predicting the more complex decisions associated with socioscientific issues" (Aikenhead, 1989, p. 11). Therefore, I considered using the combined decision-making framework proposed by Ratcliffe

(1997) as the basic concept for the development of the PGO. The development and evaluation of the PGO will be chronologically discussed in methodology chapter.

Theoretical Background

This section discusses the theory which guides the present study. The theory of Social Constructivist acts as the vital foundation that drives this study. The selection is based on how this theory can be utilised to support the theoretical framework of this present study.

Theory of Social Constructivist. The social constructivist theory proposes a social cognition learning that emphasises social interaction in the development of cognition. It recognises that the knowledge an individual possesses at any one point in time would be dependent on each individual students' unique set of experiences and the total sum of conceptions that the students have constructed. They construct different meanings from the information presented to them (Mintzes & Wandersee, 1998). This is because almost all knowledge would have been built upon some basic concepts on to which more complex concepts would have been built.

Social constructivism focuses on the artefacts that are created through the social interactions of a group. It emphasises the profound influence of social contexts in the advances in the level of knowing. One key concept of Vygotsky's social constructivism theory is that knowledge construction is both a social and cognitive process. The connections are as follows:

1. Knowledge and meanings are actively and collaboratively constructed in a social context mediated by frequent social discourse.

2. In a social constructivist learning environment, effective learning happens only through an interactive process of discussion, negotiation, and sharing.

Vygotsky (1980) has claimed that culture influences cognitive development. Infants are born with the basic materials or abilities for intellectual development. Eventually, through interaction within the sociocultural environment, their intelligence and knowledge are developed into more sophisticated and effective mental processes or strategies, which he refers to as Higher Mental Functions. Vygotsky also believes that social interactions influence cognitive development. Young children are curious and actively involved in their own learning and the discovery and development of new understandings/schema. As emphasised by Anderson (1984), the essence of knowledge is structure and this structure needs to be developed if a learner hopes to acquire subsequent knowledge in a subject domain. Furthermore, language also influences cognitive development. Language is an accelerator to thinking/understanding. Language develops from social interactions and communication. Later, language ability becomes internalised as thoughts and 'inner speech'.

There are two main principles of Vygotsky's work:

1. More Knowledgeable Other (MKO): It refers to someone who has a better understanding or a higher ability level than the learner, with respect to a particular task, process or concept. The key to MKOs is that they must have (or be programmed with) more knowledge about the topic being learned than the learner does.
2. Zone of Proximal Development (ZPD): This is an important concept that relates to the difference between what a child can achieve independently

and what a child can achieve with guidance and encouragement from a skilled partner. Vygotsky perceives the ZPD as the area where the most sensitive instruction or guidance should be given.

The principle of MKO is integrally connected to the second important principle of Vygotsky's work, ZPD. Vygotsky (1978) defines the ZPD as an "actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers" (p.86). An encounter between the learner and MKOs within the zone allows the students to learn collaboratively while being mediated by a support. It involves the assistance from teachers, peers and other resources in developing understanding about the task given. Figure 2.4 describes the three ZPD in learning.

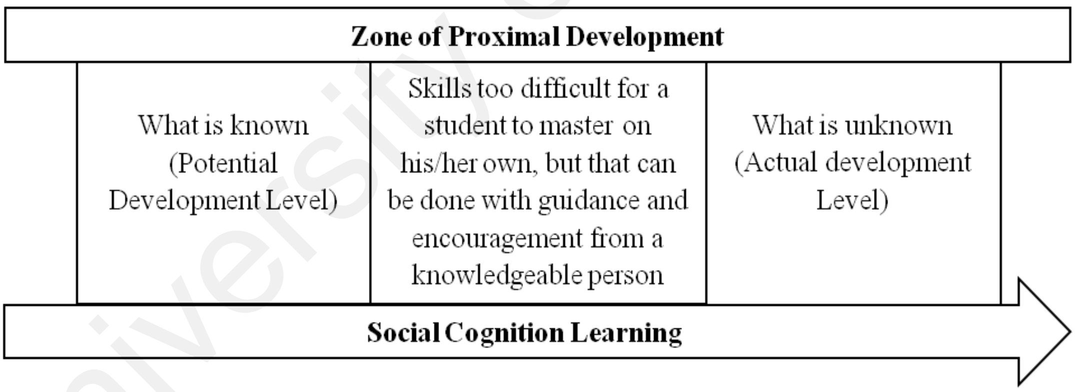


Figure 2.4. The Zone of Proximal Development (ZPD)

Vygotsky's ZPD emphasises his belief that learning is fundamentally a socially mediated activity. Thinking and problem-solving skills can be placed in three categories. Some can be performed independently by the children while others cannot be performed even with help. Between these two extremes are the skills in the ZPD, which a child can perform with the help from others. Those skills are in the ZPD. If a child uses these cognitive processes with the help of others, such as teachers, parents and fellow students, they will develop the skills that can be practised independently. Vygotsky's idea can be summarised as such: what a child is able to perform in collaboration at this moment can be performed independently in the future.

Zone of Proximal Development (ZPD). The main principle in ZPD is scaffolding. In this context of the study, the function of scaffolding is to provide sufficient 'boost' for the students to complete the task pertaining to the socioscientific issue.

As described in Figure 2.5, scaffolding requires social interaction and guidance from capable adults, peers and resources. The existence of scaffolding depends on the two learning settings which are encountered before and after learning takes place.

1. The learning settings must be interactive and dynamic during scaffolding phase (Vygotsky, 1980). Learning must be organised in a constructive environment where a student is able to talk, write and communicate freely with their peers. In other words, learning must be conducted through social interactions and collaborations.
2. The learning settings must collaborate with the existence or guidance from capable adult, peers and resources.

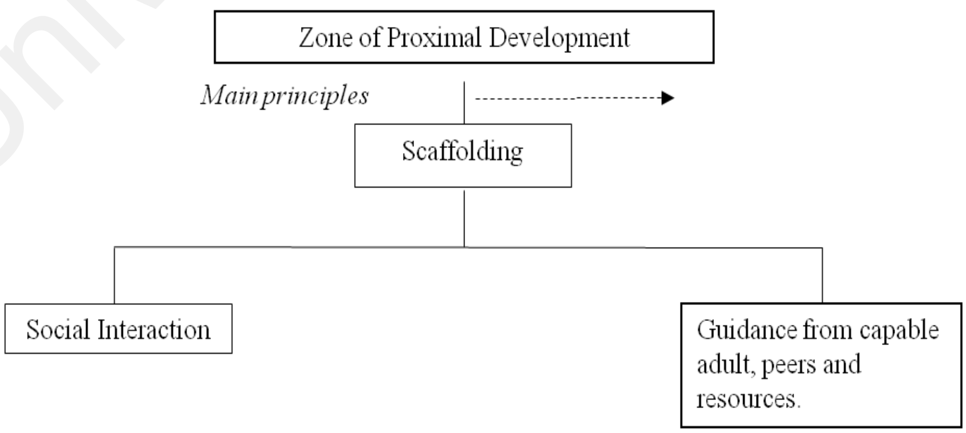


Figure 2.5. The main principles of scaffolding in the ZPD

This theory focuses on the interconnected zone of the study conducted in informal setting yet it facilitates the scientific cognitive growth in learning. Four principles that can be applied in any Vygotskian learning are:

1. Learning and development in a social and collaborative activity.
2. The ZPD can serve as a guide for curriculum and lesson.
3. School learning should occur in a meaningful context and not to be separated from learning and knowledge that students develop in the 'real world'.
4. Out-of-school experience should be related to the student's school experience.

Parallel to the context studied, this theory serves as the relevant backbone, specifically in interrelating students' understanding in making a decision about the SSI within the co-curricular setting.

The Contextualisation-Decontextualisation-Recontextualisation Phase Model. The Contextualisation-Decontextualisation-Recontextualisation Phase Model developed by Holbrook and Rannikmae (2010) highlights the three phases of learning which are applied in achieving the goals of education towards enhancing scientific literacy. The significance of using this model for the research procedure is to ensure the systematic guideline and simplify the implementation of the socioscientific instruction by the practitioners. Figure 2.6 illustrates the frame of this phase model.

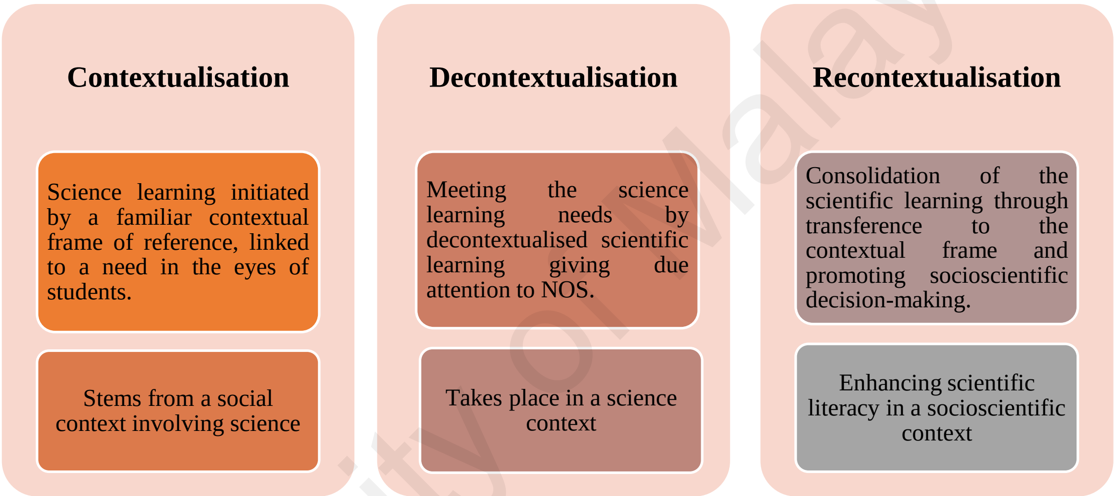


Figure 2.6. The Contextualisation - Decontextualisation - Recontextualisation Phase Model
Sources: The Contextualisation - Decontextualisation - Recontextualisation Phase Model (Holbrook & Rannikmae, 2010, p.13)

Contextualisation. Contextualisation phase stems from a social context involving science. In this phase, science learning is introduced to the students by a familiar contextual frame relevant to their daily lives. As relevant issues will have an impact on the students' lives, their role in handling these issues is desired. This is an important phase and indicates a requirement in establishing the relevance of science teaching in daily life, hence it triggers the students' intrinsic motivation.

This phase involves the introduction of science component that embeds society complexity in a suitable context. The initial sequence is not necessarily parallel with any formal concept map, but the priority is put forward on the teaching that progresses from one issue to the related interpretation and meaning. Instead of promoting relevance and triggering students' motivation, the conceptual science learning that evolves must be considered carefully as being within the ZPD for the students involved (Vygotsky, 1980). The science learning will then be broken down into an appropriate level of content and context of knowledge, where students are permitted to seek and investigate the information related to the issue given.

Decontextualisation. Decontextualisation is a phase where learning takes place in a science context. This 'need to know' phase provides a scientific learning platform consolidating on the scientific ideas, solving scientific problems and evaluating relevant scientific information. It focuses on structuring the scientific learning that enables students to support the decision-making process related to the initial issue presented in the contextualisation phase.

In this Decontextualisation phase, the teaching and learning are not constrained within context-based learning but it moves towards inquiry-based learning. This phase focuses on the student-oriented approach with some significant guidance that can be used to overcome the issue. Furthermore, it provides the need of scientific platform towards developing scientific problem-solving. In this phase, the appropriateness of scaffolding is heavily reinforced by the guidance as an extrinsic motivation through some guidance from the teacher and other attributes.

According to Holbrook and Rannikmae (2010), the intrinsic motivation must be initially strengthened and the preference of open inquiry mode for learning at the secondary level is desired. In order to determine that students are committed and operating this mode, the level of inquiry must be structured, guided and open. At the end of the phase, the initial context can be revisited by acknowledging the new scientific knowledge to be applied in the issue presented during contextualisation stage.

Recontextualisation. Recontextualisation is the phase where the consolidation of scientific learning through the knowledge transformation to the contextual frame (science and social), thus promoting socioscientific decision-making. This phase is put forward as a further essential, not-to-be-neglected phase. It encourages the students to utilise their newly gained knowledge to be transferred to the socioscientific frame, thus leading the students to enhance their scientific literacy in a greater social context.

In this Recontextualisation phase, students are encouraged to undertake the reasoned decision regarding the issues that were first addressed. Students are expected to relate the old knowledge and newly acquired scientific components towards making a decision about SSI. This phase encompasses the requirement for consensus decision-making and at the same time promotes students' oral and written presentation skills. To date, there are three aspects that need to be considered when conducting this phase: 1) enabling students to express their opinions and enhancing scientific literacy in socioscientific context 2) establishing the value of scientific knowledge when making decision and 3) deriving well-reasoned justification on the specific decision in oral and written presentation format and hence enhancing scientific literacy.

The three phase model becomes procedural phases for the researcher to explore on how students' understanding and decision-making skills can be promoted when dealing with SSI within the co-curricular context. In this present study context, the current study has made some modifications to fit the need of designated research objectives. The actual phases of implementation will be further explained in Chapter 3.

Theoretical background: Decision-making skills. Decision-making, in general, involves the process of choosing and considering the potential consequences of different alternatives after making a thorough examination on each option (Beyth-Marom et al., 1989; Fischhoff, Crowell, & Kipke, 1999). In the theoretical background of decision-making, there are different approaches of decision-making such as normative and descriptive models, which largely correspond to different disciplinary interests. According to the most general normative models, an individual who is encountering problem tasks should consider the cognitive skills for the decision-making process. It requires reasoning skills which refer to the cognitive abilities, including evaluation of probability and employment of abstract thinking in the decision-making process (Beyth-Marom et al., 1989). The fundamental process that one individual needs to use when confronted with decision-making situations are as follows (Figure 2.7).

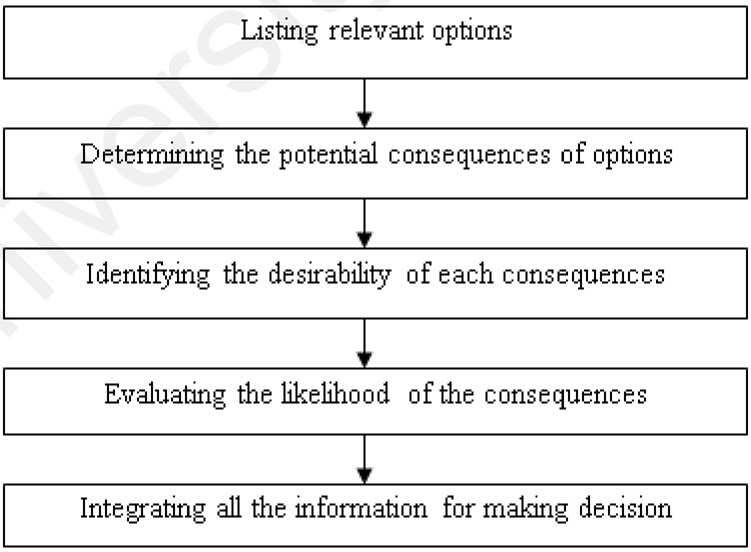


Figure 2.7. The decision-making framework

(Reference: Fischhoff et al. (1999))

The characterisation of normative principle can be explained using the following prescribed steps that are specific to the particular decision-making tasks. Figure 2.8 illustrated the nine steps of the normative framework for the decision-making process.

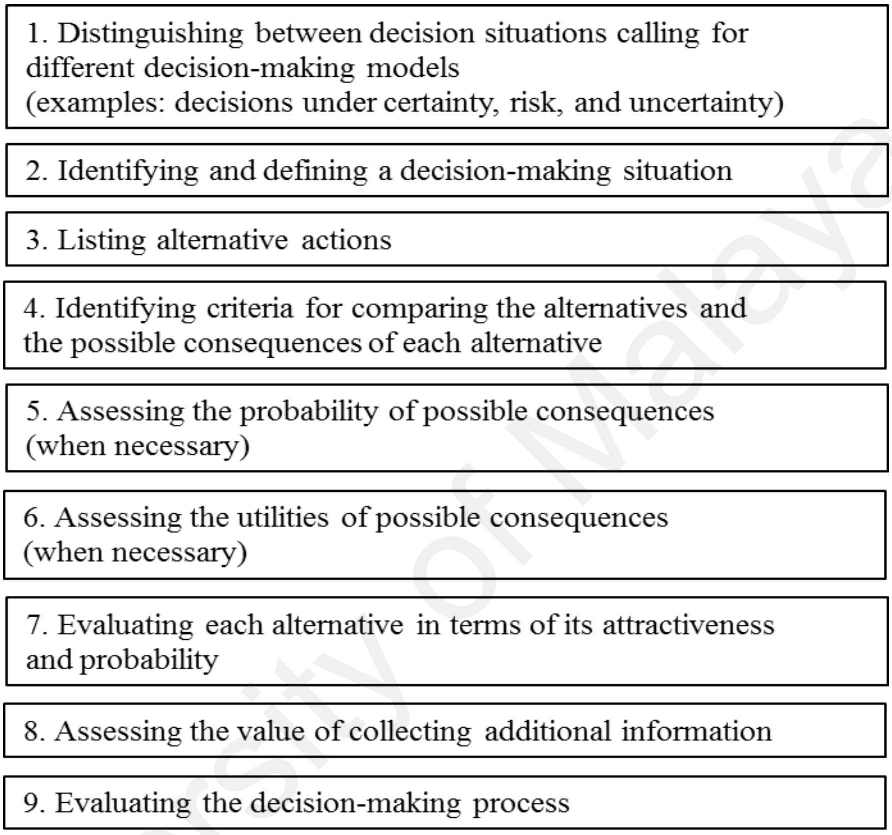


Figure 2.8. The normative framework for the decision-making process

(Adopted from Beyth-Marom et al. (1989, p.9))

However, the normative models for decision-making that have been developed contribute to the complexities including the basic steps as well as specifying the steps in the decision-making process (Beyth-Marom et al., 1989).

The descriptive principle of decision-making stresses on the preference of choosing and conveying the task that provides an understanding for students to intuitively approach decision-making tasks (Beyth-Marom et al., 1989). With such understanding of descriptive principles, students are required to use their cognitive skills, hence directly promoted to move forward from their current state to a more sophisticated one. The systematic overviews of the decision-making process that reveals something about the strength, difficulties and how they face the decision-making tasks need to be further explored (Beyth-Marom et al., 1989).

According to Beyth-Marom et al. (1989), there are two suggestions concerning decision-making skills that might give big implications for curricular development in educational context:

1. Uncertainty. Uncertainty is the fundamental component of decision-making and ought to be the main concept in the curriculum. It includes uncertainty in dealing with ill-structured situations, reflecting among other things and realising the complexities of a decision-making process. With these above-mentioned uncertainties, the students have the simplistic views of thinking. Therefore, the integration of topics that represent uncertainty possesses a different kind of uncertainty and linking the relationship between uncertainty and the amount of information should be more focused on in the future.
2. The definition of the basic components of decision-making. The basic components of decision-making such as the alternatives, consequences and sources of uncertainty play an important role in the decision-making process. The curriculum must give the opportunities for students to provide multiple alternatives, clearly specifying those alternatives and evaluating each alternative given. To that end, the generic techniques of generating options that follow the decision-making steps should be taught to students.

For the sense of normative and descriptive principles in decision-making, the important competencies that need to be fostered are by providing a better engagement in the decision-making tasks concerning SSI. The first important aspect is in accordance with the visual representation that structured the complexities of decision-making process (Choi et al., 2014; Grace, 2009; Ratcliffe, 1997). Secondly, the aspects emphasised on influencing the students to provide an adequate criteria for socioscientific decision-making tasks, where students must possess an effort to use compensatory strategy in facing the problems (Eggert & Bögeholz, 2010; Eggert, Ostermeyer, Hasselhorn, & Bögeholz, 2013; Hong & Chang, 2004; Sakschewski, Eggert, Schneider, & Bögeholz, 2014). The adaptability of these aspects, which result in the sophisticated decision-making skills, is considered acceptable for complex socioscientific tasks. It is imperative to note that these aspects are in line with suggestions of curricular development in decision-making, highlighting the decision-making skills as the 'essentials' rather than the decision that students make (Aikenhead, 1985).

Summary of Theory and Model

The theory of Social Constructivism becomes a primary driving mechanism that supports this research. The principles of social constructivism are incorporated within the research's framework because it provides scaffolding and feedback from the social environment understudied. In the learning process, the social constructivist theory provides an explanation for the observations of the processes internalised by the learner. The Contextualisation-Decontextualisation-Recontextualisation Phase Model becomes a procedural phase in implementing the socioscientific instruction during actual study. It describes the phase's objective and requirement of each activity in detail. The theoretical background for decision-making skills is also presented as the foundation for this study. The combination of this theory and model will lead the researcher to conduct this study strategically, according to the proposed objectives.

Chapter Summary

In this chapter, I commenced the literature review with a brief description of scientific literacy and SSI, its constitutional factors and the challenges of socioscientific implementation in the secondary school classroom. The discussions then focused on the potential of informal learning in developing students' understanding and decision-making skills. This chapter also examined the previous literature regarding the various strategies of methodological aspects and methods used for socioscientific instructions that were carried out in formal and informal environments. Towards the end, this chapter emphasised the theoretical background and procedural phase of this study. The next chapter will reveal the methodology used in this study.

Chapter 3 Methodology

Introduction

Research is a form of systematic inquiry into an important problem. Merriam (2001) postulated that the research questions constructed at the planning phase are designed to guide the inquiry and they reflect the researcher's thoughts on the most significant factors or issues to be studied concerning the problem identified. The methodology opted in the inquiry should also be decided by the purpose and research questions put forward (Merriam, 1998). The overall purpose of the current study was to explore the students' understanding in making global warming decision within the co-curricular context.

This chapter focuses on topics pertaining to the research methodology that was adopted in the present study. The first section presents a discussion of the rationale for adopting a qualitative research methodology. The following sections then address the development and validation of the PGO and the preliminary study. The next section describes the stages of the study and data collection techniques. This is followed by the context of the study including the selection of participants, duration of the study, data collection and data analysis procedures. The last section presents a discussion on issues related to the method validity and reliability, followed by a summary of this chapter. This chapter describes the detailed accounts of the methods and procedures of the study to get a better understanding of the whole research process in answering the research objectives.

Design of the Study

A research design is an outline that provides logical and systematic sequences which relate the empirical and descriptive data starting with the initial research questions and its conclusions of the study (Yin, 2017). The research design should recognise the purposes and the objectives of the study hence provide guidance in determining the data collection and data analysis.

The most appropriate study design for the purpose of this study was qualitative design. The generic qualitative design is preferred when the researcher is seeking to explore and understand a phenomenon, a process, or the perspectives and world views of the people involved in the setting under study (Merriam, 1998).

Marshall and Rossman (2014) highlighted that the qualitative researcher should determine the overall strategy and the rationale of the study according to the form of the research questions. They specified that exploratory research strategy is the most adequate and efficient framework that provides the researcher with a better understanding of the phenomenon and process that students experienced in the social context.

This can be particularly pertinent to the purpose of this study as the aim was to elucidate students' understanding in making a decision about the SSI as well as the factors affecting students' understanding in making a decision through the co-curricular context. Understanding the decision-making process is not only considered as choosing alternatives, but it takes into account the process of knowledge acquisition and the understanding to reach the decision. This strategy is also significant in terms of the usage of the qualitative method. It allows an in-depth investigation to identify the students' criteria and evidence that support the decision-making process within this social context (Jho et al., 2014).

It is imperative to note that most of the studies concerning understanding and decision-making in SSI have employed quantitative assessment such as multiple choice questions, hence restricting the students in making their justification (Eggert &

Bögeholz, 2010; Gresch et al., 2013; Sadler & Zeidler, 2005; Sakschewski et al., 2014). To gain a deeper insight into the students' understanding in making a decision, it would be enriching if the students were given an explicit instruction of the decision-making process such as mentioning some issues that need to be considered in decision-making (Choi et al., 2014; Ratcliffe, 1997; Uskola et al., 2010). This would be beneficial if the students were provided with an explicit visualisation method (Jonassen & Kim, 2010) and framework of the structural complexity that must be considered during the decision-making (Grace, 2009; Ratcliffe, 1997; Uskola et al., 2010). Therefore, the visualisation instrument in the decision-making structure was developed in the present study to explore the students' knowledge, accompanied by the understanding of the processes that precede a decision.

Development and Validation of Persuasive Graphic Organiser (PGO)

The development and validation of the PGO followed the qualitative paradigm. It consisted of five developmental phases (Figure 3.1) which reflected the fundamental processes involved during the entire period of the study. The developmental phases of the PGO involved the PGO framework design, the collection of the initial feedback, experts' reviews on the PGO, PGO revision and PGO evaluation. Overall, the current study required thirteen months to fully develop the PGO (September 2013-November 2014).

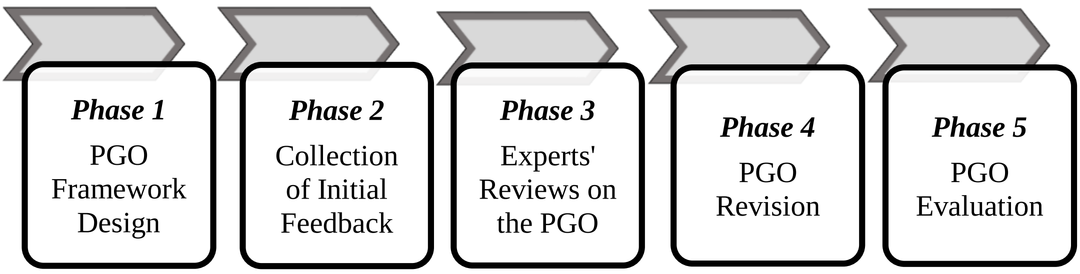


Figure 3.1. The five developmental phases of the PGO

Phase 1: PGO framework design. For Phase 1, the current study has employed a thorough literature review in designing the PGO framework to acquire a comprehensive foundation that frames this study. As discussed earlier, the initial design was developed based on the theoretical framework from academic reports drawing on the vast body of research on literature reviews on SSI decision-making (Lederman & Lederman, 2015; Chang & Chiu, 2008; Ratcliffe, 1997; Ratcliffe, & Grace, 2003), and graphic organisers (Gallavan & Kottler, 2007; Tishman & Palmer, 2005).

The development of the PGO was derived from the combination of two principles: persuasive essay and graphical organiser tool. It was relevant due to the purpose of visualisation skills in the decision-making process requires persuasive ideas before finalising the preferences. The two components, ‘scenario’ and ‘decision-making graphical organiser’ composed the PGO.

The first component, ‘scenario’, was contextualised with relevancy, neutral and content-related, that linked to the socioscientific context undertaken. The global warming issue was chosen as the controversial socioscientific scenario because it is categorised as a major socioscientific area of the middle school education, relevant to students’ daily life experience, linkable to the formal curriculum, vital for informed citizenship and capable of stimulating the interest in science learning (Hundal et al., 2014b). In determining the scenario, a systematic analysis of the Form One and Form Two Malaysian curriculum was carried out. The rationale was to make it age-appropriate, content-related, and suitable for the socioscientific discussion, thus fitting the relevancy.

The second component, 'decision-making graphical organiser' emphasised on the structure of decision-making. This structure was developed based on the common elements in normative and descriptive decision-making models (Ratcliffe, 1997). The rationale is because both normative and descriptive models seem to hold little promise in predicting the more complex decisions associated with SSI (Aikenhead, 1989).

The PGO structure followed the ascending orders, beginning with options, criteria, information, survey, choices, review and provision (Table 3.1). It is imperative to mention that Ratcliffe eliminated the 'provision for implementing decision-making' element from the normative model because of some limitations in a formal classroom setting.

The provision element is the action of supplying related aids so that the decision-making process can influence students' actions. Suitable for the informal context under study, the present study has added the provisioning element for implementing the decision by supporting students with teamwork dynamics and PGO as a resource.

Table 3.1

The Structure of Decision-Making Framework

Structure	Description
Options	Identify the possible alternative course of actions in considering the problem or issue
Criteria	Develop or identify suitable criteria for comparing the alternative course of actions. The nature of these criteria is left open to discussion
Information	Clarify the information known about the possible alternatives, with particular reference to the criteria identified and to any scientific knowledge or evidence
Survey	Evaluate the advantages and disadvantages of each alternative against the criteria identified
Choice	Choose an alternative based on the analysis undertaken
Review	Evaluate the decision-making process undertaken, identifying any possible improvements
Provision[a]	Influence the students' actions in the decision-making process

Note.
Provision structure was eliminated by Ratcliffe (1997) due to the limitation of research site, however, accepted in the current study context.
(Sources: Ratcliffe, 1997, p.169)

To improve the students' understanding of the decision-making structure, the terms used for the decision-making structure was changed to more familiar terms used in the context of local formal science education. For instance, the terms 'criteria' and 'information' were changed to 'reason' and 'evidence', respectively. The terms were changed after a thorough peer review was performed.

For a decision-making graphic organiser that demands persuasive ideas, the PGO provided a visual layout for organising the two possible options (YES or NO) for the global warming scenario presented along with their suitable structure as mentioned earlier. In summary, the PGO format elaborated above was illustrated in Figure 3.2.

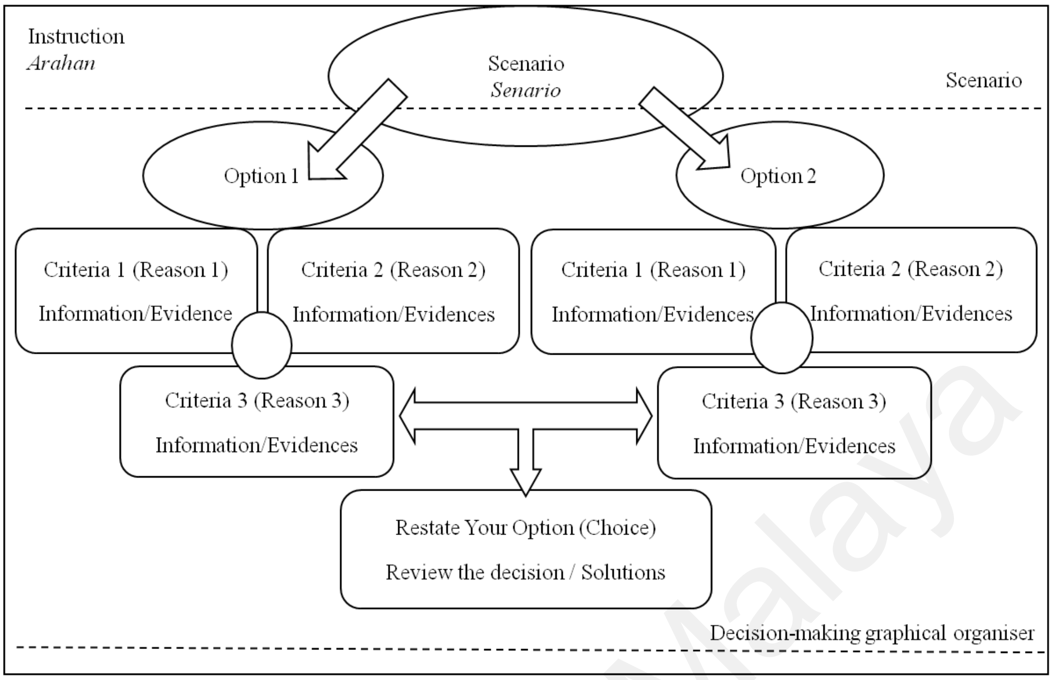


Figure 3.2. The PGO format

Three more criteria were included in designing the PGO format: Written instructional format, language and flexibility. For instance, the current study has made some adjustment on a number of words used in the questions while retaining their specificity on the context. Students were also reminded that there are no right or wrong answers to be put in their generated PGO, but they could freely organise their ideas using the PGO structure.

Furthermore, the PGO was also intended for students from diverse backgrounds. Therefore, the current study has selected two dominant languages (Malay and English) as the medium of communication and the students were free to choose the preferred language. Bilingualism was used to minimise the coverage bias and to ensure the heterogeneity of the participating students in terms of the ability to understand and complete the PGO task given and provide the dynamism in using text or image to exemplify the related knowledge.

Phase 2: Collection of the initial feedback. The primary purpose of Phase 2 is to explore an initial feedback of PGO usability. Specifically, this phase was conducted to examine students' experiences about their understanding, also the advantages and disadvantages of generating PGO. A draft PGO was piloted with 25 heterogeneous students in terms of both gender and age: Grade 7 (n=11) and Grade 8 (n=14) from a typical secondary school. This school is located in an urban area of Kuala Lumpur, which is Malaysia's capital city.

Formal data collection for this phase was performed via interview and documents. More specifically, data were collected from semi-structured interviews and work activities in the form of completed PGOs. Semi-structured interviews were conducted with each group to identify the issues experienced by the students when using PGO for socioscientific decision-making. In this interview, the students were given the opportunity to express their understanding of the decision-making process, where students were probed to reveal their experiences with respect to how they managed to finalize their preference through the produced PGO.

Prior to Phase 2, the students were exposed to a one-hour training session aimed at providing them with adequate skills in generating PGO. This training session consisted of a brief discussion of what PGO is all about, including some visual examples to show the nature of PGO. Because the PGO is unfamiliar and atypical, students were provided with PGO samples that emphasized the obesity issue. This phase demonstrated the essential components and the process of developing the PGO.

The actual PGO generation session was commenced by contextualizing the scenario. This was accomplished by presenting a 5-minute video on global warming. The students were then instructed to work in five groups of six to discuss and generate their PGO based on the skills acquired during the training session. They were allowed to practice their preferred strategy of mapping ideas when they were engaged in teamwork (Zampetakis, Tsironis, & Moustakis, 2007). This condition permitted them to develop a strategic interaction, gather different knowledge and work in groups. The teamwork learning strategies had a significant effect on providing a solid foundation for the decision-making process (Clark & Sampson, 2005; Paykoc et al., 2004), developing and evaluating solutions related to their particular issues (Eggert et al., 2013). Notably, the outcomes and hindrance detected (inappropriate justifications of the PGO written instructional format) in phase 2 were academically scrutinized and referred to the experts for revision during phase 3.

Phase 3: Experts' reviews on the PGO. The professional opinions of both the socioscientific and qualitative experts were taken into consideration to acquire a proficient academic view according to principles of PGO, rigour analysis and validation purposes.

Socioscientific expert. A qualitative socioscientific expert from a Western country was selected to obtain professional review regarding SSIs in the science education field. The socioscientific expert has incorporated research programmes specifically focused on the aspects of argumentation, decision-making, content knowledge, moral reasoning, and NOS into the socioscientific theoretical framework as a medium to promote scientific literacy. He is a prolific author in the SSIs and his work has evoked international attention and has been cited extensively within the community of science education.

For professional revision purposes, the current study has approached the expert via e-mail to gain clarifications on the scenario and directions required for posing an instructional format. The expert suggested four changes to improve the PGO. The current study was advised to:

1. emphasise the “neutrality” in the contextualising scenario,
2. conduct interviews for further significant action
3. provide explicit instructions for giving scientific and social considerations and
4. direct students’ attention to include evidence-based arguments.

For the first suggestions, the global warming scenario was refined and contextualised using a neutral statement that provides a platform for all opinions. It might be perceived as a neutral scenario that was prone to antagonism. This particular matter was modified to avoid any bias in fixing something to achieve a better quality response or the desired outcomes.

For the second suggestion, the expert has actively encouraged the current study to conduct a series of interviews to get the students to explain in detail about their experience in generating PGO. It also provides information against any possible adversities that students may encounter during the PGO generation process.

The third and fourth suggestions were to provide explicit instructions to both scientific and social considerations and to direct students’ attention to include evidence-based arguments. In other words, the experts recommended resentencing the instructions. It must be focused on providing an explicit inclusion of scientific and social facts before making a final decision. The issues of instructions were also further analysed and revised following the socioscientific and qualitative approaches.

Qualitative expert. One qualitative expert was selected following the relevance pertaining to the methodological niche in which it fits the corpus of the study needs. The expert was a prolific academician and has employed the qualitative research methods on science curriculum development and innovation, teaching, and learning in science education.

Several academic discussions were carried out which emphasised on some of the above-mentioned modifications suggested by the socioscientific expert. Students' difficulties were also traced during the Phase 2, particularly from the interviews and document analysis. The difficulties that students confronted are due to the misunderstanding of the instructional format that students hold when solving a particular socioscientific scenario. In addition to the issue, it was evident that they hardly understood the needs of instruction for the reasons and evidence columns. Following qualitative perspectives, some additional wordings were included in the instructions. However, the structure of the instructional format was retained.

Phase 4: PGO revision. The PGO was revised based on the students' feedback from documents and interviews and the experts' reviews before reaching the final stage of development. In general, the PGO was amended to ensure that the format and principles firmly adhered to the corpus as shown in Table 3.2.

Table 3.2

The Format and Principles of PGO

Components	Descriptions
Scenario	- The scenario presentation is relevant to 'everyday experiences', 'content-related' and reaching 'neutrality' significances. - Everyday experience refers to a routine life which refers to a typical action, thinking, and feeling experienced by different people. There are no right or wrong answers as this occurrence differs from one individual to another. - Content-related refers to the scenario that is connected to a particular theme or topic consolidated in the formal science syllabus. - Neutrality refers to the state that does not support either the 'agreement or disagreement' side of the controversial scenario.
Decision-making graphical organiser	- The decision-making framework is structured according to the normative and descriptive model of decision-making in which it matches the requirement of predicting the most complex decisions associated with SSI. - The seven elements of decision-making structure followed ascending orders starting from options, criteria, information, survey, choices, review and provision. Several terms of the decision-making structure has been changed to the customary terms used in local formal science curricula. - Use of the 'combine and create' type of graphic organiser which captures the concept and structure of decision-making.
Additional Considerations	
Written Instructional Format	The written instructional format should be directed as specific and context-rich, emphasising its clarity as the SSI demands broad perspective from the scientific and social aspect of the context given. It also must direct students' attention to the use of WHY for reasons and HOW for solutions.
Bilingual	The flexible utilisation of bilingual (Malay and English) in the PGO format permits the minimisation of the language coverage biases.
Flexibility	The dynamic use of text and image are allowed in representing scientific and social knowledge.

Overall, the presentation of PGO format was improved comprehensively. Thus, the process of conducting the PGO evaluation phase was carried out following the particular procedure the same as the initial feasibility study.

Phase 5: PGO evaluation. The purpose of this evaluation phase was to acquire the complete practical usability of the revised PGO. This phase involved thirty students from a school that was categorised as a Fully Residential School in a district in the outskirts of Kuala Lumpur. This evaluation phase was conducted among Form One (n=15) and Form Two (n=15) students. The selected students possessed a fundamental knowledge of global warming throughout their formal learning in primary and secondary school. The tone of the fundamental knowledge was indicated via 'curriculum mapping' from the Science syllabuses (Altman, 1989). The students who participated in this phase initially submitted the consent forms from their parents or guardians.

The procedure of administration in this phase was completely the same as the procedure ruled in Phase 2. It commenced with a training session, followed by the actual administration. In addition, the methods used for data collection were the same, consisting of a PGO and an interview. The revised PGO was administered to the students in a 90-minute learning session. Six generated PGOs were completed and returned. The evaluation process revealed that the PGO was operationally workable and conveniently utilised as a visualisation tool for socioscientific decision-making.

The Selection of Site and Participants

The decisions on the site and participants selection are important for a qualitative research. It should be relevant to the conceptual framework and the research questions addressed by the study. Coyne (1997) pointed out that all types of sampling in the qualitative research may be encompassed under the broad umbrella of 'purposeful sampling(Coyne, 1997)(Coyne, 1997)(Coyne, 1997)'. A sampling method is considered as purposeful sampling when the sampling strategies are always intentionally selected based on the needs of the study corpus. In conjunction to this, Patton (2002) highlighted that purposeful sampling is preferred when the researcher is trying to strategically select information-rich cases according to the study purposes. The selection of site and participants encourage the emergence of findings that capture the core experiences and shared dimensions of a setting or phenomenon. This sampling strategy is highly considered, and it turns the apparent weakness into strength (Coyne, 1997; Marshall & Rossman, 2014).

This study was conducted to explore the students' understanding in making a decision about global warming issue within the co-curricular context. The administration of research was conducted among the lower secondary school students (Form One and Form Two) from a school in the Rawang district in the state of Selangor, Malaysia. The school selected for this study is one the Fully Residential School, drawing students primarily from middle-class families, but consisting of a wide range of occupations and socio-economic levels, ranging from estate workers to professionals such as engineers and doctors. The selection of the school was based on the purposeful sampling principles, where the site was selected according to the feasibility of the study (Miles & Huberman, 1994). It follows the availability and the best criteria in implementing more effective practice by the school principals in the

Fully Residential School as compared with a typical school (Ghani et al., 2013). The school was also categorised as one of the excellent secondary schools in implementing effective co-curricular activities.

In the Malaysian context, the co-curricular activities range from three different categories (uniform unit, club/society and sports/games). For this study, the club/society was chosen because it represents a content-related category which fits the study needs. It is important to note that there were two clubs/society formed for the lower secondary students: 1) Science and Mathematics Society and 2) Arts Society.

The students were grouped according to their 'Interest Assessments' or 'Ujian Kecenderungan Minat' or scores evaluated at the beginning of school semester. This assessment was initiated to determine the courses that fit the students' interest. In order to achieve the aims of the study, the Science and Mathematics Society was purposely selected as the relevant context for the current study.

According to the previous literature, most of the study concerning SSI were carried out within formal classroom (Callahan et al., 2011; Ideland et al., 2011; Jho et al., 2014; Keskin et al., 2013; Klosterman & Sadler, 2010). In this setting, the evaluations were carried out continuously without a long gap between two activities. To overcome this issue, the current study had requested for cooperation from the school's principal to allocate an appropriate co-curricular schedule and time frame in order to reduce the long gap while gaining more extensive data. This was in line with this context of the present study, which required one-by-one stage of instruction and well-structured time frame for its implementation within the co-curricular setting.

Initially, the school had provided a guaranteed easy access to the students at any time in school hours or after school hours, any day of the week, either weekdays after school or during weekends through the legal approval acquired from the school's principal. One of the main reasons for the selection of these students for this study was the assurance of total cooperation and freedom to proceed with the study.

Thirty out of sixty-five lower secondary school students (Form One and Form Two) were chosen. In choosing the participants, the purposeful sampling technique was used again to obtain a group of participants with an extensive understanding of the central phenomena (Creswell, 2007; Merriam, 1998). The obvious needs for expressing scientific and social perspectives about SSI provided a strong justification to select the students from this school (Zeidler, Herman, Ruzek, Linder, & Lin, 2013). The students came from different classes which learnt general science as their science subject in school. They also had a fundamental knowledge regarding global warming which had been taught during their primary school and lower secondary school. This was to ensure that they were able to fully participate and understand the content of discussions.

Furthermore, this group of students were expected to express a higher interest in working and discussing SSI in the co-curricular context. The teacher's cooperation was also obtained in the form of suggestion on selecting the students who were active and responsive in such activities. This strategy was also relevant to ensure that sufficient data could be collected as this study involved their opinion in the respective activities.

Concerning sample sizes such as the number of school and participants, the principles which emphasise "qualitative inquiry nominated sample typically focuses in depth on relatively small samples, volunteer sample, even single cases, selected purposefully" (Patton, 1997, p. 169) were applied. He highlighted that the selection of a small sample of great diversity ranging from 1 – 40 samples possesses high potential in yielding two kinds of findings in qualitative research: 1) high quality and detailed descriptions of data which are beneficial for documenting uniqueness and 2) vitally shared patterns of cut crossing the data and contribute to the significance of that emerged from the heterogeneity. These two components of findings are highly important in qualitative research (Coyne, 1997; Patton, 1997, 2002). The significances in selecting the school, co-curricular category and number of samples provided sufficient information to understand the complexity of the phenomenon.

Figure 3.3 illustrates the connections between the research site and the participants involved in the study to explore the students' understanding in making a decision about the global warming issue within the co-curricular context.

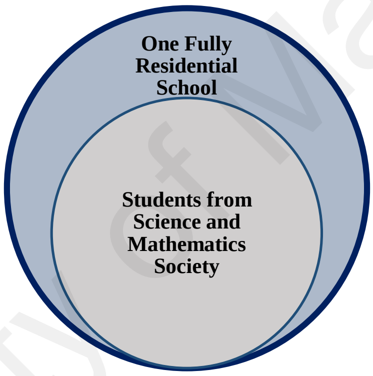


Figure 3.3. The selection of research site and participants

Research Procedure

The procedure for exploring students' understanding in making a decision on the global warming issue within the co-curricular context was divided into two phases. The first phase was the preliminary study, followed by the second phase which was actual research. The procedures of this research were discussed in the following sections.

Preliminary study. Preliminary study acts as the preparatory stage for the researcher to illustrate the ability to manage qualitative research and provide the strength of qualitative methods to entice the research questions (Marshall & Rossman, 2014). In this particular study, the main aim of conducting the preliminary study was to find the feasibility and methods used in determining students' understanding towards making a decision about the global warming issue. This study involved documents, interviews and observations as the sources of data. Therefore, it directly worked as a training platform to refine the methods such as PGO, diary and interview questions which were later used for the actual study. It also becomes a valuable opportunity to practise the interview techniques and observation skills during this stage. The data gathering and analysis procedures in this stage were modified and improved to be used in the actual study. Importantly, the preliminary study provided valuable concerns regarding the process of making the global warming decision and the learning processes which were followed up in the actual study.

The detailed description below describes how the current study formulated and arranged the research questions through the preliminary study. The general procedures during preliminary study were shown in Figure 3.4.

The preliminary study was conducted in a school which was not part of the actual study. Two teachers and twenty students from the Science and Mathematics Society of the school were approached and provided with a research information sheet elaborating the research purpose and procedures and consent forms. Three of the students were purposely selected and thoroughly informed about the interview session following the co-curricular activity.

The observation was later conducted during the co-curricular session to understand the environment and the events happening during the activities. The observation was continued for the SSI group discussion. The PGOs generated during the SSI group discussion were collected and the process was followed by the student interview. The data collected was later thoroughly analysed using the qualitative data analysis.

1. Twenty students selected from Science and Mathematics Society were approached.
2. Subject information sheet and consent sheet were delivered to the students.
3. Three students were purposefully selected for interview session.
4. The environment and activities conducted in the co-curricular context were observed.
5. The SSI group discussions participated by the students were observed.
6. The PGOs were collected from the students.
7. The data was collected through observation and interviews from students on the topic of SSI discussions.
8. The data was analysed from 4 major methods using qualitative data analysis.

Figure 3.4. Procedures for conducting the preliminary study

The schedule for the preliminary study. The preliminary study was conducted within a period of one month in November 2014. The detailed schedule for the preliminary study on the techniques of generating the PGO, student diary, observation, interviews and analysis methods were described in Table 3.3.

Table 3.3

Preliminary Study Schedule on Training Sessions for PGO and Student Diary Activities, Observation Protocol, Interview Protocol and Methods Analysis

Time	Activity
Day 1, Session 1 *(30 minutes)*	**Training session of PGO**: Students were taught about generating a basic PGO with a series of well-known SSI.
Day 1, Session 2 *(30 minutes)*	**Generation of detailed PGO**: Students were facilitated in generating a PGO related to health issues, based on the science unit learnt within their classroom context (Science Form 1 and 2). The sample of PGO was given to make students understand and familiar with PGO.
Day 1, Session 3 *(2 hours)*	**Co-curricular activities observation:** The environment of the activities within the co-curricular setting was observed to deeply understand the nature and potential of this context for learning SSI.
Day 1, Session 4 *(1 hour)*	**Training session to generate the student diary:** The students were facilitated to understand how to generate their personal diary according to the template given. It was prepared to understand the students' perspective regarding their experiences of learning SSI within the co-curricular environment.
Day 2, Session 1 *(1 hour)*	**Generation of PGO:** The first stage of Activity 1 (contextualisation) was conducted. The actual PGO which portrayed the global warming scenario was given to each group to identify the students' prior understanding in socioscientific decision-making.
Day 2, Session 2 *(1 hour)*	**Student interviews**: Three volunteering students were selected based on the students' availability. The students were interviewed for 20 minutes about their understanding in making a decision regarding the issue and their understanding was probed based on the generated PGO.
Day 2, Session 3 *(1 hour)*	**Teacher interviews for researcher's reflection:** Two Science and Mathematics Society teachers were approached. The teachers were interviewed for 30 minutes to understand their perspective regarding their experience in implementing SSI conducted in formal and informal learning environment (co-curricular context).
Days 4-30 *(25 days)*	**Review, Reflection and Evaluation of Methods**: Critical reflection on the preliminary study data was conducted and referred to professionals for comments and betterment. The methods were reviewed and evaluated for the preparation in actual study.

As described earlier, the use of PGO and diary were the two types of document needed in assessing students' understanding in making a global warming decision as well as the factors which influence their learning. The instructions were given to the students prior to writing in their PGO and diary. At this stage, some weaknesses were acknowledged and considered for improvement for the actual study. For example, the use of PGO individually seemed to be irrelevant because the students tended to work on their own instead of working in a team. According to students' opinion, they were equally comfortable using one PGO per group compared with one PGO per student. Therefore, only one manila card was supplied per group to encourage them to collaborate in completing the task.

Identifying the elements of observation is crucial as this aspect functions as a gatekeeper to help with the process (Creswell, 2007). The initial elements of observation identified in the present study included who or what to observe and when and for how long the observation needs to be conducted. As referred to the appropriateness of research focus, observation on the physical and norms of teaching and learning within the co-curricular setting, particular events and activities and the practices of discussion among the students had been added. An observational protocol had been designed (refer Appendix A) to record specific facts and details of what happened at the site.

While conducting the preliminary interview, a few techniques were applied to draw out the in-depth information and meanings given by participants. For instance, an assessment of the suitability and the students' ability to understand the interview questions was carried out by taking note of the students' perceptions of the questions. Weaknesses and ambiguities identified during the interview were duly corrected and were later used in the actual study.

Based on the discussion through peer review, additional interview questions were included to capture the strategies used by the students in generating the PGO. In addition, certain complicated words such as ‘discourse’ and ‘justify’ were changed into the ‘discussion’ and ‘explain’ respectively to avoid misunderstanding. Moreover, the use of bilingual in the interview questions also appeared to be relevant in parallel with the bilingual medium used for formal science learning. Therefore, the refinement of interview protocol included translating the interview questions into the Malay Language.

For the interview, the current study purposely selected students who were not hesitant to speak and share ideas to prevent the problem of inadequate data collection (Creswell, 2014). Other than that, a quiet location that is free from distractions was necessary as it would lead to an accurate information recording process. Memorisation of the questions and their order could also minimise the loss of eye contact with the students, hence providing an appropriate verbal transition from one question to the next. A good listening attitude in place of the frequent speaker approach was taken into consideration to improve the interview process.

In summary, the experiences encountered during this session provided us with some helpful tips and experiences especially in observing, interviewing, and recording of learning environments. It also acted as a platform for training to establish a relationship with the participants, technical use of the video recorders, sitting position while conducting observation and interview, ways in dealing with inquisitive students and dealing with school administration. The preliminary study had also proved the feasibility of a study on how teachers and students worked in co-curricular settings. More importantly, this preliminary study had provided an impact in deciding the best methodology to be used in the actual study. Stable findings were obtained from this preliminary study and the current research convinced the researcher that this study could be expanded to be a broader study using the adopted methodology.

Preliminary findings. The preliminary insights discovered in the preliminary study were explained. It was performed by collecting and analysing completed group work documents such as PGO and student's diary writings and by conducting interviews and observations. The preliminary findings described the collective insights of the students' understanding in making a decision about SSI within the co-curricular context as well as the factors affecting the student learning.

The PGO preliminary findings indicated that students were able to give the justification on the Option 1; stopping the developmental activities to reduce global warming impacts. As referred to Figure 3.5, the students were able to identify the general effect of global warming in terms of the health aspect. However, the type of heart diseases, leukaemia and H1N1 were the wrong examples or evidence of health problems.

For Option 2, they were also able to explain the low educational system affected by continuing developmental activities. From here, the match of scientific and non-scientific knowledge existing in the understanding of global warming can be identified. The students were able to use both scientific and non-scientific knowledge when framing the decision about the SSI (Anna Mikulak, 2011; Zohar & Nemet, 2002).

Based on the PGO, it can be observed that the scientific knowledge was extremely lacking especially in giving evidence to support the reasons (Chang & Chiu, 2008). In conjunction to that, the students were focused on their personal beliefs and preference. of their personal experiences as the resources to support the reasons in the decision-making process (Chang & Chiu, 2008). The following Figure 3.5 illustrates an instance where the students used poor scientific evidence to support their decision stated earlier.

Persuasive graphic organiser, Group 3
Answering Research Question 1 and 2

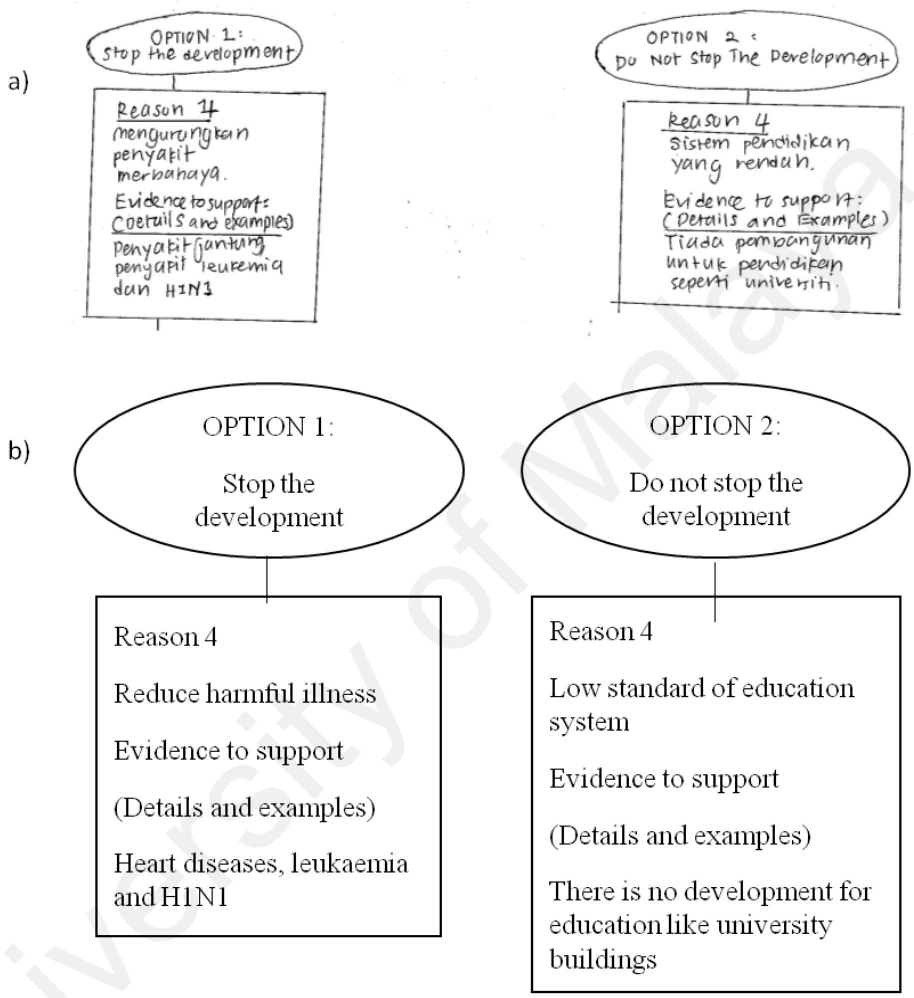


Figure 3.5. PGO Drawn by Group 2 during Preliminary Study
a) Original version by the student
b) Translated version by the researcher

The information from the interviews revealed that the students could refer to the GHG and anthropogenic factors as the contributor to global warming. The reference clearly showed that students had the ability in identifying the factors which affect global warming.

Interview, Student 2
Answering Research Question 1

> "I do not know about the term of greenhouse gasses or GHG previously, but now I realise that GHG such as carbon dioxide and methane are the main contributor of global warming. It increases the earth's atmosphere mainly caused by deforestation and burning of fossil fuels".

According to the preliminary interview findings, the main barriers limiting the knowledge regarding the issue in that particular secondary school were inadequate time and information, poor access to internet connection and lack of socioscientific academic supports or materials. These barriers could be detected from the students' and teachers' interviews transcription respectively.

Interview, Student 1
Answering Research Question 2 and 3

> "My mum always tell me about the importance of hygiene, the impact of open burning. Errr but in this case, I acquire more information from TV and internet. The socioscientific thing is rarely taught in our formal classroom. Err, we just learn it when entering certain topic like natural phenomena. But sometimes we skip."

Interview, Teacher 1
Answering Research Question 2 and 3

> "It will be good if we educate our students beyond the classroom. For instance KLCC, Petrosains and so on. If you stay still in the classroom or school, students will assume that science is only a rigid subject. As we know, science is dynamic, when you watch TV – yes it is science, day and night also related to science. TV, media papers… yes that are the informal resources that can promote students' learning. But seriously I have a big constraint in term of time and how to conduct it in a properly manner".

> "Learning formally in classroom is boring actually. If we implement that kind of activities within co-curricular context, students will realise about the importance and consequences of learning in classroom, co-curricular context and at home! For example, Ohhh I learnt this in class and this is what happened when I am at home... This is what teacher told me! So the students can easily understand and relate them".

In the aspect of work collaboration and flexibility, most of the students preferred to work in a heterogeneous group in terms of gender and achievement level rather than work in a homogeneous group. The combination of different students from

Form One and Form Two of Science and Mathematics Society led them to share ideas, appreciate and understand more about the SSI under study. For example, the following quote illustrates the manner in which the students conducted a group discussion in order to complete the task.

Observation, Group 3
Answering Research Question 3

> "One student (Student 11) has invited all the group members to contribute the knowledge by jotting down the key ideas on an individual paper within one minute stipulated time given. They were then discussed and seek the opinion of how to support the reasons using appropriate evidence".

Instead of polishing on some content and technical aspects, these preliminary findings revealed that there were some data emerging, which could be explained from the aforementioned evidence. This evidence represents the preliminary findings revealed from the preliminary study and it should not to be considered as the final findings or as the final summary of the present study.

Actual study. Research in learning SSI within the co-curricular context was implemented using the qualitative research method. The research was carried out through three stages: Contextualisation, Decontextualisation and Recontextualisation.

Research procedure. This study involved 'entry negotiation'. The formal approval was obtained from the Educational Planning, Research and Development Division (EPRD)-(KP(BPPDP)603/5/JLD.03(29), University of Malaya Research Ethics Committee (UMREC) and Department of Environment (DOE)-(B)B91/110/910/042 before the research commenced. The permission from the school authority was also received three weeks prior to the actual study started. This study involved the familiarisation period to help in establishing a rapport with the participants. It also functioned as a way to include the involvement of the world being studied. An observation was made in the routine of learning and the students' interaction. The strength and barriers encountered by the students in the co-curricular context were also identified.

As an 'instrument' of the study, the researcher acted as the instructor for the three stages of socioscientific instruction (Figure 3.6). Each stage was elaborated in the following section.

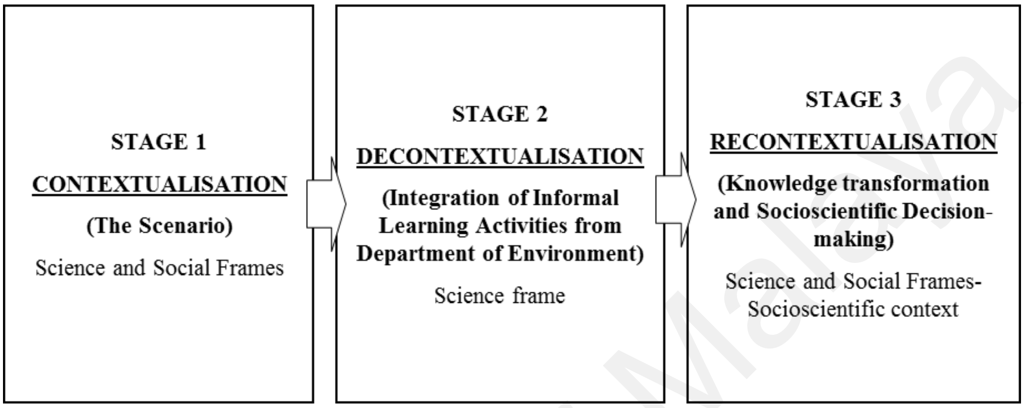


Figure 3.6. The three stages of Contextualisation, Decontextualisation and Recontextualisation of the actual study

Stage 1 – Contextualisation. The contextualisation stage is the initial stage where one complex situation is introduced to trigger the students' intrinsic motivation as well as the students' scientific understanding or prior conceptual knowledge (Vygotsky, 1980). This stage is parallel with the Vygotskian views, emphasising on the intrinsic motivation and scientific understanding as the key learning focus that must be recognised as a starting point in conceptual science learning which evolves within the ZPD. The complex situation which consists of science and social frames, are authentic in nature can be categorised as real life contextualisation, open-ended, relevant to students and having the capacity to develop possible responses as a function of option used (Jiménez-Aleixandre, 2008).

At this stage, the scenario which is relevant and connected to their daily life events must be introduced. The issue is often made attractive by media throughout the students' life. It is infused to directly stimulate interest and meaningful engagement among the students (Hundal et al., 2014b). Furthermore, incorporating an overarching issue into the introduction of an activity can assist students to link the science content knowledge and the issue being studied in order to detect the students' prior understanding and decision-making directions about the issues (Lenz & Willcox, 2012). During this stage, the students will determine their prior knowledge related to the scenario given. It encourages the students' ability in articulating ideas about the issue, thus providing them with relevancy and experiences of daily life which linked to the understanding of the context undertaken (Lewis & Leach, 2006).

The activity was conducted following the instructions suggested in the activity guide about how to introduce the issue to the students. The guide consists of the ideas about appropriate questions and resources to use during this Contextualisation stage. It was also noted with an important remark which did not suggest detailed teaching sequences or work forms. It was free to work with the tasks in a way which was comfortable and appropriate to the co-curriculum regular routine.

In this framework of the study, thirty students were divided into six groups of five, consisting of different class, gender and ages. The rationale of grouping them into five students per group was to allow the effective facilitation of discussion in science learning (Hughes, 2000), following the principles of Malaysian co-curriculum that encourage students' interactions from different backgrounds (MOE, 2016).

At the beginning of this stage, a 5-minute video presentation was carried out as an introduction phase. After that, every group was requested to discuss the global warming phenomena that occurred locally and globally. The objective and procedure of the activity were detailed in Table 3.4.

Table 3.4

The Objectives and Procedures of Activity 1: Global Warming Introduction Phase

Objectives	*Contextualisation* *Global Warming Introduction Phase* 1. To introduce and provide a visually stimulating overview of the topic global warming. 2. To probe students' understanding of the global warming phenomena.
Procedure	Step 1: The students were introduced to the controversies of global warming which relate to the country's development and global warming was provided. Step 2: The students were divided into 6 groups and required to discuss the topic introduced. Step 3: A 5-minute video simulation regarding global warming phenomena was displayed. Step 4: The students were instructed to discuss the global warming situation that happened locally and globally.

The procedure of Contextualisation stage was explained as Figure 3.7. The Decontextualisation stage was then conducted after the Contextualisation stage had ended.

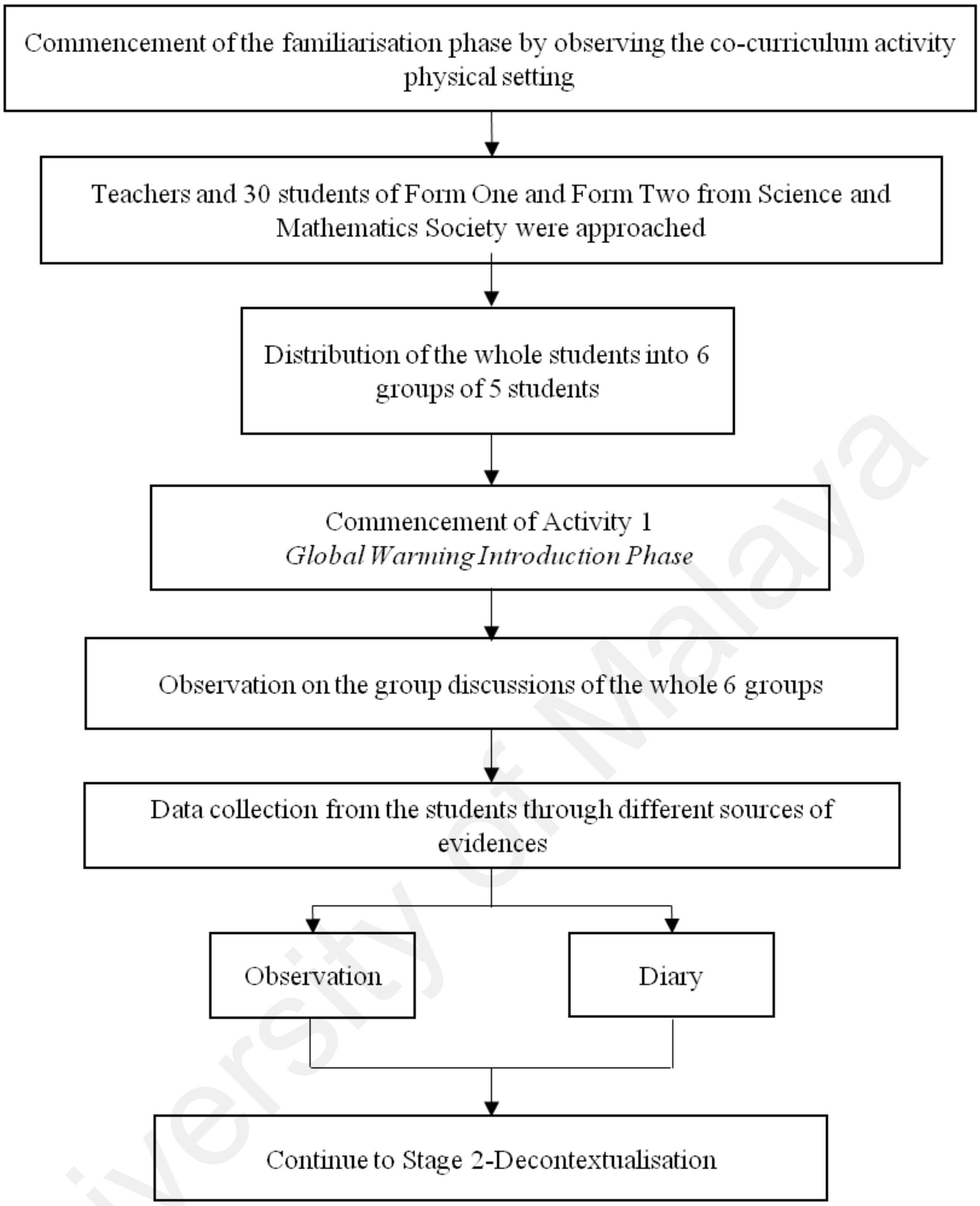


Figure 3.7. Procedure of the study for Stage 1 (Contextualisation)

Stage 2 – Decontextualisation. Decontextualisation is a stage where science learning takes place in the science frame, marking strong scientific principles and scientific concepts and allows the students to develop their social capabilities and interaction skills with a strong science background. The decontextualised learning stresses on the scientific concepts and principles, overcoming scientific problems, investigating and evaluating pertinent scientific information.

In the context of the current study, the designed Decontextualisation stage occurred within the co-curricular context via several activities supported by the Education Department from Department of Environment Malaysia (DOE). The main aim was to break down the complex issue by allowing students to strengthen the scientific knowledge, hence maximising the self-constructed learning. The relevant scientific knowledge and information were decontextualised by providing some activities related to the scenario. This was performed by integrating two activities which were reading posters and exploring the internet for Activity 2 and a talk by a scientist for Activity 3. These two activities were conducted separately in different Science and Mathematics Society meetings, Meeting 2 and Meeting 3.

Due to the current scenario of local issues related to global warming, there were many cases interrelated to the students' personal experiences. Therefore, the choice of both activities was appropriate, emphasising on quality lifestyle and global warming risks in a rather normative or formal way. From this informal learning ways, students were supposed to acquire new scientific knowledge and concepts regarding the issue presented in Stage 1. The content of events emphasised on the general scientific and context knowledge about global warming, climate change, health and other related information.

For Activity 2, which was reading posters and internet exploration, simple instructions were given such as reminding them to follow the activities they were supposed to do or to get them to stay focus. This activity was introduced by a brief introduction on the importance of gaining knowledge of global warming issues and connecting it with students' daily life experiences. The students were then provided with posters and brochures from DOE and each student was also provided with a computer. From the resources supplied, they were required to find scientific information based on the guiding questions as follows:

1. What is global warming?
2. Is global warming a challenging problem?
3. What are the pollutants of global warming?
4. What is the controversy associated with global warming?
5. Find appropriate scientific information related to global warming.

The objectives and procedures for Activity 2 were portrayed in Table 3.5

Table 3.5

The Objective and Procedures of Activity 2: Reading Posters and Exploring Internet

Objectives	*Decontextualisation* *Reading Posters and Exploring the Internet* 1. To develop students' understanding of science as a complex social activity. 2. To provide an ample evidence from multiple scientific perspectives of the global warming. 3. To stabilise students' scientific understanding towards making decision about global warming issues.
Procedure	Step 1: The students were provided with posters and related scientific brochures pertaining to global warming. They were also provided with one computer per person. Step 2: They were requested to identify any scientific information they gained from the activities. A simple guidance was given, emphasising on the scientific perspectives of the whole scenario (Refer Appendix E)

Activity 3 featured a talk by a scientist and this was conducted in a different episode. The scientist initially explained about global warming by presenting a video and a slide show presentation within a 45-minute duration. A quiz session related to the information discussed earlier was then conducted. At the end of the activity, the students were encouraged to participate in a "Question and Answer" session. The objectives and procedures for Activity 3 were portrayed in Table 3.6.

Table 3.6

The Objectives and Procedures of Activity 3: Science Talk

Objectives	*Decontextualisation* *Science Talk* 1. To infuse scientific knowledge about global warming issues. 2. To provide scientific perspectives and opinion regarding global warming. 3. To integrate informal learning to support formal knowledge gained from classroom.
Procedure	Step 1: For introduction, the students were reminded by the teacher to pay full attention to the talk given by the scientist. Step 2: The students were requested to write any information presented during the talk. They were also free to post the questions related to the issues during the presentation. Step 3: The science talk commenced in a 45 minute session which included video and slide show presentation. Step 4: The quiz session was carried out, emphasised on the information discussed earlier. Step 5: The 'Question and Answer' session from the scientist and students took place at the end of the activity.

Figure 3.8 shows the procedure of conducting Stage 2 - Decontextualisation. The Recontextualisation stage was conducted right after the Decontextualisation stage had ended.

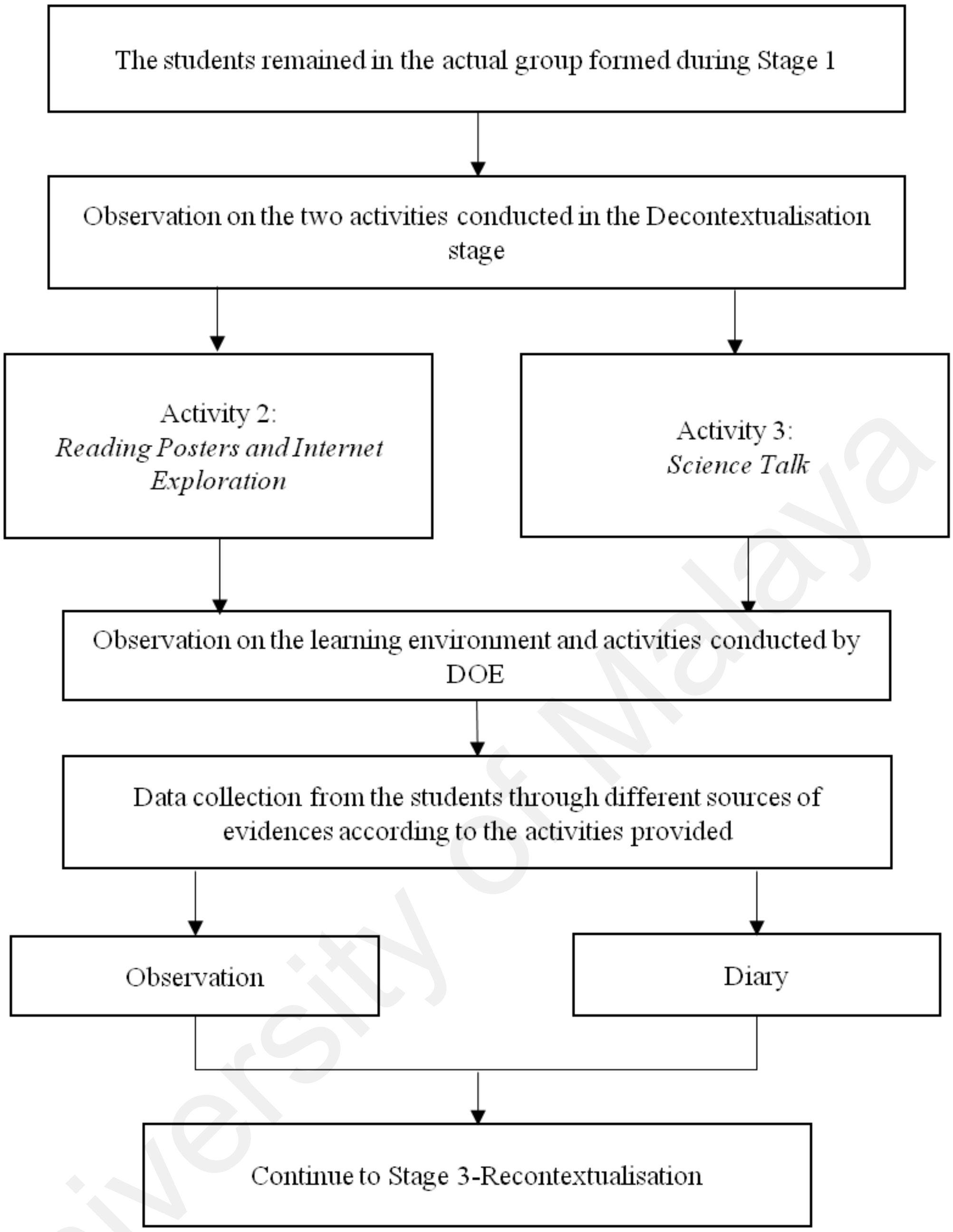


Figure 3.8. Procedure of the study for Stage 2 (Decontextualisation)

Stage 3 – Recontextualisation. Recontextualisation is the stage where the science learning is consolidated through the transformation of knowledge into the socioscientific frame, promoting students' understanding and decision-making (Holbrook & Rannikmae, 2009). This stage can also encircle the consensus for decision-making in a social environment and provide a platform for the enhancement of students' oral and written presentation skills. According to Vygotsky (1980), the opportunity of connecting relevant activities enables the students to relate new and old science knowledge, hence leading to knowledge map construction.

At the beginning of this stage, every group formed previously was given 40 minutes to generate a PGO on the scenario entitled 'Global Warming: A Silent Killer!'. After the PGO generation was completed, each group was required to assign one student to carry out an oral presentation. The presentation session was aimed to enable the students to give detailed justification on the decision they made. While conducting the presentation session, each group was suggested to write down any information which they considered as important and meaningful for the SSI under discussion. They were also motivated to increase their knowledge by sharing and connecting ideas among peers (Zeidler & Nichols, 2009). Table 3.7 shows the objectives and procedures of the final activity titled 'Let's Organise Ideas and Decide!'.

Table 3.7

The Objective and Procedure of Activity 4: Closure Phase - Lets Organise Ideas and Decide!

Objectives	*Recontextualisation* *<u>Closure Phase – Lets Organise Ideas and Decide!</u>* 1. To provide a platform for each group to share and enrich their knowledge related to global warming. 2. To provide a platform for students to organise the ideas and make a final decision about the scenario posted earlier. 3. To build up students' confidence in facing the socioscientific controversy.
Procedure	Step 1: Every group was requested to organise their ideas/knowledge and generate a PGO based on the scenario 'Global Warming; A Silent Killer!'. Step 2: Every group was requested to make an oral presentation to convince people about the decision undertaken. Step 3: One student from every group was requested to make a final decision by restating their position, summarising the reasons and giving evidence behind the decision undertaken. They were free to consider the point of views and information presented by their friends. Step 4: Note taker: When the other group agreed on the issues (for example, whether or not the development is harmful), they disagreed mostly because they fully relied on the scientific facts without taking considerations from multiple angle. Students were permitted to make their decision by considering moral values or personal motives. Again, students were asked to make their own judgement and make a decision on the scenario given earlier.

After completing the whole study, the six focus group students were purposely selected for an interview session. Two weeks were allocated for completing the interview session due to the time constraint encountered during the examination period. All interviews were recorded using audio tapes to avoid the loss of essential data. Figure 3.9 demonstrates the procedure of the study that was conducted during Stage 3 –Recontextualisation.

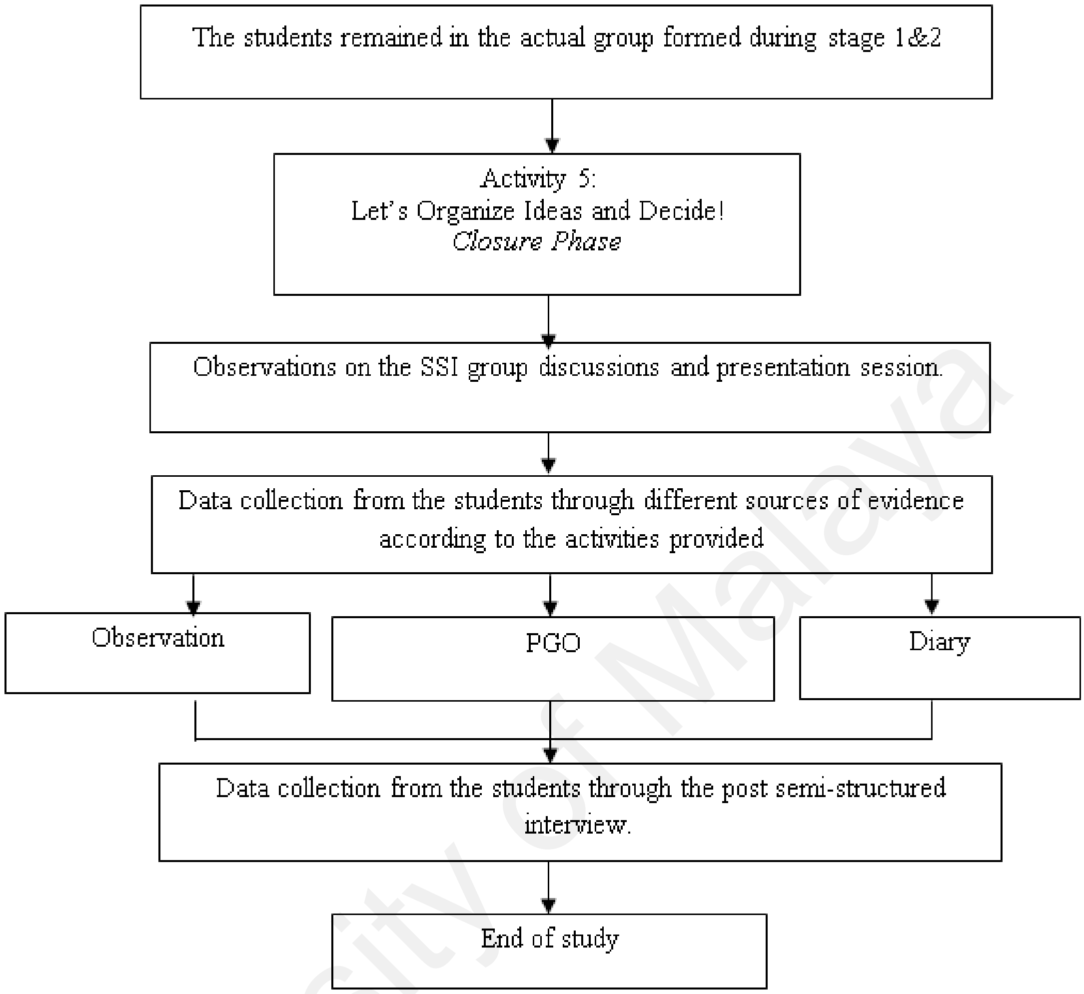


Figure 3.9. Procedure of the study for Stage 3 (Recontextualisation)

The overall procedure and timeline of the actual study were portrayed chronologically in Table 3.8.

Table 3.8

Chronology of Procedures for the Actual Study

Stage	**Stage 1 (Contextualisation)**	**Stage 2 (Decontextualisation)**	**Stage 3 (Recontextualisation)**
Timeline	April 2015	May – August 2015	August – September 2015
Participants	Participants of the Actual Study		
Event	Meeting 1 29 April 2015	Meeting 2 and Meeting 3 20 May 2015 and 19 August 2015	Meeting 4 26 August 2015
	- Observation on the environment and students' interaction - Initiation of the introduction phase (Activity 1) - Distribution of diaries to explore the factors that influence students' learning.	- Observation of the environment and students' interaction - Implementation of two different activities (Activity 2 and 3). - Distribution of diaries to explore the factors that influence students' learning.	- Observation of the environment and students' interaction - Initiation of the closure phase to explore students' understanding in making SSI decision (Activity 4) - Distribution of PGOs to explore students' understanding in making a decision on global warming issue - Distribution of diaries to explore the factors that influence students' learning. - Initiation of the interview session to explore students' understanding in making a decision on global warming issue as well as the factors that influence their learning.

Note Socioscientific Instruction: Four activities conducted during Stages 1, 2 and 3.
Activity 1: Global Warming Introduction Phase
Activity 2: Reading posters and Internet Exploration
Activity 3: Science Talk
Activity 4: Closure Phase - Let's Organise Ideas and Decide!

Data Collection

This section describes four data collection techniques conducted for the analysis: observation, interviews, PGO and diary. During the data collection process, all participants were informed that the responses and tasks tested in this study were not evaluative. They were also informed that their responses to the survey would be kept confidential and would only be used for academic purposes.

Six months were allocated to carry out the entire process of the data collection. The process involved the preliminary observation as well as the actual observations to all activities, the training session for the PGO generation and the interview session at the beginning and the end of the socioscientific instruction. Figure 3.10 represents the data collection timeline during the actual study, which was chronologically conducted from April to September 2015.

Stage 1 Contextualisation	Stage 2 Decontextualisation	Stage 3 Recontextualisation
Activity 1: **Global Warming Introduction Phase** - Video Simulation - Group Discussion	Date: 20 May 2015 Time: 3.30 pm – 4.45 pm (1 hour and 15 minutes) Date: 19 August 2015 Time: 3.00pm – 4.30 pm (1 hour and 30 minutes)	Activity 4: **Closure Phase** - Group Discussion - Group Presentation - Generating Persuasive Graphic Organizer (PGO)
Date: 29 April 2015 Time: 3.30 pm – 4.15 pm (45 minutes)	Activity 2: **Reading Posters and Internet Exploration** - Poster Reading - Internet Exploration Activity 3: **Science Talk** -Video and Slide Show Presentation -Quiz -Question and Answer Session	26 August 2015 Time: 3.00 pm – 4.45 pm (1 hour and 45 minutes)
Observation, PGO, diary and Initial Interview	Observation and diary	Observation, PGO, diary and Initial Interview

Figure 3.10. The timeline for data collection during the actual study

Observation. Observation is another source of data in qualitative research. This technique brought the researcher to the first-hand encounter with the phenomenon of interest (Merriam, 1998). Identifying the elements of observation is crucial as it plays as a gatekeeper, helping in this process. Creswell (2007) suggested that the researcher must initially identify the aspects of who or what to observe and when and for how long the observation needs to be conducted.

Prior to the actual study, a Science and Mathematics Society meeting was observed for the familiarisation purpose. This initial observation provided the current study with an overview of the society management, the physical settings, the norms of teaching and learning and the occasion which occurred during the group discussion. The observation also allowed the current study to discover the overall patterns of behaviour and relationships in the norms of the co-curricular setting of the target population. After such patterns were identified, the focused observation was used in the three later stages of the study. For example, the current study used the early observation to discover and note the ‘interaction of passing the notes between peers in a group’, in addition to the students’ words ‘not confident in sharing ideas’. This indicated the familiarisation of the group which may hinder the students’ learning within this context.

In this study, the observation protocol (refer Appendix A) was employed during the three stages of instruction to examine the students’ understanding in making a socioscientific decision within the co-curricular context. During the observation, the wide aspects of behaviour and relationships such as portraits of the informants, the physical setting, students’ interaction and body language were recorded without interrupting the students’ work during the task performance. The observations included the way the students handled the group discussion and generated their PGO and diary usage to identify the students' preferred method. Additionally, any interesting observation was recorded in the field notes. The current study also employed constant analysis of the observation to diagnose the situation without being affected by any personal bias on expected outcomes.

In addition to direct observation, all the learning sessions were also recorded using the video recorder. Six cameras were used to simultaneously capture the entire phenomena including the students' behaviour and actions. One of the technicians was also assigned to capture the whole angle view and focus on any groups which exhibit uncommon and notable behaviours or situations. For example, the non-verbal cue of student A who 'took a nap' was later used as an evidence to support the students' statements which indicated that they had reached the point of saturation.

All the observation field notes were transcribed and analysed accordingly. The observational data were triangulated with other data for the sake of gaining validated findings.

Interviews. The interview is defined as any interaction in which two or more people are engaged in direct contact and benefits for at least one party to learn something from the other (Taylor, Bogdan, & DeVault, 2015). According to Merriam (1998), interviewing is necessary if the study was restricted to the observation of behaviours, feelings or how participants interpret the world around them. She added that interview method enables the researcher to interpret another person's perspective, which permits researcher's entry into the participants' perspectives and understand the individual's ideas in detail (Patton, 1980).

The current study applied the general guideline in qualitative research where the researcher did not only aim to study a phenomenon or individuals but also to collect extensive details about the site or individual studied (Creswell, 2007). However, interviews have several disadvantages in the process and could be time consuming, thus the method could not be applied to a large sample size. As for this reason, the present study limited the size of the sample to 6 students, representing each of the group involved.

The interviews were semi-structured and deemed to be suitable for the current study. In this research, an interview protocol was constructed to discover the overall research questions (Appendix B). By using semi-structured interviews, the current study was able to explore the student's understanding when making a decision, to determine the issues experienced by students during socioscientific learning and their perception about the process of making a decision. Additionally, the student's beliefs on what was important in the process of making a decision were also explored.

The time intervals between the observation on students completing the PGO tasks and the interview session were fixed to be short so the students would be able to recall the knowledge and skills shown earlier. The use of interviews was recommended because it serves as a fruitful procedure for triangulation to enhance the internal validity in a complex topic such as students' learning in SSI (Meijer, Verloop, & Beijaard, 2002).

The interview protocol used followed the general format that had been completely refined after the preliminary study. The general interview protocol was detailed in Table 3.9.

Table 3.9

General interview protocol format during the actual study

Interview Steps	Interview Protocol
1.Building a Rapport	The researcher introduced and explained on the aim of the interview. The private and confidential terms used in this interview were explained and the rule of no "correct" and "wrong" answers were emphasised to focus on the importance of students' perspectives.
2.Probing Students' Information	Students were permitted and encouraged to explain freely about the issue until the discourse reached the maximum state. Critical awareness on any key statements stressed by students was taken. Students' narratives were obtained through audio-recorded interviews, and the guiding questions were asked accordingly (refer Appendix B).
3. Summation	The students were given the opportunity to ask and make any final questions.
4. Analysing the Discourse	A deeper understanding was acquired on individual students' understanding in socioscientific decision-making and perspectives regarding the co-curricular context. The audio-recorded narratives were transcribed and analysed to obtain verbal documentation.

The interview session was commenced by building rapport with the students. The central purpose and the procedures that were used in the interview were informed verbally in order to let them understand, feel comfortable and acquire information about the protection of human subjects (Creswell, 2007). Subsequently, the students' information was probed by encouraging them to explain the global warming issue as well as the factors' affecting their learning, until the discourse reached the maximum state. Non-directive questions were asked to get maximum and valuable information, such as "Describe how you would handle this problem".

Moreover, a considerable amount of time was given for the interview session so the students could be interviewed by their personal ability to concentrate and provide meaningful data. The data collection processes were prolonged to collect additional data and these were established as conventional practices for the study. The selection of six students which represented their group was manageable and likely to provide adequate sources of data. For summation, the student was given the opportunity to ask and make any final questions.

The interview sessions were maintained by polishing the repertoire by addressing the uncomfortable silence, echoing and letting people talk (Berg & Lune, 2014). Uncomfortable silence involves consciously creating a long, silent pause after asking a student a question, even if the student offers only one word or a cryptic response. This strategy leads to the formation of a comfort zone and letting them to freely talk. This was conducted by tolerating pauses in the conversation, thus, allowing participants to reflect and then break the silence themselves with suitable information (Kvale, 1996).

As suggested by Merriam (1998) the conversational interaction was maintained in the current study in order to gain deep exploration about the students' understanding, why they chose to make the final decision and the factors that influenced learning within this context. Furthermore, the conversational interaction with the students was created by utilising the same level of the language normally used by them. The Malay Language used in the teaching and learning context differs slightly from the colloquial Malay Language used by the students outside of the classroom setting. The use of colloquial Malay Language during interview session had incredibly contributed to a friendly conversational atmosphere. Despite using colloquial Malay Language, the questions were asked based on the interview protocol (refer Appendices B).

The discussions were always followed with probing questions to get an in-depth meaning of the learning experience within this setting. A few examples of probing questions include, “Can you tell me more about the ideas you have mentioned?”, “What is the relationship between the ideas you have mentioned?” and “Can you give me the examples of GHG?”. All interviews were recorded using an audio recorder and later transcribed verbatim to avoid the loss of any useful information.

Document – PGO. Creswell (2014) pointed out that the document is a valuable source of information in a qualitative research. In this study, one of the documents used as the source of data was the PGO. As discussed earlier, PGO is a visualised tool developed by the researcher aiming to explore the students’ understanding in making a decision about SSIs. Besides, it helps students to visualise the decision-making structure, hence, improving their decision-making skills (Halim & Mohd Saat, 2015).

Prior to the contextualisation stage, students were exposed to a training session emphasising on the process and skills to generate the PGO. The main emphasis of this session was to ensure that students would be well enabled to generate a highly-ordered and well-structured PGO following the elements of decision-making model highlighted earlier. The training session consisted of a brief discussion of what a PGO is, including some visual examples of showing the nature of the PGO.

Such PGO was unfamiliar and atypical to them, thus, a 1-hour training session was required to provide the students with adequate skills. Also, the students were distributed with the PGO sample that emphasised on the obesity scenario (refer Appendix C). The session was also conducted in a way that was consistent with the research method, including step by step instructions detailed in Table 3.10.

Table 3.10

Instructions Provided to the Students on the Process of Generating the PGO

Step	Instruction
1	Read and understand the socioscientific scenario carefully.
2	Draw the two boxes of options: Positive (yes) and negative (no) options respectively.
3	Map out the major reasons of each option you know about the SSI given.
4	Write down these major reasons for each option into the 'ovals' drawn.
5	Write down the evidences to support your reasons. You may use the terms you know about the issues (examples: If we are to make a reason about "obesity", we may include the evidences to support the reason such as carbohydrates, fats and calories intake). You can present any form of evidences such as pictures, bills, newspaper cuts and so forth.
6	Think about how each of these reasons and evidences are related to one another.
7	Once you are satisfied with the way you have presented your group ideas, discuss with all the group members of what is the best option to take.
8	Restate your option and summarise your reasons to support your group option. You can rewrite your evidences or solutions to make a strong supportive decision.

The PGO task was administered during Activity 4. During this course of instruction, students were allowed to start their discussion by contributing their own ideas of how various science and social aspects were related to the 'Global Warming: A Silent Killer' scenario. The scenario was described as follows:

> *"The earth is warming! By 2025, global warming in Malaysia is projected to compound pressures on humans, natural resources, and the environment. These impacts occur as a result of association with the rapid development of urbanisation, industrialisation, and economic development. There is now overwhelming scientific consensus that it is happening, and its effects are numerous and varied, accelerating and affecting all people, considering its surprising positive and negative impacts. However, we cannot deny the importance of these development activities because they have assumed a primary role in bettering our lives. You were assigned as an expert advisor to the Department of Environment, Malaysia and required to make a decision about whether to stop or not stop the developmental activities to reduce the impact of global warming."*

Based on the scenario given, the students were required to make the decision regarding the choices of stopping or continuing the developmental activities in order to reduce global warming. The decision made by the students needed justification for support, including any forms of evidence such as words and visual presentations. Furthermore, they were allowed to freely organise their ideas using PGO structures (refer Appendix D) which they generated themselves as there is no right or wrong PGO evaluated.

During the PGO administration, the researcher repeated the instructions whenever needed and the students were free to ask any question to clarify the subject and terms they did not understand. They were given 60 to 90 minutes to discuss and generate the PGO. Every group was required to submit their group PGO using a piece of manila paper on which they used to present their ideas to make a decision about the scenario given.

Document – Diary. The student's diary is seen primarily as a log of what students do in their activity within the phenomenon under study. A qualitative researcher might consider this kind of data in the data collection process (Glesne, 2015). She suggested choosing techniques that were probably able to elicit data to advance understanding of the phenomenon, contribute dissimilar perspectives on the same matter, and make operative use of the time available for data-collection. Creswell (2014) also stated that the use of document collection such as diaries would yield rich data for the thick description of this phenomenon.

In this research, the purpose of utilising students' diaries was to explore the students' learning, particularly on their understanding in making a decision related to global warming. Moreover, the use of the diaries requires the students to reflect on the influential factors which were connected to their socioscientific learning. It included the strategies in solving the tasks, describing any strength or problems that they faced and the ways they managed to overcome them, the observation that they had made and their reflection about the activity.

A protocol for the diary (refer Appendix F) was administered to seek the student perspectives regarding the ongoing learning experiences conducted within this context. The suitable diary entries that should be included were decided through the discussion with peers and professionals. Sample entries for the diary were provided to serve as a guide and focus for the students and to ease the students' writing process compared with formulating the entries on their own (refer Appendix G). The entries were connected and arranged in an orderly manner following the suitability of each activity. The following diary protocol was the instruction provided to the students to complete the entries:

Guide: Write about a specific experience that you are having when conducting the following activity within the co-curricular setting. This experience can be positive or negative for you. Provide details about the following section:

1. Do you like/dislike this activity?
2. Which part of the activity you like/dislike the most?
3. Why do you like/dislike the activity? Use your own words to describe it.
4. Does the facilitator/friends help in making you understand better? Please elaborate.
5. Do you prefer working in a group or individually? Why?
6. Based on this Activity 1: 'What is Global Warming', how do you solve the problem presented through the scenario given? (Global Warming: A Silent Killer!)
7. How do you complete the task? Can you show me how this is done?

8. Do you understand more about global warming in terms of scientific and social aspects? Please describe.
9. Where did you get the information/ideas stated above?
10. Are there any additional comments that you would like to address on your whole experience with this activity?

The students were required to complete their diary entries and express their opinion after they had been involved in every activity conducted in the co-curricular learning context. All diaries were collected right after the completion of every activity. 5 minutes were allocated for the diary completion.

Data analysis was conducted continuously and iteratively throughout the data collection process from April 2015 until December 2016. The different data sources were compared with one another for the triangulation of emergent themes and as an authentication mark of excellence for the qualitative research. Peer review was employed simultaneously, acting as an additional element of rigour (Creswell, 2007).

Data Analysis

Data analysis is a process of bringing order, structure, and meaning to the mass of collected data (Marshall & Rossman, 2014). Patton (2002) stated that "ideas for making sense of the data emerge while still in the field constitute the beginning of analysis; they are part of the record of the field notes. Recording and tracking analytical insights that occur during data collection are part of fieldwork and the beginning of qualitative analysis" (p.436). Additionally, Glesne (2015) forwarded that the beginning process of data analysis is conducted simultaneously with the data collection. It assists the researcher to focus and shape the study as it proceeds.

In this study, the students' understanding in making a decision was observed during the socioscientific instruction conducted within the co-curricular context. The socioscientific instruction was carried out by dividing students into groups to let them decide about the global scenario given. Each team responded to the scenario following their shared understanding which consisted of science and context knowledge. Thus, there were variations in the global warming understanding. The different ability in applying their comprehension when making global warming decision and the factors influencing the socioscientific learning within the co-curricular context were analysed, hence, acting as the primary phenomenon to be explored. It is imperative to mention that four data sources were utilised to address the research questions. The summary of the data gathered in this particular study is shown in Table 3.11.

Table 3.11

Summary of Data Sources

Sources of Data	**Summary**	**Stages of Data Collection**
1.Interview	Conducted using face-to-face interview technique	Stage 3– Recontextualisation
2.Observation	Observation of the group discussion and learning atmosphere	Stage 1 – Contextualisation Stage 2 – Decontextualisation Stage 3 – Recontextualisation
3.PGO	Generated during the execution of decision-making task	Stage 3 - Recontextualisation
4.Diary	Diary entries collected from the students right after the four activities	Stage 1 – Contextualisation Stage 2 – Decontextualisation Stage 3 – Recontextualisation

Altogether, there were six PGOs and 120 diary entries from the students. Furthermore, there were twelve audio recordings derived from the students' interviews. A total of 4 activities were observed during the socioscientific instruction, resulting in 4 hours and 30 minutes of video recording. These were transcribed verbatim into electronic files.

Constant comparative method of data analysis. As the generic qualitative became a research design for this present study, the data was analysed using the standard procedures of the constant comparative method. The constant comparative method of data analysis was used to compare incoming data constantly (Merriam, 1998). Corbin and Strauss (2015) highlighted that the data must be chronologically collected and analysed and structured by the major analytical procedure. It involved open, axial, and selective coding processes. This was an endeavour to understand that both the 'structure' (why) and 'process' (how) were inherent in the research questions which was to explore the students' understanding in making a global warming decision within the co-curricular setting. Specifically, the Corbin and Strauss (2015) data analysis strategies were selected because these provided more detailed steps in the process of data analysis (Creswell, 2007).

The specific procedures and canons described in Figure 3.11 provide the major basis of data analysis process for this study. Figure 3.11 illustrates the overview of 'back and forth' or the dynamic approach to data analysis procedure building from the bottom to the top or vice versa. The data analysis proceeded on two levels which were data familiarisation and microanalysis. In this study, the data familiarisation process initially began by organising and preparing data for analysis. The process involved transcribing interviews and field notes and optically scanning the PGOs. After that, the data were read and examined which provided an overall sense of information, thus acted as the opportunity for reflection on the all-inclusive meaning.

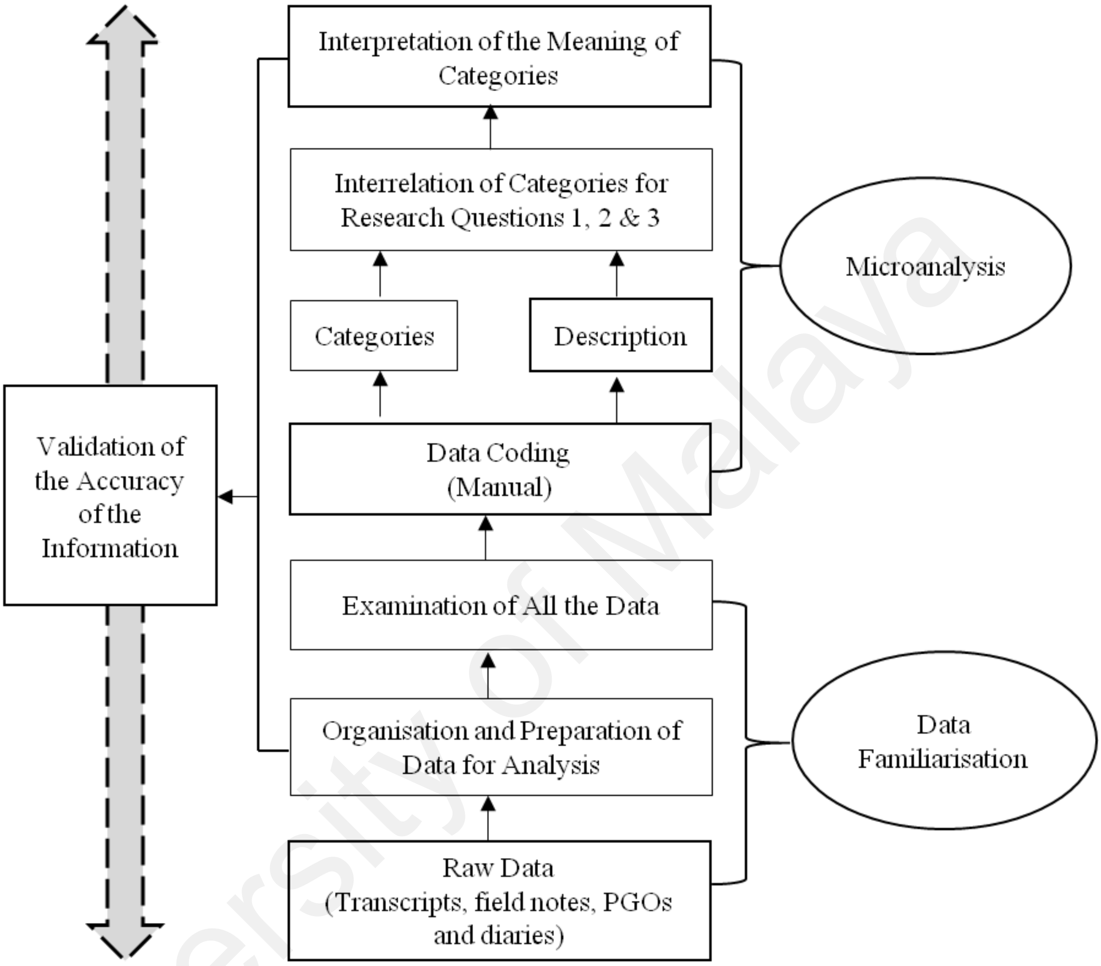


Figure 3.11. Data analysis procedure using constant comparative method

Early in the familiarisation level, one of the transcribed interviews which was found as relevant was chosen for a thorough examination. A thorough understanding of the underlying information on the interview was obtained. Additional notes on the interpretation of the transcript were also documented on the margins of the transcript to record the general thought together with the impression of the overall depth and credibility. For example, the tone of "heterogeneity" idea for the statement forwarded by a student *"I like working with juniors and seniors! They have different experiences that can help in solving this problem"* was reflected. This statement provided the researcher with an answer for the factors that influenced students' learning within the co-curricular context.

The second step of analysis involved a more rigorous, detailed and systematic step (microanalysis). The process involved generating categories of information according to three measures of analytical techniques: open coding, axial coding, and selective coding. As suggested by Creswell (2014), consideration was given on the three aspects during the overall coding process which were related to the type of codes to develop when analysing the data. They were 1) codes on topics that the readers would expect to find, 2) codes that were not anticipated at the beginning of the study and, 3) codes that were unusual and provided interest to the readers. Additionally, the coding process provided an encouragement to think forward about the data appropriateness for the phenomenon explored. The codes are usually connected to 'chunks' and varying size-words, expressions, judgements, associated or independent to a specific setting (Miles & Huberman, 1994).

The process of open coding was conducted where the data was organised by imaging segments and writing an appropriate word representing a category in the margin (Corbin & Strauss, 2015; Gretchen & Sharon, 2011). Corbin and Strauss (1990) pointed out the purpose of open coding is to fracture the data, thus, forcing preconceived notions to be investigated against the data itself. They added that the researcher might inadvertently group information in a category where they do not analytically own, when he or she should group it by comparing information in a systematic means. This process enables error detection and eventually locates the data and concepts in proper classifications.

The unit of data from the observation, interviews, PGOs and diaries was studied, analysed and compared with the previously analysed data. A continuous comparison was conducted on the data to generate the appropriate categories for each research question. In this study, the process of open coding was started with a small part of relevant data to guide the process of forming a set of initial categories. The detailed line-by-line analysis was carried out where transcribed observations were compared with others to identify the commonalities and differences. This method enabled the grouping of the similar interactions to form categories and sub-categories. For example, several interactions between 'a girl and two boys from different group' which appeared to be directed as 'flexibility in learning' were noted and the interactions were labelled as 'learning flexibility'. From here, the category was subdivided into specific characteristics or dimensions. The category 'learning flexibility' had the property type, which could be dimensionalised into homogeneity and heterogeneity. In making the next coding, other examples of 'learning flexibility' were searched and specific notes of a different kind flexibility such as preference, familiarisation and so forth were documented.

Then, the process of axial coding was conducted by relating and grouping the major ideas that were linked to one another. In this stage, the categories identified were compared and later linked to other categories. The process was performed to seek the relationship, hence, to be tested against other data. A precaution was taken on the sub-categories and dimensions as the two must be connected and related to the categories. Following the previous step on 'learning flexibility', a further analysis on the signs of learning flexibility was conducted by scrutinising the data to explain the situations that facilitate or inhibit learning, the types of learning, and the consequences.

Despite the abundance of the collected texts and images, not all of them were usable as they were not answering the research questions. The data was thoroughly screened to focus only on the appropriate data. According to Creswell (2013), the rationale of this process is to aggregate data into a small number. For example, the aggregation process in this study occurred where the code for 'positive thinking' was eliminated as it was inappropriate in the context of the current study.

During this analytic stage, a previous experience of my teaching within the co-curricular context was required to facilitate the analysis. The circumstances that might lead the students to work with a different gender and the possible consequences were thoroughly considered. It could reflect 'who', 'when', 'why' and 'how' the learning flexibility took place to link the category to a more specific group.

The analytical process was followed with organising and structuring the condensed data into matrices. The matrices assisted in evaluating and drawing a conclusion from the emerged findings. Miles and Huberman (1994) described this analytical process as 'data display' that necessitates the analysis of matrices from many sources of data.

The next step concerned about the selective coding where the process of choosing one category to be the core category was scrutinised. During this stage, the core category emerged and represented the central phenomenon of the study. The identification of the core category was confirmed by reflecting questions like "what can I say to conceptualise my findings using a few sentences?" and "what is the variation between these categories?". The use of the diagram in the integration of categories was considered to overcome the difficulties in determining and finalising the core categories.

Beyond identifying the categories during the coding process, the categories were also interconnected into a storyline. The categories were shaped into a general description. Repeated discussions and reviews with professionals were required to advance the categories and sub-categories to be properly conveyed in the findings. After several trials on writing the qualitative narrative were conducted, the current research decided to elaborate the findings by discussing the categories in details rather than using the chronology of events.

A repeated 'abstraction process' was also conducted specifically in the later phase of selective coding. According to Corbin and Strauss (1990), this method enables the researcher to verify critical reflections regarding categories unified around the phenomenon of the study and categories that require further clarification are filled in with evocative detail. They added that for the last categories or framework to have explanatory power, both categories and sub-categories must occupy conceptual density. The whole data was revisited and circumnavigated to fill the framework gaps. The process of abstraction was conducted over the entire course of the study to enable the generalisation for the qualitative research (Corbin & Strauss, 2015).

Overall, the sample of open coding was represented as in Appendix J. The coded transcripts were then moved into the matrix (Appendix K). At the beginning of open coding, there were 224 open codes which emerged from the whole research questions. The codes were then collapsed into 30 different categories during axial coding. The selective coding then ended with 10 core categories. They were related and compared to represent the central phenomenon of the study (Corbin & Strauss, 1990). Figure 3.12 summarises the complete visual model of the coding process for the overall research questions.

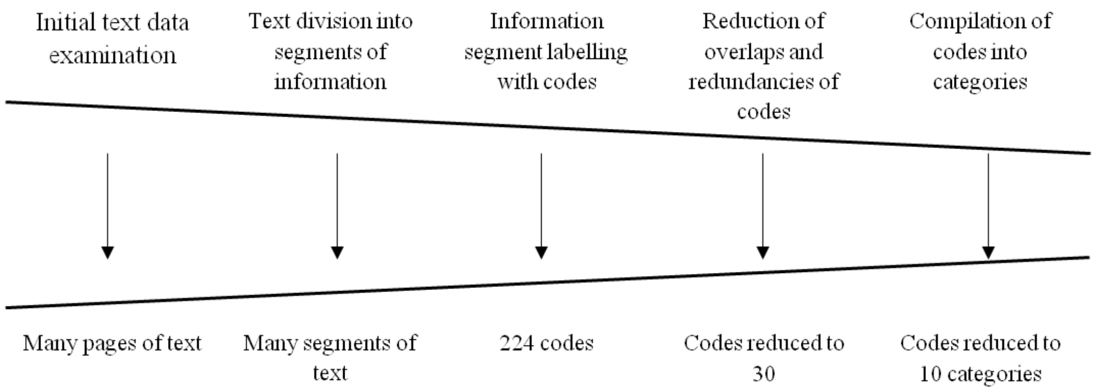


Figure 3.12. A Visual Model of the Coding Process

It is important to note that the first draft of categories emerged six months after the data collection ended. Initially, there were 14 categories and 41 sub-categories. Figure 3.13 is the graphical representation of the categories and sub-categories created to properly divide the responses provided by the data analysis process.

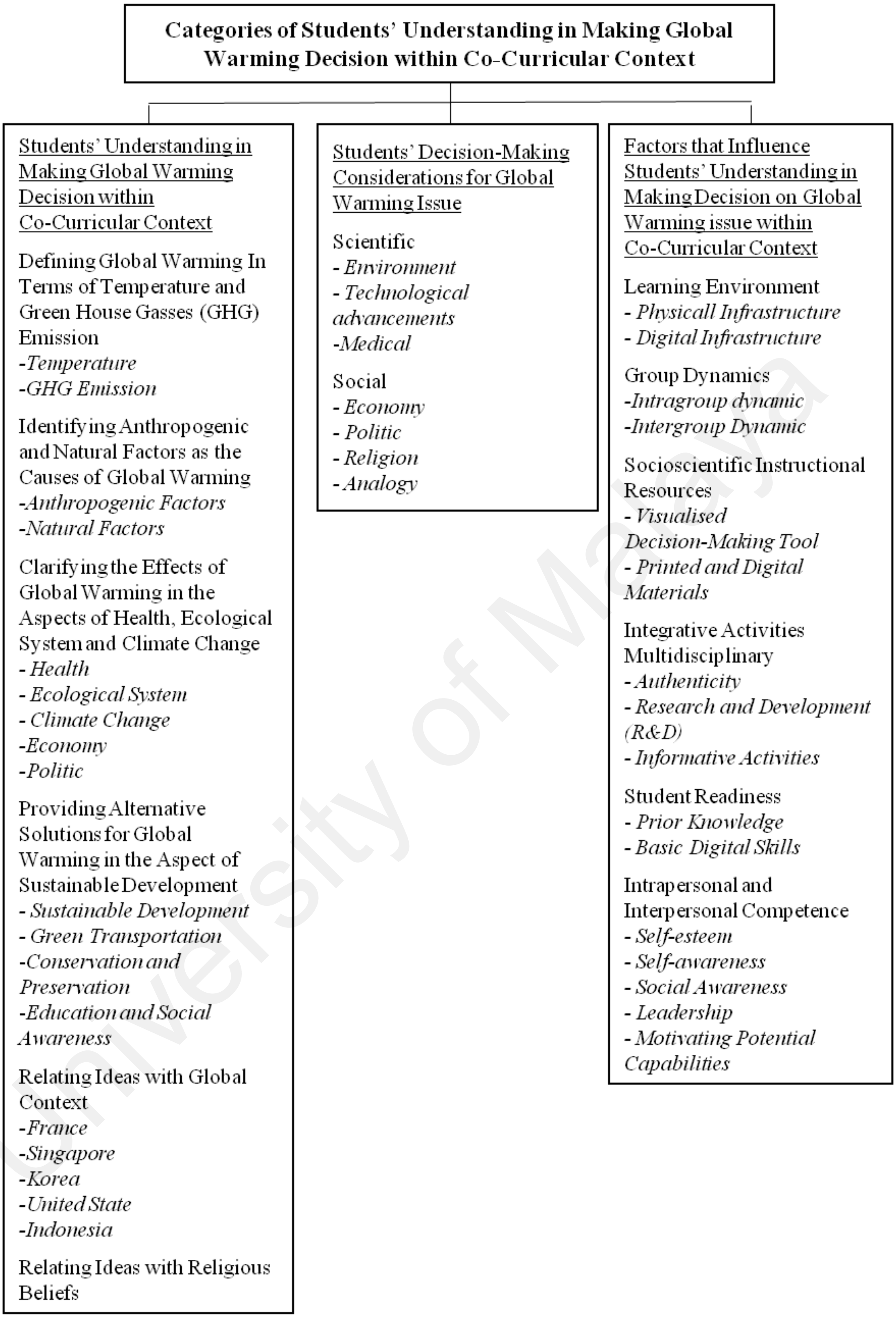


Figure 3.13. The first draft of categories and sub-categories

Extensive discussions and reviews on the first draft were performed with experts and peers from the same field. Prior to the second draft construction, the category of 'relating ideas with religious belief' in Research Question 1 was eliminated because it was similar to the consideration of 'religion' for Research Question 2. The 'intrapersonal and interpersonal competence' category in Research Question 3 was also removed in the second draft because it did not determine the factors but the products of learning SSI within the co-curricular context. The second draft was then constructed following the revision of categories and sub-categories. The content was collapsed into 12 categories and 32 sub-categories. The graphical presentation of the draft was exhibited in Figure 3.14.

Categories of Students' Understanding in Making Global Warming Decision within Co-Curricular Context

<u>Students' Understanding in Making Global Warming Decision within Co-Curricular Context</u>

Defining Global Warming In Terms of Temperature and Green House Gasses (GHG) Emission
-*Temperature*
-*GHG Emission*

Identifying Anthropogenic and Natural Factors as the Causes of Global Warming
-*Anthropogenic Factors*
-*Natural Factors*

Clarifying the Effects of Global Warming in the Aspects of Health, Ecological System and Climate Change
- *Health*
- *Ecological System*
- *Climate Change*

Providing Alternative Solutions for Global Warming in the Aspect of Sustainable Development
- *Sustainable Development*
- *Green Transportation*
- *Conservation and Preservation*
-*Education and Social Awareness*

Relating Ideas with Global Context
- France
-*Singapore*
-*Korea*
-*United State*
-*Indonesia*

<u>Students' Decision-Making Considerations for Global Warming Issue</u>

Scientific
- *Environment*
- *Technological advancements*
- *Medical*

Social
- *Economy*
- *Politic*
- *Religion*

<u>Factors that Influence Students' Understanding in Making Decision on Global Warming issue within Co-Curricular Context</u>

Learning Environment
- *Physical Infrastructure*
- *Digital Infrastructure*

Group Dynamics
-*Intragroup dynamic*
-*Intergroup Dynamic*

Socioscientific Instructional Resources
- *Visualised Decision-Making Tool*
- *Printed and Digital Materials*

Integrative Activities Multidisciplinary
- *Authenticity*
- *Research and Development (R&D)*
-*Informative Activities*

Student Readiness
- *Prior Knowledge*
- *Basic Digital Skills*

Figure 3.14. The second draft of categories and sub-categories

The second draft was later refined by conducting another extensive discussions and reviews. At this stage, the category of 'learning environment' term was changed into 'learning flexibility'. The category was further processed to allow a complete data analysis. On the other hand, the 'group dynamic' category seemed inappropriate to stand alone, thus it was then condensed under the 'learning flexibility' category.

After a thorough review and discussion, the third draft was generated. The final (third) draft consists of 10 categories, and 24 sub-categories. Figure 3.15 illustrates the final version of categories and sub-categories after the series of extensive revisions.

Categories of Students' Understanding in Making Global Warming Decision within Co-Curricular Context

<u>Students' Understanding in Making Global Warming Decision within Co-Curricular Context</u>

Defining Global Warming In Terms of Temperature and Green House Gasses (GHG) Emission
-*Temperature*
-*GHG Emission*

Identifying Anthropogenic and Natural Factors as the Causes of Global Warming
-*Anthropogenic Factors*
-*Natural Factors*

Clarifying the Effects of Global Warming in the Aspects of Health, Ecological System and Climate Change
- *Health*
- *Ecological System*
-*Climate Change*

Providing Alternative Solutions for Global Warming in the Aspect of Sustainable Development
- *Green Transportation*
- *Conservation and Preservation*
- *Education and Social Awareness*

<u>Students' Decision-Making Direction for Global Warming Issue</u>

Scientific
- *Environment*
- *Technological advancements*
-*Medical*

Social
- *Economy*
- *Politic*
- *Religion*

<u>Factors that Influence Students' Understanding in Making Decision on Global Warming issue within Co-Curricular Context</u>

Learning Flexibility
- *Physical and Digital Infrastructure*
- *Strategies of Learning*

Socioscientific Instructional Resources
- *Visualised Decision-Making Tool*
-*Printed and Digital Materials*

Integrative Activities
- *Relevance*
-*Multidisciplinary*

Student Readiness
- *Prior Knowledge*
- *Basic Digital Skills*

Figure 3.15. The final draft of categories and sub-categories

The final step in data analysis was the interpretation of the findings. This involved the process of elaborating the meaning of the results. Creswell (2014) emphasised that the interpretation in qualitative research can be described by many forms: research-based, flexible to convey personal and action meaning. The overall tone of this study is the forms of rigour and scientific credibility in which the process of validating the accuracy of information was carried out starting from the beginning to the end of the data analysis process (Creswell, 2007, 2014).

Trustworthiness (Validity and Reliability Issues of Research)

The main concern in all qualitative research are the issues on validity and reliability (Cooper & Endacott, 2007). LeCompte and Goetz (1982) defined validity in three aspects: 1) the accuracy of data representing the sample, 2) whether the conclusions effectively represent empirical reality and 3) whether the construct devises or measures the categories of human experience. Two types of validity have been identified, namely internal and external validity. Internal validity refers to the congruencies of the findings with the reality, while the external validity deals with the extent to which the findings can be generalised to other situation (LeCompte & Goetz, 1982; Merriam, 1998).

Merriam (1998) identified the six following strategies that should be considered to enhance the internal validity of the study. The six strategies are 1) triangulation, 2) member checks, 3) prolonged engagement, 4) peer review 5) participatory or collaborative modes of research and 6) researcher's biases. Among the six strategies, this study employed the triangulation, peer review and prolonged engagement in enhancing its internal validity.

Triangulation. Triangulation is a method originating from navigation science and has long been fruitfully applied to social science inquiry to enhance the validity of a study (Marshall & Rossman, 2014). The triangulation is a stage in which the process of validating the accuracy of information is carried out starting from the beginning to the end of data analysis process; a form of validation which conveys more than one source of data to stand on a single point (Corbin & Strauss, 1990; Marshall & Rossman, 2014; Merriam, 1998). This single point is reflected in a study through the research questions. The general concept is that with more sources of information, the more likely one can obtain a complete perception of the phenomenon (Newman & Benz, 1998) while strengthening the internal validity (Denzin, 2017; Merriam, 1998).

This particular study adopted the methodological triangulation, where various methods were used to increase confidence in the interpretation. The data was obtained through interviews, observations, documents of PGO and diary. This procedure is well acknowledged as 'multi-method triangulation' which served as a means to enhance the internal validity in a qualitative study on students' learning (Altrichter, Feldman, Posch, & Somekh, 2013; Meijer et al., 2002) within the co-curricular context.

For the reliability sense, Meriam (1998) acknowledged that it was difficult to achieve in a qualitative research due to the changing nature of human beings as studied in their 'natural' settings. In adherence to a prescriptive set forth by Merriam (1998), triangulation through the use of multiple data sources employed in this study was identified as a way to set high standards of reliability.

Peer review. Another strategy employed in this study was peer review. Peer review was regarded as one of the strategies used to ensure the trustworthiness of a qualitative study (Shenton, 2004). The validity of PGO task, interview protocol and diary entries was determined by the peer review process during the preliminary and actual study. Categories and sub-categories recognised during the data analysis process were also evaluated through peer review. Furthermore, the feedbacks of experts and scholars from science education field were obtained and scrutinised over the duration of the study. For instance, the fresh perspectives that certain individuals suggested enabled the process to refine the methods, develop a greater explanation of the research design and strengthen the final categories. The validation of qualitative findings was done by the expert in Biology background (Appendix M).

Prolonged engagement. Creswell (2014) pointed out that prolonged-engagement would provide an in-depth understanding of the context studied. It could also transfer the details regarding the site and samples that lends the credibility to the accounted experiences. He added that the longer the time and experience the researcher shared with samples in the settings, the more valid the findings would be.

The study time was prolonged to enable the current study to obtain a more holistic view of the students' understanding in making a decision regarding global warming as well as the factors influencing their learning. There was much information that did not determine the factors affecting the students' learning until some time had passed. To address this issue, a six-month period had been used to establish a good relationship with the participants in this setting to acquire more accurate and valid findings.

Reliability. Reliability or external validity refers to the ability to generalise the findings to the general population. The issue of external validity related to generalisation in a qualitative research cannot be treated the same as the experimental or the correlational research designs. As the fundamental aim of qualitative research was not meant to be generalised in other situations, a thorough understanding of the decision-making process in the co-curricular setting was required. In a qualitative sense, Merriam (1998) suggested that the external validity of the findings should be delegated to and decided by other researchers and practitioners. In this regard, it is up to the discretion of others to determine whether the results apply to their specific needs.

To enhance the external validity of this research, the numerous participants who represented a broad category of students were contemplated (Marshall &

Rossman, 2014). In this particular research, students from different backgrounds participated in this socioscientific instruction. These students were from the age group of 13 – 15 years old and from different classes. Moreover, the generalisability of this study was partly achieved through a "process of abstraction that takes place over the entire course of the research. The more abstract the concepts, especially the core category, the wider the theory's applicability (Corbin & Strauss, 1990, p.15)". This process was applied during data analysis especially in the later stage of coding process.

Methodological Reflection

Time was the main challenge encountered in the current study, especially during the data collection period. Even though the formal schedule had been finalised for each stage of the instruction prior to the data collection period, there were delays and changes to the schedule that needed to be considered. In this study, various inevitable changes involving various aspects occurred as the study engaged with an external educational department, which is the DOE. As Activity 2 and 3 for Decontextualisation Stage involved the DOE collaboration, they required five reschedules due to the internal problems such as overlapping activities and lack of staff from the department. During this period, official approval from the school principal on the changes was requested along with related clarification on the changes made. Thus, the sessions conducted during this period affected the once-a-week rotation for the co-curriculum activity schedule. In addition, the prolonged time for the particular session contributed to the delays of the subsequent activities. The long delays in the students' learning may cause 'decay' in students' psychological aspect (Vygotsky, 1967).

Chapter Summary

This chapter had presented a description of how the study was conducted. A relevant justification of opting qualitative research design as a paradigm-setting of this study had been made. The methodology of this research was described chronologically. It commenced with development and evaluation of PGO, the preliminary and the actual study. The following section provided an in-depth clarification on the research procedure for the actual study. Further data collection and analysis process were explained following the usual scientific canons for a qualitative study. It involved a detailed outline of the methods used for the data collection and constant comparative method as the framework for data analysis. The establishment of trustworthiness was also applied through the application of triangulation, peer review, and prolonged engagement. In the current study, the relevant research questions of 'what', 'how' and 'why' attempted to capture the essence of holistic and meaningful characteristics of real-life events.

Chapter 4 Findings

Introduction

This chapter presents the outcome of the study. The findings are organised into four main sections. The first section attempts to answer the first question where it provides an elaboration of the students' understanding regarding global warming issue within the co-curricular context. The second section aims to uncover the considerations that the students draw as they engage with the global warming decision. This is followed by the third section, which determines the factors and how do these factors influence the students' understanding in making the global warming decision within the co-curricular context. The overall findings are summed up in the final section of this chapter.

Figure 4.1 represents the overview of the findings. The findings obtained from the study represent the students' understanding in making the global warming decision, the considerations that students used when making the final decision, as well as the factors affecting their learning within the co-curricular context. The first research question which emphasised on students understanding of global warming was represented within the triangle shape. Their understanding was divided into four categories: 1) defining the global warming phenomena in terms of temperature and GHG emissions, 2) identifying anthropogenic and natural factors affecting global warming, 3) clarifying global warming effects in the aspects of health, ecological system and climate change and 4) providing alternative solutions for global warming phenomena in the aspect of sustainable development. The second research question that was presented on the right side of the figure determines the two categories of students' consideration when making the decision regarding the global warming scenario: scientific and social considerations. The outer layer shows the factors that influenced socioscientific learning within the co-curricular context. They were 1) learning flexibility, 2) socioscientific instructional resources, 3) integrative activities and 4) student readiness. The characteristics of each category were discussed in the respective section.

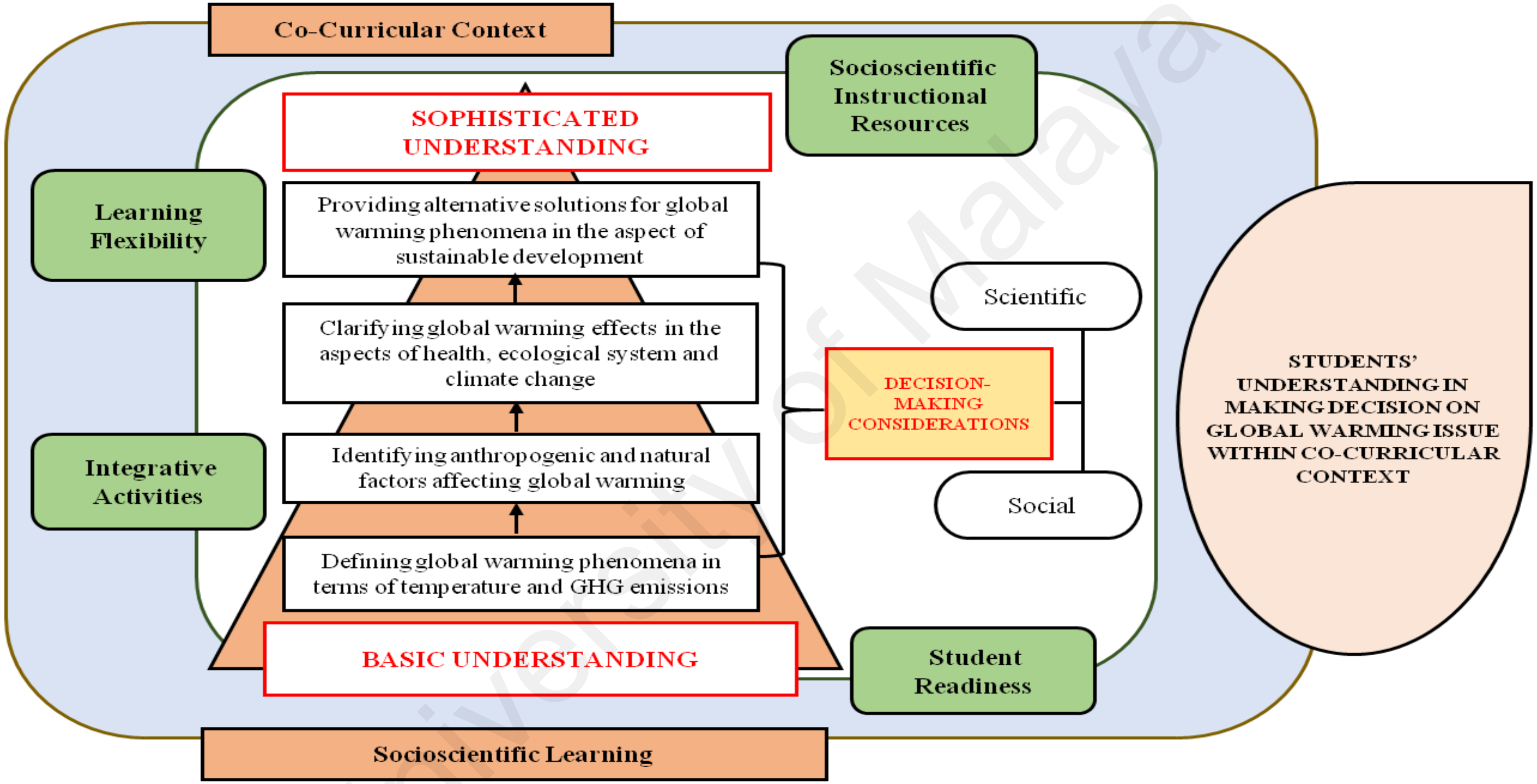


Figure 4.1. The overview of findings

The findings presented in this chapter were mainly supported by excerpts from interview transcripts, PGOs, diary entries and also the researcher's field notes as evidence. Pseudonyms were used to protect the confidentiality of the participants. For the excerpts from transcripts, abbreviations were used to denote the sources of data. The transcript follows the conventions as presented in Table 4.1.

Table 4.1
The Convention of the Transcript

Convention	**Explanation**
S	Represents the 'Student'. For example 'S2' refers to 'Student 2'
Int	Represents the 'interview'. For example, 'Int-S4' refers to the excerpt from the interview with Student 4
Act	Represents the 'Activity'. For example, 'Act1' refers to 'Activity 1'
Obs	Represents the 'observation'. For example, 'Act1Obs' refers to the observation during Activity 1
G	Represents the 'Group'. For example, 'G4' refers to 'Group 4'
PGO	Represents the 'PGO'. For example, 'G4-PGO' refers to the PGO generated by Group 4
D	Represents the 'diary'. For example, 'Act1D-S2' refers to diary entry for Activity 1 written by Student 2

The Students' Understanding When Making Decision for the Global Warming Issue within the Co-Curricular Context

The analysis revealed that students were able to offer their knowledge on the global warming issue, indicating the understanding they possessed when making the decision on this issue. The verbal and non-verbal data suggested that they were able to:

1. define the global warming phenomena in terms of temperature and GHG emissions,
2. identify anthropogenic and natural factors affecting global warming,
3. clarify the global warming effects in the aspects of health, ecological system and climate change and
4. provide alternative solutions for the global warming phenomena in the aspect of sustainable development.

These findings summarised the broad fundamental categories of global warming which students regarded as being responsible about the global warming issue based on their group understanding.

Defining the global warming phenomena in terms of temperature and greenhouse gasses (GHG) emissions. Based on the interview and PGOs, the students defined global warming by representing their collective understanding of the scenario given. It is imperative to mention that the ability to define global warming mostly emerged from the interviews. There were two ways the student defined the issue, which was described by defining the temperature and GHG emissions.

First, the students defined the global warming phenomena according to temperature rise. They related the temperature rise by individually defining the word "global' and "warming". The definition can be best portrayed in the following transcripts.

> "There are two important words that we must understand when talking about global warming. Global is Earth. Warming is one condition that one thing or object is receiving heat. So meaning to say that global warming is the condition where the Earth is heating up due to the increase of temperature."
>
> (Int-S5:23-25)

> "Ok, let me first tell you about global warming definition. First, the global means of all the Earth while warming is the process that causes temperature increases. Meaning, global warming is the temperature increases through the Earth's atmosphere."
>
> (Int-S5:369-370)

This condition, however, differed from another group, which related the GHG emission in the global warming definition. They highlighted, *"global warming is happening when too much carbon dioxide (CO_2) in Earth's atmosphere. CO_2 can absorb sunlight so that the Earth will be warmed*" (Int-S6:22-23). A similar response emerged from other students who defined, *"global warming has something to do with the greenhouse effect. Greenhouse effect causes the Earth to getting warmer. One of the reasons for this is the greenhouse effect like CO_2"* (Int-S1:25-27).

In a different episode, one student attempted to elaborate the global warming. The following excerpt represents a GHG emissions definition provided by the student.

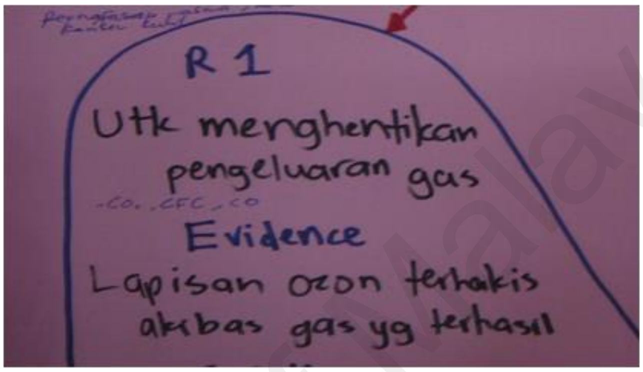
> "Ok, global warming is a kind of warming phenomena that occurs in the Earth's atmosphere. Often it is caused by the greenhouse effect. When the outside layer of the ozone layer has a hole, the gasses such as CO2 will cover it. Consequently, the sunlight is trapped in the atmosphere and cannot be emitted in a natural way."
>
> (Int-S2:22-25)

The definition of global warming and the GHG emissions were further divulged by providing abundant examples of pollutants. The students highlighted the ultimate GHG compounds in the atmosphere, which lead to global warming. They stressed that the abundant GHG in Earth's atmosphere is *"dominantly may we say* CO_2 *and water vapour"* (Int-S3:41). Some related examples were mentioned, *"such as methane and chlorofluorocarbon (CFC)"* (Int-S2:48-49). Therefore, *"the much GHG composition plays a major connection and directly increases the global warming potential"* (Int-S6:47)

The definition of global warming related to GHG emissions in students' response involved temperature increase, designating they knew that the greenhouse effect had a relation with Earth warming. Relevant examples were also included such as, *"the scientists studied that the GHG such as carbon monoxide (CO) are trapped close to the Earth's atmosphere, causing the Earth is getting hotter vibrancy"* (Int-S5:41-43). Furthermore, the student explained about the cause of heat trapping through the statement, *"the gasses trapped in the Earth's atmosphere like CFC is extremely dangerous and resulted in global warming"* (Int-S2:69-70).

The revelation of GHG emissions could also be grounded from the following PGOs that were generated during the Recontextualisation stage. Although bilingual languages (Malay and English) were utilised for the PGO format, a majority of the students preferred to use the Malay language as a written medium. Therefore, the generated PGO drawn by students will be initially shown followed by the translated version by the researcher. These translations were verified by a senior lecturer from the Institute of Teacher Education.

Figure 4.2 shows that students of Group 1 agreed that GHG such as CO_2, CFC and CO production contributed to the global warming where the excessive GHG emission caused ozone layer erosion.

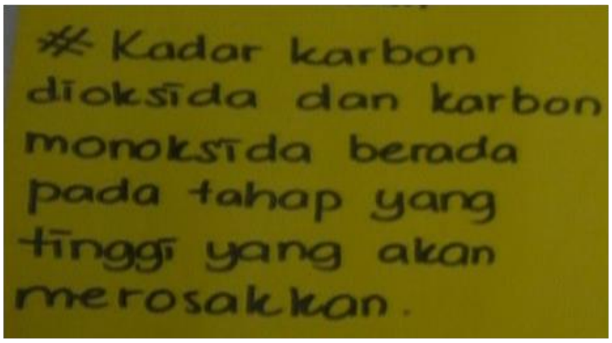


Reason 1
To stop gas production
-CO_2, CFC, CO

Evidence
Lead to eroded ozone layer due to the gas production.

Figure 4.2. Generated PGO drawn by students and PGO translated by the researcher (G1PGO). (GHG-related emission)

Figure 4.3 shows that the students from Group 3 agreed that the CO_2 and CO gasses were in excess and at a level high enough to cause damage on Earth.



Carbon dioxide and carbon monoxide are at a high level, and it is damaging.

Figure 4.3. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G3PGO). (GHG-related emission)

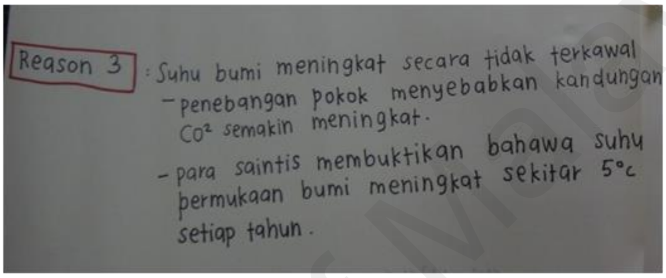
Other than that, students were able to further clarify the connection between GHG emissions and global warming. For example, a student knew that the composition of gasses in the atmosphere was losing balance through the statement, *"ok, we do know that the composition of gases in the atmosphere is just nice to live. However, when there was too much CO_2 and more GHG are trapped in the Earth's atmosphere, it will warm the Earth drastically"* (Int-S5:73-75). Another GHG has been giving indirect effects on global warming. *"GHG are really there all the time but due today, due to the rapid development of technology, there is some new presence of GHG such as CO"* (Int-S3:48-50).

They added that heat was absorbed by the GHG where "*more CO_2 will cause the gas to absorb heat and raise the temperature of the Earth"* (Int-S6:31). More elaboration of GHG could be grounded from the relevant excerpts, as below.

“The ozone layer allows sunlight to enter but prevents the UV rays from entering into the Earth. However, if CFC gas suddenly appears from the Earth, it will affect the ozone layer. It’s kind of depleting the ozone layer. To note, CFC won’t affect us in the Earth but affect the ozone, surely!”

(Int-S6:61-64)

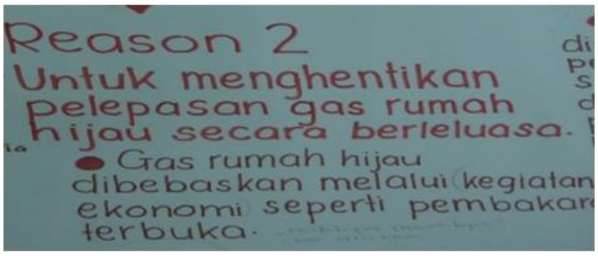
The above-mentioned element of GHG-related emissions and its explanation also emerged as the link that leads to global warming, found from the generated PGOs. Figure 4.4 illustrates the increase of CO_2, which resulted in Earth’s temperature rise. The relation of CO_2 increase and scientific facts were also stated.



Reason 3	Earth's temperature rises uncontrollably - Tree felling caused CO_2 content to increase. - The scientists proved that the Earth's surface temperature rose about 5 °C per year.

Figure 4.4. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G6PGO). (GHG-related emission)

The next Figure 4.5 explains on the need to reduce GHG emission from the open burning activity.



Reason 2
To stop the greenhouse gasses emissions that produced rampantly

- Greenhouse gasses released through economic activities such as open burning.

Figure 4.5. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G2PGO). (GHG-related emission)

Ozone depletion was also recognised as an indirect factor in global warming due to the high accumulation of GHG. Other than identifying GHG factors, the students were also able to explain the importance of the ozone layer in preventing global warming issue.

> "We know that the Sun is essential and necessary to all life on Earth. Without the Sun, so we cannot live because the Sun is the primary source of energy. When the Sun radiates sunray, the ultraviolet (UV) rays such as UVA, UVB and UVC are radiated simultaneously. Moreover, when it penetrates the Earth's atmosphere, there is a layer called ozone function as preventer. It only prevents UV radiation from penetrating the Earth. However, it permits sunlight used for plants to undergo photosynthesis. So that is the function of the ozone layer, it acts as a filter."
>
> (Int-S5:33-37)

To further explain the definition of GHG-related emission, the students used an analogy or metaphors to explain a common situation of daily life related to global warming.

"Heating that occurs throughout the Earth cannot be removed. Heating or greenhouse effect is likely the same as the processes in which we enclose ourselves in the oven. I understand it just like that. So why we warm ourselves is by what we do, these GHG cannot escape and cause us hotness. Again, it is light trapping itself and causes it to be hot."

(Int-S3:34-39)

Identifying anthropogenic and natural factors affecting global warming. When identifying the factors affecting global warming, the participants' responses can be divided into two sub-categories, anthropogenic and natural factors. The explanation for each sub-category was described in Table 4.2.

Table 4.2

Factors Affecting Global Warming

Sub-Categories	Definition
Anthropogenic Factors	The factors that were caused or influenced by human activities
Natural Factors	The factors that were caused or influenced by natural processes

Anthropogenic factors. In this context of the study, anthropogenic factors refer to the factors affecting global warming which were influenced by human activities such as forestry, transportation, energy supply and waste disposal.

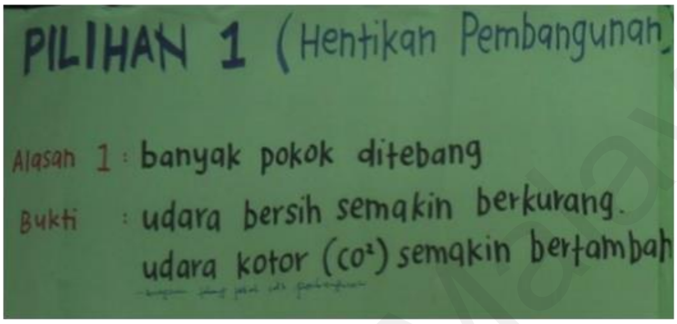
Forestry. The first sub-category which reflected the anthropogenic factors was forestry. Forestry refers to the field of managing and using related resources of forests to fulfil individual benefits. The ability to identify the forestry factor to the global warming issue was the most basic understanding that the students need to comprehend. This is because the Form One and Form Two Science learning outcomes have emphasised this factor as a critical focus to be consolidated.

The students showed the ability in identifying the forestry factor for global warming during the interview session. The majority of the group could list the forestry dimensions such as deforestation, logging and forest fires as the main contributing factors to global warming.

Deforestation was recognised as an anthropogenic factor of *"global warming, which I understand is the impact arising from everyday human activities. For example, deforestation!"* (Int-S4:21-23). The deforestation factor was first detected when the students acknowledged, *"the first reason we think about is a lot of trees fell. As evidence, the government cut down a lot of trees to run some activities related to industrialisation* (Int-S6:37-39). This factor becomes the vital reason where the student confessed, *"first, CO_2 accumulates when many trees were removed"* (Int-S2:27).

In the subsequent global warming understanding, students described that the deforestation activities conducted to obtain natural resources was the factor affecting global warming *"I want to say about deforestation reasons. For this reason, people will cut down the forest to run development activities. So yeah, deforestation is one of the factors!"* (Int-S5:46-48). Other than that, they were able to provide some examples of trees that have been cut down for personal benefits *"usually the government will cut timber and chengal for house construction, furniture making and so on"* (Int-S6:45-46).

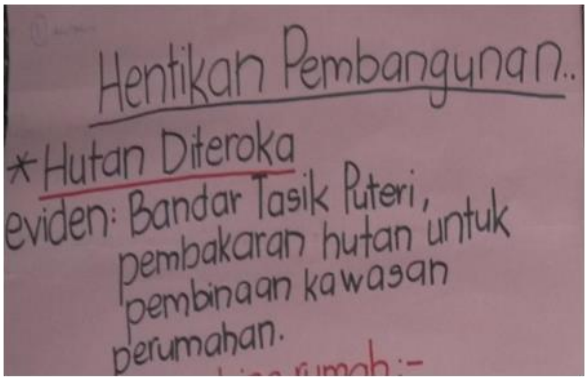
Instead of admitting that deforestation activities contribute to this issue, the student of Group 6 revealed that logging also serves as an important factor in global warming. This identification of the forestry element was supported by the PGO generated by Group 6, which agreed that the developmental activities lead to deforestation, causes reduction of clean air and increase of CO_2 concentration (Figure 4.6).



OPTION 1	**(Stop the developmental activities)**
Reason 1:	Development activities lead to a lot of logging activities.
Evidence:	Lack of clean air. Carbon dioxide concentration (CO_2) becomes higher.

Figure 4.6. Generated PGO drawn by students and PGO redrew and translated by the researcher - (G6PGO). (Anthropogenic factors)

The forestry activity also involves *"forest open burning"* (Int-S2:26) which leads to global warming. The open burning is also due to *"human activity and irresponsible attitude. For example, we are famous for the cultural village which like to burn garbage or forest openly"* (Int-S4:113-115). The next PGO in Figure 4.7 illustrates the students' knowledge on the forest burning activity conducted to build a new residential area.



Stop the developmental activities.
Reason : Conducted a periodic forest exploration activities.
Evidence: Bandar Tasik Puteri, burning forests for construction of a residential area.

Figure 4.7. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G4PGO). (Anthropogenic factors)

The elaboration of forestry factors was clarified further as the students revealed, *"ok, the simple physical factor of global warming is deforestation"* (Int-S2:104-105). Consequently, the temperature of the Earth increased in response to the increase of GHG concentration. *"As we can see the effects of deforestation physically, the less the existence of the tree, the less generation of oxygen"* (Int-S2:105-106). The students supported this reason by elaborating on the effect of logging activities that collapsed the function of trees, as the excerpt below demonstrates.

> "Forests and trees are the natural form of protection. However, due to the extensive logging activities, there will be no canopy or Earth protector from the top. The sunlight will radiate and hit the ground directly. So we have no direct natural protection any more."
>
> (Int-S4:22-26)

On the other hand, one student from another group offered his opinion during the interview on the traditional routine of forest fires that contributed to the critical condition of global warming nowadays.

"So if we continue with our traditional routine, in fact the traditional routines contribute to environmental damage dramatically. For example, we have built and opened a wide land for the development activities via traditional terms. In a modern terms, the developer will cut the forest but in terms of traditional way, they will just burn the forests"

(Int-S4:77-81)

The emergence of the forestry factor was supported by the PGO in Figure 4.8, which explains the physical and natural cycle disturbances leading to global warming.

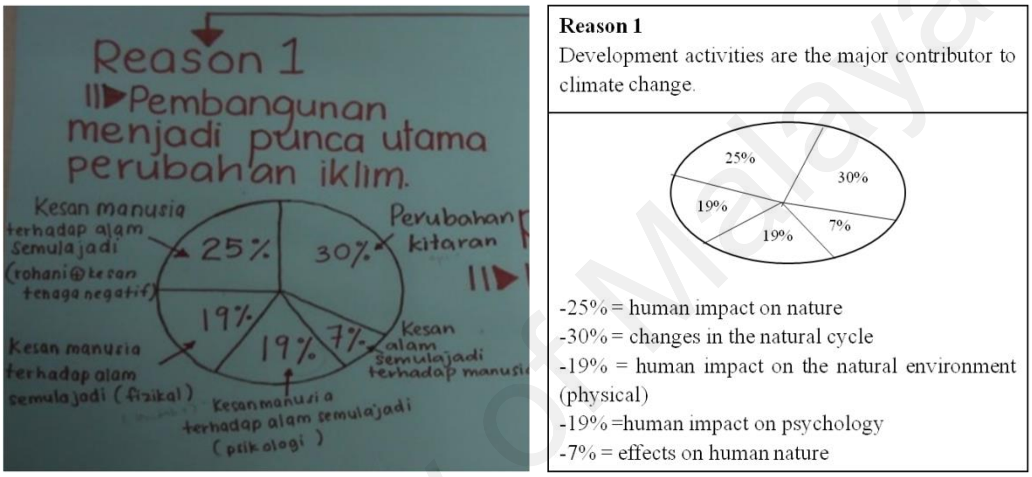


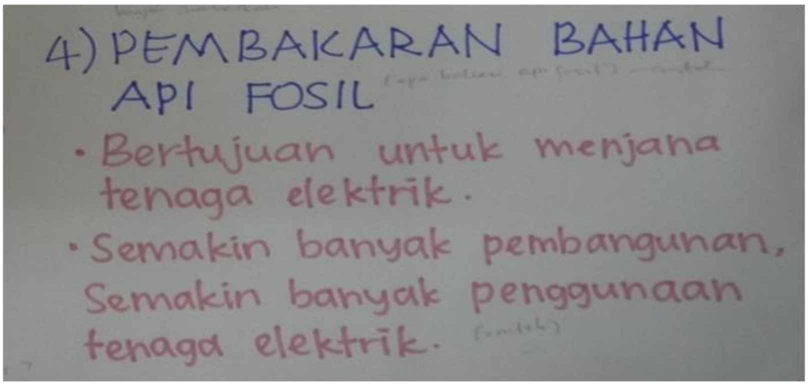
Figure 4.8. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G2PGO). (Anthropogenic factors)

Energy supply. Energy supply in this context refers to the production of energy for transportation, industrialisation and construction demands. Based on the analysis, transportation was considered as the greatest contributor to global warming. The students revealed that the GHG from the transportation contributed a significant level of pollutants that directly warm the atmosphere *"if we walk at the roadside, we can feel the hotness due to the GHG from the many numbers of vehicles*" (Int-S4:117-119). The examples of global warming caused by the pollutants emitted from *"vehicles is all that consist of CO_2"* (Int-S2:28). They also specified the road transport vehicles that released *"CO_2, CO gases are also from the cars that we drive"* (Int-S3:41-42).

Furthermore, the student explained that the generation of vehicle energy came from the burning of fossil fuels, mostly from *“petrol if we want to drive our vehicles such as a car. Differently, if we want to move the aeroplane engine, we have to burn kerosene”* (Int-S5:89-91). They generalised, *“all product comes from petroleum gas, and for sure we need that basic product for the useful applications. To note, the combustion of this fossil fuel also actually to generate vehicles energy”* (Int-S5:92-95).

The current study noted that the students could relate energy production with industrialisation and construction demands. The burning of fossil fuels in the development activities from industrialisation sectors was described as *“very important in generating electrical energy”* (Int-S5:88-89). The student also provided two examples of fossil fuels used in the plastic industry and highway construction development through the statement, *“we need naphtha if we want to make plastic, if you want to make a road, paved road we have to use bitumen”* (Int-S5:91-92).

The following PGO shows the factor of burning fossil fuel for transportation energy generation that causes global warming. In Figure 4.9, the students of Group 5 stated that the fossil fuels were used to generate electricity. They further elaborated that the increase of construction activity will require more energy and fossil fuels. Therefore, the uncontrollable use of the fuels may lead to global warming.



4)	Burning of fossil fuels
•	Aims to generate electricity.
•	When there is an increase in construction activity, the more energy is needed.

Figure 4.9. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G5PGO). (Anthropogenic factors)

Waste Disposal. Solid waste disposal and treatment can produce several GHG that directly contribute to the global warming occurrence. It is imperative to note that the Malaysian Form One and Two students have not been introduced with biodegradable and non-biodegradable wastes in the Science curriculum (MOE, 2011). Despite the lack of introduction to the topic, the students managed to discuss the topic of waste disposal and relate it to the “biodegradable and non-biodegradable materials”. In addition, the concept of non-biodegradable waste was elaborated by a student through the interview, where the student stated, *“and one more thing that plastic is not easy to decay, it takes approximately 500 years to decompose. So the use of plastic will cause the global warming problems”* (Int-S5:425-427). There was no consolidation on this particular terminology exposed by the teacher and the expert during instruction. Therefore, it was logical to assume that the students showed some improvement in their understanding regarding this factor. The following excerpts from the interviews can illustrate additional elaboration on the waste disposal factor.

> “Plastic is everywhere, it is very dirty and gives harm effect. It is also hard to be eliminated. To be specific, it takes hundreds of years to decay. Yeah, the term is biodegradable. But in this case, plastic is a non-biodegradable products because it cannot be disposed biologically.”
>
> (Int-S3:280-283)

> “Ok, we know that plastic bags that do not biodegrade make a pile of garbage. If there is a pile of junk that is not biodegradable, so people would not want to collect that wastes. Nobody wants that waste. Normally, people will take an easy way, burning the plastics! So it surely smelly and it’s already proven to produce the bad gas. Ok, that is the biodegradable concept.”
>
> (Int-S5:432-436)

Natural factors. Natural factors indicate the factors that cannot be controlled by human and the natural processes such as the process of decay and animal waste.

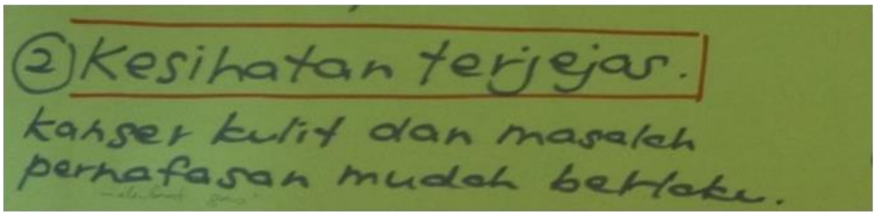
Process of Decay and Animal Wastes. From the analysis of this study, some of the students were able to identify the natural factors affecting the global warming phenomena. For example, they were able to relate the decaying process and animal wastes decomposition as the natural factors affecting global warming. In conjunction with this point, students were able to explain further, where *“global warming is caused by fossil organic material, meaning that the material originated from dead animals and plants that have decayed”* (Int-S5:86-87). The pollutants involved in the decaying process such as *“methane, produced by the dead plants or animals contribute to this critical point”* (Int-S2:26).

Likewise, another student simplified that global warming was also caused by animal wastes *“carbon monoxide gas which produced by the carcasses and faeces of animals”* (Int-S6:49-50). They mentioned, *“from what I know of cow dung produces too much GHG such as methane. Frankly speaking, I do not know about this thing before”* (Int-S1:30-32).

Clarifying global warming effects in the aspects of health, ecological system and climate change. The students' understanding involves the ability to clarify global warming effects pertaining to health, ecological system and climate change. These effects were discussed in the following section.

Health. Regarding health aspect, a majority of the students were concerned about the effects of global warming on human health. The six sub-samples stressed about the health effects through the interviews and generated PGOs. The findings indicated that the students' collective understanding about the health effects range from effects to the respiratory system, skin diseases, eye diseases and death.

The respiratory system may be affected, as *"due to global warming scenario, breathing problem may be more severe for those who are close to the smoke from factories area"* (Int-S3:109-110). This condition happened *"as a result of trapped gases that leads to breathing problems. These gases can directly damage the respiratory system"* (Int-S2:50-51). They related that the GHG molecule *"GHG* contained a high carbon content *and it can damage our respiratory system"* (Int-S2:33-34). For example *"like CO_2 can damage our lungs and respiratory tract"* (Int-S2:51-52). Figure 4.10 illustrates the PGO listing the health problems that may occur because of global warming which also include skin cancer and respiratory problems.

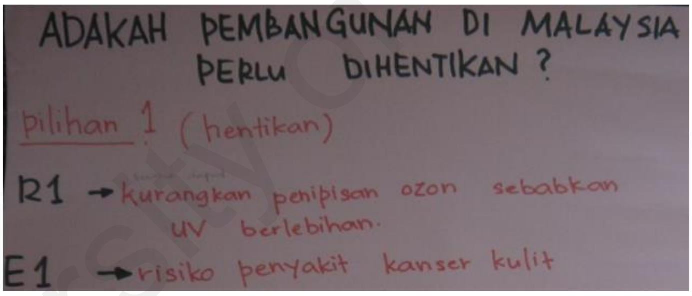


2) Health will be affected.

Skin cancer and respiratory problems are likely to occur.

Figure 4.10. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G2PGO) - (Clarifying effects)

The following PGO presented in Figure 4.11 also indicates that the skin cancer problem emerged because of the ozone layer depletion. Thus, the situation allowed the high-intensity UV rays to reach the skin surface.



DOES MALAYSIA NEEDS TO STOP DEVELOPMENT ACTIVITIES?

Option 1 (Stop)
Reason 1 = To reduce ozone depletion that cause excessive UV.
Evidence 1 = Risk of skin cancer.

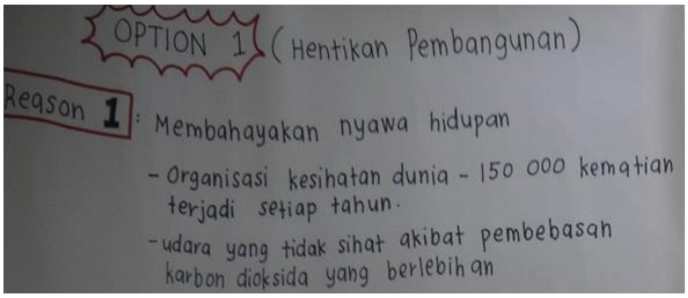
Figure 4.11. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G1PGO). (Clarifying effects)

One of the students stated, "*the effects of many diseases that may come is higher if the global warming is too critical*" (Int-S2:146-147). Again, one student mentioned, *"maybe it can even causes eye diseases, the eyes can be reddish and so on"*

(Int-S6:33). This student continuously shared his friend's experience. *"Yes there is! My friend is suffered from eye disease. His eyes became sore because of the UV rays penetration. That was what the ophthalmologist explained"* (Int-S6:147). Furthermore, the critical condition of global warming *"can directly damage the eyes"* (Int-S2:36).

The effect on the eyes was stated to be more severe during hazy or hot seasons as the student mentioned, *"there are members of my group shared this idea, when we get out during hot days, there are more serious side effect too. Meaning that we can't see the beauty of the Earth clearly due to the blurred vision problem"* (Int-S1:141-143). Giving one example, *"we can see the sky scrapers, lakes and trees previously. Differently now, if we look at the view outside, it was visible haze, hazy! It disturbs our vision"* (Int-S1:143-145).

Other than that, the following PGO presented in Figure 4.12 indicates that students had prioritised health aspect in representing their understanding pertaining to the global warming issue. They stated that the development activities should be stopped because it will threaten the organisms' life. Surprisingly, they were able to elaborate this reason by giving a statistic reported by the World Health Organization (WHO), which stated that global warming causes 150,000 fatal incidents annually. This condition happened due to the unhealthy air quality that contained excessive CO_2.



OPTION 1 Reason 1: Evidence:	**(Stop the developmental activities)** Endanger the lives of living beings. -Statistics Health Organization world- 150,000 deaths occur each year. -It is caused by unhealthy air due to excessive release of Carbon Dioxide.

Figure 4.12. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G6PGO). (Clarifying effects)

Furthermore, the spread of epidemic diseases was mentioned due to the hot condition at a particular time. It allows a widespread occurrence of infectious diseases in the community *"when the air is unhealthy, and conditions are hot; it encourages the disease to be spread easily"* (Int-S3:108-109).

It is imperative to note that the students in this context were able to explain about the biological conceptualisation. They explained about the health effects in the aspect of dehydration together with its scientific concepts, as portrayed through the excerpt below.

> "If the Earth is scorching, we will feel discomfort. Surely, our body will be dehydrated. When the water in our bodies already evaporated, dehydration occurs. It happened when the water of the body had evaporated due to the extreme heat."
>
> (Int-S2:30-33)

Next, the interconnection of humidity concepts and skin problems were also revealed to show that global warming worsens human health.

> "We know that bacteria cannot adapt to extreme hotness and coldness temperature. So global warming affected air humidity, meaning that air is unhealthy at that time. Yes, surely global warming gives a harmful effect especially for those who suffer skin problem. That is the context in which we understand."
>
> (Int-S3:105-108)

In another episode, a student was able to clarify the global warming effects by talking about an instance of global warming in Korea as an example for the global circumstances, especially regarding health effects.

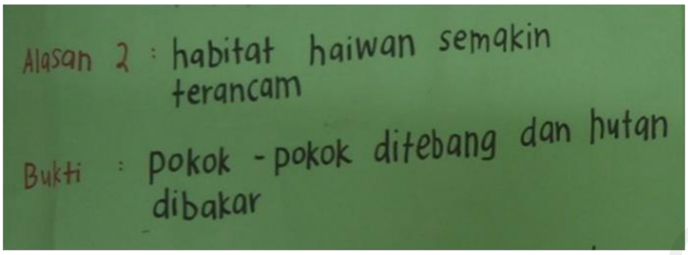
> "I remember when global warming happened in Korea. The temperature is too hot at that time, around 40 degree Celsius. As we know, the normal human body temperature is 37 degree Celsius. Consequently, many babies and elderly died due to the extreme temperatures. They cannot withstand hotness."
>
> (Int-S3:95-101)

Additionally, the use of plastic in daily practice was identified as toxic and dangerous for human health.

> "Plastic is not biodegradable because plastic cannot be disposed biologically. By using it, the Earth is will be heated and is filled with chemicals and CFC. Similarly, if our body we're sticking with toxins, surely it affects our health and we cannot live."
>
> (Int-S2:-285-288)

Ecological system. Based on the findings, the majority of the students emphasised that the effects of global warming on the ecological system were a result of forestry. The elaboration of the effect on the ecological system was centralised on biodiversity destruction. They noticed that the forestry sector destroyed natural habitat, food sources, flora, and fauna, hence collapsing the entire ecological system.

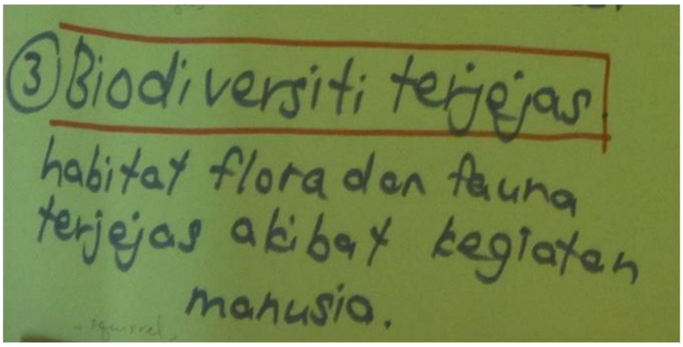
The students mentioned that the forestry factor gave direct effects in terms of *"habitat destruction that caused by forestry mainly"* (Int-S3:86). The increased risk of losing land habitat was *"because of the deforestation activities, so that there is no habitat for the animals to be sheltered"* (Int-S6:40-41). Figure 4.13 illustrates the discussion on habitat destruction in PGO, which was due to deforestation. The students perceived that logging and forest burning activities reduced the area of animal habitat, thus threatening their existence.



Reason 2: Evidence:	Animal habitats are increasingly threatened. This is because the trees are cut down and the forests are burned.

Figure 4.13. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G6PGO). (Clarifying effects)

The biodiversity of the flora and fauna, both the land and aquatic life, will also be affected due to the habitat destruction. Majority of the students revealed, *"about the threatening of the whole population"* (Int-S3:81) such as the extinction of flora and fauna. The generated PGO shown in Figure 4.14 best demonstrated the threat of the biodiversity extinction due to the destruction of flora and fauna habitat.

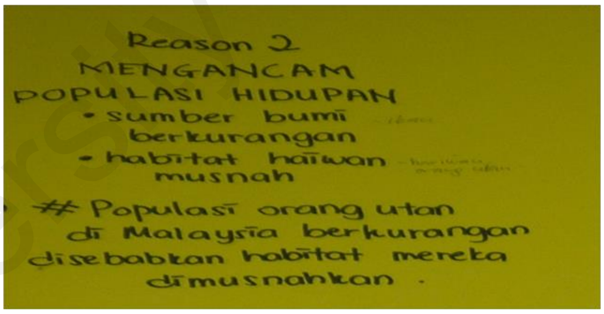


3) Biodiversity is affected.

Flora and fauna habitats affected by human activities.

Figure 4.14. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G2PGO). (Clarifying effects)

The PGO in Figure 4.15 also discusses the disruption of the animal population due to the reduction of sources and the destruction of normal habitats, such as the decrease of the orang utan population in Malaysia.



Reason 2

THREATENING ANIMAL POPULATION

The Earth sources are reduced.

Animal habitats are destroyed.

Evidence

Orang Utan population in Malaysia decreased due to the destruction of habitat.

Figure 4.15. Generated PGO drawn by Students and PGO redrawn and translated by researcher - (G3PGO). (Clarifying Effects)

The students were also able to connect between the habitat destruction and the extinction of flora and fauna. They emphasised, *"perhaps the first effect is habitat destruction. For example, the forest in Sepilok, Sabah.* (Int-S6:41-42). From the habitat destruction effect, *"the extinction of flora and fauna can be another reason that can be divided or interlinked"* (Int-S6:39). The students were convinced, *"that surely the extinction of fauna species happened due to the habitat damage"* (Int-S2:26). They were also able to give the correct instances, such as "*fauna example is like orang utan, they have extinct directly"* (Int-S6:41), while *"Rafflesia is the case in flora that now decreases in number. Perhaps because of the heat or the high temperature, so they cannot adapt to it"* (Int-S6:40-41). This situation, like the natural forest fires mentioned by the student in the statement, *"because the global warming causes the temperature becomes too high and the trees will suddenly catch fire by itself"* (Int-S6:42-43) will lead to the destruction of the entire ecosystem. The above-mentioned effect *"causes the ecosystem turns to irregular in nature"* (Int-S2:118).

The current study was able to obtain other correct examples of flora and fauna population extinction. Other students stated, *"the destruction of forest habitats"* (In-S6:42). The students selected a locally relevant example of fauna *"ok, if we can take related examples at mainland such as tigers and orang utan are becoming hard to find in Malaysia right now, extinct!"* (Int-S3:84-86). In addition, *"the elephants and Malayan tigers are threatened now. Birds species is like hornbills that already endangered"* (Int-S6:42-43). The relevant excerpt explains the students' ability in making connections between habitat destruction and the extinction of flora and fauna caused by the global warming.

"Global warming may affect forests ecology. Also, the habitat of flora and fauna to be destructed. For example, the squirrel that live in the trees, as well as birds. Birds living on the trees, and when the tree charred on fuel, the birds already lost their habitat to build the nest."

(Int-S2:54-57)

They also attempted to clarify the effects of habitat destruction by elaborating on the functions and the benefits of forests in minimising global warming as described in the following excerpt.

"But in fact, forest is an important natural resource because it gives a balance of air, oxygen and prevents soil erosion. As I know, the roots of trees in the forest have an attraction called geotropism. The roots of any plants would grip the ground with respect to the force of gravity. So if we cut down forests, who wants to hold the ground? So who is going to grip the ground? Surely soil erosion will occur!"

(Int-S5:202-206)

Other than that, one student focused on the impact of global warming that destroyed *"the aquatic habitats. When this happen, the aquatic species will died because they can't reproduce, also can't survive!"* (Int-S3:79-80). This situation will also destroy the food sources thus collapsing the entire aquatic ecosystem.

"We also think that global warming will destroy the whole aquatic ecosystem. For example, aquatic life, it cause the population of fish species to decrease. Wait, because of what? Indeed, because of the destruction of habitat, the water is evaporated and cause it dry!"

(Int-S376-79)

Climate change. The standard practices of conducting developmental activities cause catastrophic effects such as climate change. In this context of the study, the climate change refers to the change of regional climate patterns, which happens globally such as iceberg melting, drought and flood. In particular, this condition has been predominantly attributed to the high accumulation of GHG caused by the above-mentioned factors.

The connection between global warming and climate change was identified as a disastrous effect in the aspect of iceberg melting where they revealed, *"global warming is causing an increase of sea level, the melting of the poles and so forth"* (Int-

S3:40-41). These occurrences were identified "*because of the high temperature at the North Pole and the South Pole leads the Earth getting hotter, so the iceberg melting and the rise of the sea level will occur tremendously"* (Int-S6:40-41). They also stressed on their worries about *"this particular issue that will cause sea level to rise and perhaps after the next few years the islands will be submerged due to global warming phenomena"* (Int-S6:29-31). Parallel with this condition, one student from Group 4 was able to elaborate the consequences of the increasing sea level in detail.

> "Global warming could cause sea levels to rise. When heating occurs, the glaciers will melt and indirectly the water level will rise simultaneously. Glaciers are melting in the north and south poles, but because we know that glaciers are wide and spacious, so it will involve the whole Earth to be affected."
>
> (Int-S4:32-36)

Global atmospheric warming, in turn, will trigger major alterations in the climate change as well as air quality. The students were able to connect the climate change with *"air pollution aspects"* (Int-S3:58) by *"specifically taking carbon as an air pollutant that led to air pollution"* (Int-S3: 62-63). This situation *"cannot be neglected as air pollution will be getting worst simultaneously"* (Int-S4:128-129). In this case, the students revealed, *"extreme hotness of the entire region will affect the air quality, hence, causes air pollution to happen"* (Int-S5:47-48). The convection process *"that transfer heat through the air space or atmosphere happened, thus, polluting the air dramatically"* (Int-S5:76-78).

Furthermore, the extensive data regarding monsoon inconsistency was expressed during the interview session. One of the students attempted to relate the global warming phenomena with the climate change through the statement, "*if global warming is already extreme, then it will make trouble and cause a global change of climate"* (Int-S5:78-80). Such trouble could be critical in terms of following and predicting an expected weather period, where the student continued, *"if you follow the*

September expected weather, now the middle of the southwest monsoon winds, but why now is rainy? If in the north-eastern region, why it's so hot. The monsoon is erratic! (Int-S5:83-85). The student further clarified his justification by providing relevant example indicating that the Malaysian monsoon was experiencing inconsistencies.

> "Let's narrow the scope. Malaysia follows two types of monsoon, northeast and southwest monsoon wind. By right, there are regular and specific periods of the monsoon. But now we can see the instability of monsoon due to global warming effects. It's inconsistent."
>
> (Int-S5:83-85)

Noticeably, the inconsistency of the monsoon involves temperature that causes *"changing in climate, sometimes it was too dry" (*Int-S3:42) and *"suddenly it was too rainy up to flooding"* (Int-S3:43-44). The local circumstance of *"climate change is happened in Malaysia lately, we can see that in recent years this situation is quite uncertain"* (Int-S3:41-42). This situation was *"like we saw in the middle of last year, dry condition. The drought lead up to water shortage. From there I learned that it actually has something to do with global warming"* (Int-S3:44-46). The shortage of water was explained through the excerpt below.

> "If the drought happened especially to the countries in the middle of the continent. For example in the country that is not close to the water as no source of water near it. So the global warming will make the country dry because no source of water in that particular area."
>
> (Int-S6:35-38)

The flood situation was also caused by the climate change that makes rain *"sometimes can be too heavy, as we see at Kelantan that day"* (Int-S3:43) and surely *"flooding caused by excessive water."* (Int-S6:34). The flood tragedy was *"the human impact on the natural environment, or human beings cause global warming. However, this is more likely due to change of climate system"* (Int-S2:95-97).

Providing alternative solutions for the global warming phenomena in the aspect of sustainable development. In general, alternative solutions involve the science of sustainable development. In this framework of the study, sustainable development was defined as one of the alternative solutions practised to sustain the ability of the natural system (e.g. continue providing the natural resources or energy) upon which the society and economy depended on. It involves eco-friendly development, transportation, preservation and conservation, and education and social awareness. The description of each sub-category was represented schematically in Table 4.3 which summarises the alternative solutions for global warming which students regarded as being responsible for their groups' understanding.

Table 4.3
Alternative Solutions for Global Warming

Sub-Categories	Definition
Eco-friendly Development	Eco-friendly development is a sustainable guideline that uses green and nature-friendly concepts in order to minimise global warming effects upon ecosystem and environment
Transportation	Minimising the transport impacts on the environment and society by integrating safe principles used in the transportation aspect.
Conservation and Preservation	Conservation is the action of preserving and protecting biodiversity, environment and natural resources, while preservation is the action of continuing and maintaining biodiversity, environment and natural resources to make them last.
Education and Social Awareness	Education is the process of acquiring knowledge, skills, values, beliefs and habits, hence, developing the consciousness of the global warming issues among the societies.

Eco-friendly development. Eco-friendly development in this study refers to the guidelines that utilise the green and nature-friendly concept, minimising the effects upon the ecosystem and environment. Findings revealed that students were able to identify eco-friendly development elements as alternative solutions for global warming *"as mandatory! The country's development must adhere to environmental friendly rules"* (Int-S5:158-159). Also, the application of *"environmental friendly technology must be widely used"* (Int-S5:163-164).

The following PGOs illustrate the students' understanding, which proposed green and nature-friendly principles in an eco-friendly development.

Figure 4.16 describes the requirement of developing environmentally friendly buildings as the alternative solution to reduce global warming. The students specifically offered one recommendation of constructing university buildings covered with grass roof.

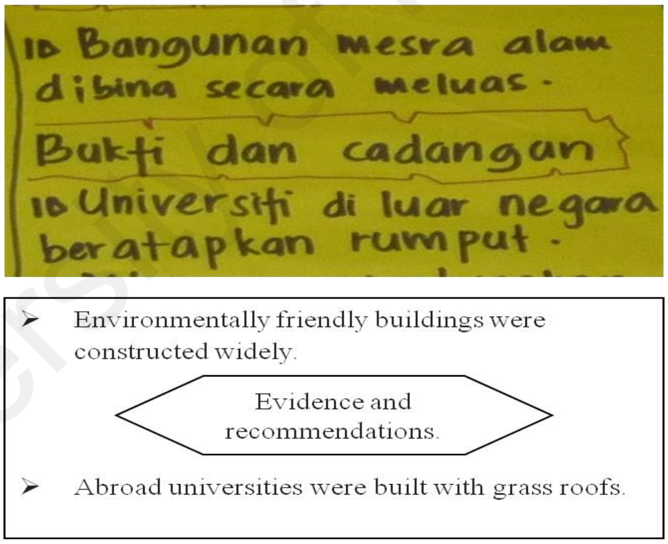
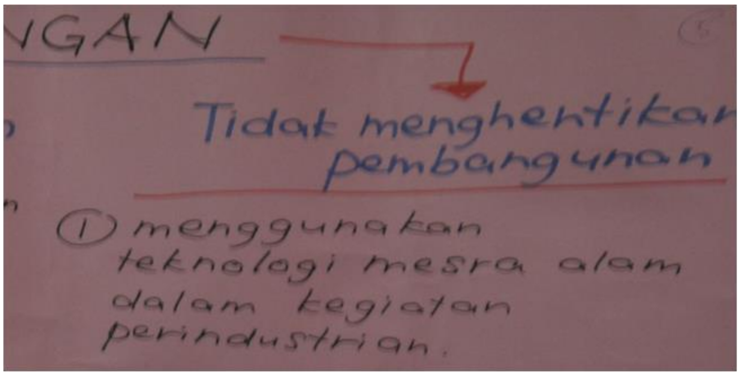


Figure 4.16. Generated PGO drawn by students and PGO redrawn and translated by researcher - (G5PGO). (Providing alternative solutions)

The use of environmentally friendly technology in the industrialisation sector was also suggested, as portrayed in Figure 4.17.



SOLUTION

Do not stop the developmental activities.

1) Using environmentally friendly technologies in industrial activity.

Figure 4.17. Generated PGO drawn by students and PGO redrawn and translated by researcher - (G2PGO). (Providing alternative solutions)

Green development is one of the recent developments that help preserve the environment by remarkably reducing the global warming or pollution produced by a developmental activity. The findings revealed that the students' understanding of the green development was impactful in terms of this sub-category where they found *"so for me this green development is a good idea or initiative for us to continue our progress on our side to protect the environment"* (Int-S3:92-93). They provided a recommendation for developers *"to apply green technology principles. So that the Earth was not destroyed"* (Int-S6: 178-179). For instance, *"applying green building such as using friendly products and materials are advantageous"* (Int-S6:68-69). The principles of green development were conceptualised by providing relevant examples in the construction field, as the following excerpt demonstrates.

> "The construction that follows green development principles promotes initiatives to make one area to be green as a whole. A garden city concept is one of the green constructions that apply this concept in terms of water and electric saving technology. These are the examples of green technology that has been infused, thus, helps in green construction field."
>
> (Int-S3: 101-105)

For the eco-friendly construction field, they continuously articulated, *"the materials used to create a building must be made of eco-friendly elements-based"* (Int-S5:66-68). One student volunteered "*giving one example. If we want to develop a so called "eco-friendly city", we must make sure that the building must be built up by the materials that can reduce or do not give contamination on the environment"* (Int-S3:98-101). They were also able to take a global example to explain more about this sub-category.

> "Nanyang Technological University at Singapore is actually applied the eco-friendly development. The building construction follows eco-friendly concept where its building tower was made from eco-friendly materials. Even though it is a high tower, but it was set up by filling plant vegetation along the building. It's not on the land, but at the edges, top and circumferences of that tower. Yes, we call it green roof!"
>
> (Int-S5:154-158)

The use of high technology sensors was also listed as an applicable solution for this purpose. A high-tech sensor or intelligent sensor is an eco-friendly technology that can analyse room conditions and adjust the equipment power use accordingly. Other than that, it can indirectly detect and control the waste of energy produced by human activities. For example, it can monitor human movement, location and sunlight intensity. The technology was also mentioned in the spontaneous responses given: *"one example is like ECONAVY system"* that was *"installed in an electronic devices used by Panasonic"*. In addition, *"it is used to detect energy waste from electrical devices"*. In a global context, one example was provided, *"danchi is a type of lower condominium in Japan. All the items used follows energy-saving principles"* (Int-S4:159-160). The smart technology used for eco-friendly development was promisingly applicable enough to enable a person to practise better energy savings, especially in his or her daily life routine.

> "We can apply an intelligent sensor technology. It's a kind of detector that install a timer to it. It detects the presence of a human. If there is no human so the light will continue closed. Yeah, if we are not in our home, the lamp will be switched off automatically."
>
> (Int-S3:230-233)

The findings revealed that the students' understanding for the intelligent sensor matched the scientific concept and principles of this technology and they managed to list it as an alternative solution to overcome global warming. The emergence of this response was different from the learning outcomes proposed by the Form One and Form Two Science syllabus. Students' understanding was observed to be more sophisticated as they were able to cope with more advanced knowledge beyond the formal curricular specification.

The aforementioned alternative solutions were proposed, *"the best solution for reducing global warming is by implementing sustainable development"* (Int-S5:384). The concepts were clarified, *"ok on my understanding, sustainable development emphasises on the advanced development while maintaining and conserving the environment in general"* (Int-S3:87-88). The students gave local examples, *"kind in Malaysia there are some projects that embrace the concept of sustainable development, but so far this has mainly near urban area like Kuala Lumpur"* (Int-S3:251) *"such as Malaysia City and City Park for examples"* (Int-S3:251).

Transportation. Transportation was an example of the alternative solutions mentioned in this study. Students revealed that the vehicle GHG emission was proven to be the main factor leading to the global warming. Therefore, shifting daily practices in the transportation aspect was a reasonable solution to reduce global warming. This includes using green transportation, public transport, car-pooling. All of the alternative solutions have been recognised as a considerable way to save energy, environment and reduce traffic congestions, thus reducing global warming directly.

As an alternative to reduce the global warming effects, many students were able to come up with suggestions for a new concept in transportation. In this context of the study, the improvement in green transportation refers to the transportation that sustained the environment by limiting the emission of GHG. The system and modes of green transportation are consistent with the principles of sustainability, thus, they meet the global scopes of reducing global warming impacts.

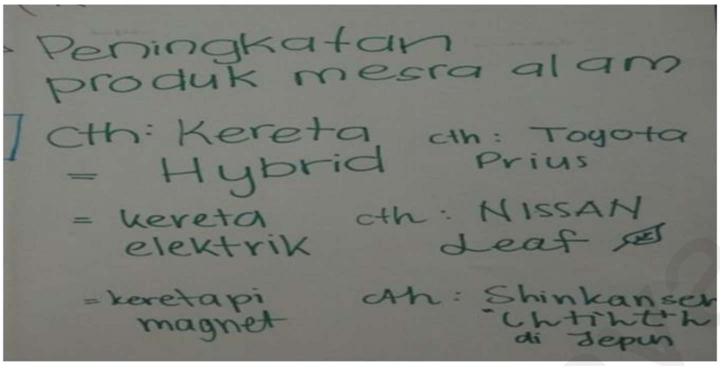
The suggestion of green transportation was given widely such as *"using hybrid car"* (Int-S2:148-149), *"magnetic train, and yes, other than hybrid cars we can use electric vehicles too!*" (Int-S2:152). They explained about the advantages of *"a hybrid car that has been used among the developed countries, so that it won't pollute the environment"* (Int-S4:92-93). Instead of providing its single solution, they were able to explain the scientific concept used for that particular matter.

> "For transportation, we can use hybrid cars. Hybrid car is a car that is more eco-friendly. It has an adverse effect too, but we have to notice about its real or positive impact. Importantly, it can reduce GHG emissions due to less petrol consumption."
>
> (Int-S2:148-151)

For the magnetic train, the scientific concept was explained by taking the Japanese transportation development 'Shinkansen', as an example.

> "As referred to Japanese language, Shinkansen is a magnetic train. Magnetic train increases the magnetic speed due to the reduction of frictions between the rail and wheel. In this case, the rail and wheel just can detect the same polarity but not in contact. Thereby, it reduces frictions and allows very high speeds, thus, produce electricity."
>
> (Int-S3:174-178)

Figure 4.18 portrays the recommendation of developing environmentally friendly transportation, together with its examples such as the hybrid and electric cars as well as the magnetic train.



The increase in environmentally friendly products.
Example: Hybrid car (Toyota Prius)
Electric cars (Nissan Leaf)
Magnetic Train in Japan (Shikanzen)

Figure 4.18. Generated PGO drawn by students and PGO redrawn and translated by researcher - (G4PGO). (Providing alternative solutions)

They also connected this particular aspect with related suggestions in the transportation sub-category. For example, "*we can reduce global warming by cutting out vehicle emissions. We use the services provided such as monorail and LRT. Car-pooling also can applied in this context"* (Int-S4:122-124). Furthermore, *"air pollution index can be monitored by commanding control on the use of public transport more rigorously* (Int-S1:211-212).

Preservation and conservation. Preservation is the action of continuing and maintaining natural resources to make them last. On the other hand, conservation is the action of preserving the natural resources accordingly. Based on the analysis, preservation and conservation refers to the action of maintaining and protecting natural resources that include biotic and abiotic natural resources.

Biotic natural resources. Students were able to discuss the preservation and conservation of biotic natural resources that comes from living and organic materials such as animals, forests and fossil fuels (coal and other renewable fuels). They initially defined and gave animals as an example while explaining *"preservation and conservation of natural resources, meaning we have to maintain and protect animals"* (Int-S3:205-207). Forests were the other biotic natural resource that was highlighted by the students due to the *"recognition of Malaysia as having the oldest forests not only in Asian region, but in the world"* (Int-S5:93-94). They mentioned, *"forest seems like pleasure and Malaysia is among 12 countries with the richest biodiversity such as flora and fauna"* (Int-S2:86-88). As a forest heritage country, *"we have the largest mega biodiversity, and as we know it is the habitat for wide variety of flora and fauna"* (Int-S5:95-97).

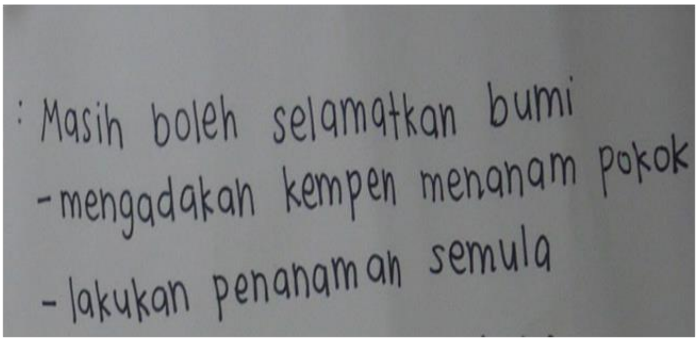
Therefore, *"the recognition of mega biodiversity country and forestry activities reflected us to rebuild that thing [refers to biotic natural resources] back automatically. It's just like we have to maintain and protect our forests"* (Int-S3:209-211). Additionally, they mentioned other countries *"exemplary of forests that exhibits preservation and conservation as seen in Malaysia, Indonesia, Brunei and Brazil. In Brazil alone, we can always see the beauty of the Amazon forest until now"* (Int-S5:91-93). Moreover, *"France is suitably taken as other example. France is very beautiful because this country maintains its nature through the preservation and conservation of its forest"* (Int-S2:67-68).

The justification on the preservation and conservation of biotic natural resources was in line with human responsibility, *where "we descended to Earth to manage the resources, to live in peace"* (Int-S2:121-122). The students suggested that global warming should be controlled systematically *"for me, now we have to very focus* *about conservation"* (Int-S3:298-299). The specific action was also given, *"ok, preserving and conserving the environment is our suggestion here. We specified it in the context of the damaged and treeless forests. Replanting is one of them"* (Int-S3:293-295).

The action of replanting and *"planting trees is something like preserving and conserving the environment"* (Int-S6:88). They elaborated on global warming solutions, such as *"preserving and conserving the botanical gardens is a great initiative handled by UNESCO. It is because, it obliges and requires each country to have its own national park. So for me this kind of alternative should be implemented more"* (Int-S5:295-298). The students also applied a concept in the engineering field, by mentioning that *"the eroded slope must be hold up by planting some plants, not by installing a concrete retaining wall. So for me the conservation of plants is very important here" (Int-S3:306-307).*

They further clarified the scientific facts given, *"global warming is said very worst because we're really hurting the Earth. The preservation and conservation for the whole Earth should be focused. And we must take care of all this"* (Int-S3:302-30).

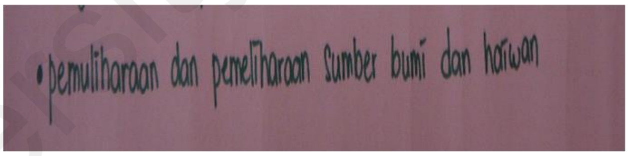
The preservation and conservation of biotic natural resources as an alternative solution to global warming was also portrayed in the following PGO displayed in Figure 4.19. The students suggested that the campaign to plant trees and promote the replanting activities could be used to save the Earth.



We can still save the Earth.
- Conducts campaign to plant trees.
- Propagates replanting activities.

Figure 4.19. Generated PGO drawn by students and PGO redrawn and translated by researcher - (G6PGO). (Providing alternative solutions)

They further recommended to preserve and conserve the *"natural resources such as coal"* (Int-S3:184-185) and *"other natural resources to be used efficiently, so that they can be sustainable"* (Int-S3:185-187). The next PGO in Figure 4.20 indicates the suggestion on the preservation and conservation of biotic resources (natural resources and animals) as the alternative solutions to overcome global warming.



Conservation and preservation of natural resources and animals.

Figure 4.20. Generated PGO drawn by students and PGO redrew and translated by researcher - (G3PGO). (Providing alternative solutions)

The preservation and conservation of abiotic natural resources involve the resources originating from non-living and non-organic materials including water, sunlight and air. Students were also able to emphasise the importance of abiotic natural resources: *"global warming may also be fixed or we helped by preserving and conserving the abiotic natural resources"* (Int-S3:91-92) such as *"water"*

(Int-S3:207). They added, *"when we use water limitedly, so there is enough time for the contaminated water to undergo water conservation process through specific system. It can be equally used, indeed. Do limit water consumption, then use sparingly"* (Int-S3:187-190).

They recommended that this alternative solution should involve every citizen *"which means that we have a society that is very efficient in the use of resources such as water"* (Int-S3:225-226). This can be applied by *"the utilisation of machine in the mall public toilet. That's the way of how to save and reduce water consumption"* (Int-S3:253-254).

Renewable energy was included in this sub-category because it was obtained from natural resources such as water, sunlight and wind. For this aspect, the students explained about "*the use of solar energy* (Int-S6:160) that is applicable for this context. They added that the consumption of *"renewable energy that originated from water itself, wind and sunlight that produced solar energy is also suggested as solutions"* (Int-S2:82-83). The relevant excerpt shows that students were able to conceptualise solar energy with regard to this alternative solution.

> "One building must be provided with solar panels. It is compulsory to make sure that the building that we want to construct is facing the sun. The photovoltaic system is then working to supply usable solar power by a means of photovoltaic."
>
> (Int-S5:159-162)

Education and social awareness. In this context of the study, education and social awareness refer to the alternative solutions that are essential for reducing the effects of global warming. The aspects involved in this sub-categories are education, campaign, daily practices and law enforcement.

According to the interviews and PGOs, the alternative solutions proposed by all groups were impressive for this sub-category, education and social awareness. For example, all group representatives did explain, *"education is very necessary solution in preventing global warming issues"* (Int-S5:385). Education plays a *"significant responsibility to the public, meaning that it will help the society. This means we need to educate them until the point that they aware about this current situation"* (Int-S3:222-225).

Correspondingly, the students could reveal research and development education aspect for the global warming alternative solution. They believed, *"Malaysia mostly use products that are produced abroad. So now, we want to create for oneself a product of our country and the entire world to deal with global warming. This can be done by expanding the research and development aspect"* (Int-S5:171-173). The initiative that seemed relevant to the students was by *"adding a research-based or R&D university because it is proven as beneficial for reducing global warming issues"* (Int-S5:166-167). With that, Malaysia's progression in terms of innovation would not be stagnant, *"meaning that we created a new product that is very useful for the people over the world. So that science is not limited to purely theoretical learning but able to go beyond that"* (Int-S5: 169-170).

The research and development education could be *"possibly done through innovation"* (Int-S5:162-163). The application of aspect in *"technology may lead us to conduct in-depth research, thus create something that can reduce global warming"* (Int-S3:187-188). Other than that, the suggestion of incorporating research and development activities from informal education agencies was proposed by a student as shown in the following excerpt.

> "Because we know that research and development aspect is the vessel for everything. So, DOE and the Ministry of Education must expose more students who will become scientists. Importantly, they must help students with educational activities that keep nature healthy."
>
> (Int-S5:139-142)

Social awareness was also needed in which the society must be aware and conscious of the global warming problems they faced on a day-to day basis. The focus of social awareness was *"to create awareness among the communities and societies"* (Int-S6:87-88). The suggestion of developing social awareness could be implemented *"maybe through the campaign"* (Int-S5:414-415). The action should be taken by *"related organizations to maintain and create a campaign for preventing global warming seriously"* (Int-S4:49-50). Relating to their personal experience, the student revealed, *"this school has conducted a "No Dustbins" campaign on Wednesday. Without dustbins, the plastics and rubbish were delimited indirectly"* (Int-S5:422-423).

They accepted that global warming could be overcome through campaigns by stating, *"so I think there is a way that you can fix the problems. By the way of conducting campaign in which to create awareness among the people about the use of public transport"* (Int-S4:120-121). For example, the social awareness of the application and *"the concept of 3R (Reuse, Reduce and Recycling), could be implemented by conducting 3R campaign ever undertaken by the DOE. Yes, I have ever attend. Reduce, Reuse and Recycle Campaign!"* (Int-S3:195-197).

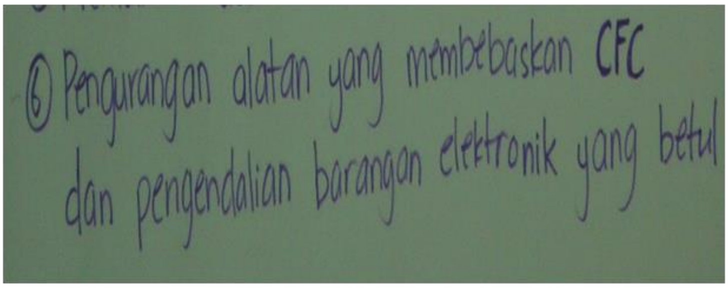
For the social awareness, the current study observed that the students were able to incorporate the essential daily practices in dealing with the global warming issue. Shifting daily practices seemed relevant "*to foster best daily practice that can overcome global warming issue"* (Int-S3:222). For instance, *"the use of environmentally friendly products or 3R product such as paper that can be recycled can save the Earth" (Int-S3:260-262).* The students continuously elaborated the daily practices in reusing, reducing and recycling products as follows.

> "Usually, the objects like tin, plastic, polystyrene and bottle were actually used only once. So we already known the consequences of throwing them unsystematically right, it will lead to environment contamination and getting worse. So we can take a step ahead to reuse, reduce and even recycling the objects. Directly, we reduce and limit its production."
>
> (Int-S3:197-202)

Moreover, changing old habits among the societies seemed important for them *"for electricity, we feel we have to teach them to switch off the light and fan if we do not use them"* (Int-S3:226-227).

In terms of electronic waste management (e-waste), it was noted that students recommended, *"disposing electrical goods in a properly methods by using e-waste management"* (Int-S4:46-47) as an example of an alternative solution to reduce global warming.

It was found that the expert from DOE had explained e-waste management as an example, to further explain the alternative solution provided by DOE. The expert highlighted that e-waste management was one of the daily practices that can be applied to reduce global warming, *"for example, we cannot eliminate electrical waste goods just like that without disposing of them properly, that is a new thing that I know"* (Int-S5:417-418). This sub-category of alternative solutions was derived from the responses above and this was supported by the PGO generated by Group 4 presented in Figure 4.21. The students highlighted that the reduction of electrical appliance usage, which contributes to GHG emission and proper appliance handling, would be able to reduce the progression of global warming.



6) Reducing the usage of electrical appliances which release CFC and the correct handling of electrical appliances.

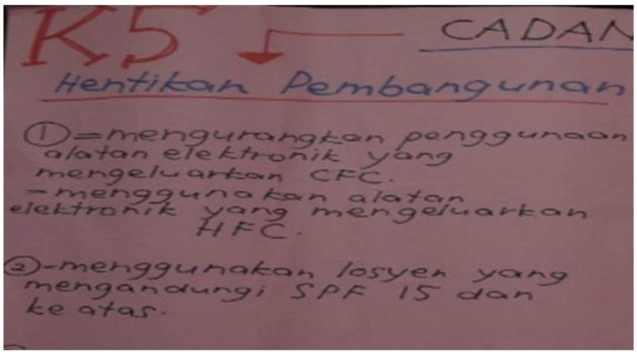
Figure 4.21. Generated PGO drawn by students and PGO redrawn and translated by researcher - (G4PGO). (Providing alternative solutions)

Other daily practices were also listed as a measure to reduce the impact of global warming, such as *"we can use sunglasses, long sleeves clothes, umbrella and cap"* (Int-S2:147-148). The following excerpts illustrate the practical daily practices of using Hydrochlorofluorocarbon (HCFC) and Sun Protection Factor (SPF) as the alternative solutions in the health aspect.

> "We can use HCFC-based electronic devices, namely Hydrochlorofluorocarbon. Hydrochlorofluorocarbon is not dangerous and not very toxic. So we can use them as a solution. To date, HCFC is quite expensive, so it is often used in developed countries such as Germany and France."
>
> (Int-S2:70-74).

> "This SPF lotion, sun protection factor is a UV light cream that can be applied onto our skin. When UV rays keep contact with skin, there would be a risk of skin cancer. As a result of the ozone layer has depleted, so we have to use SPF 15 and above to avoid it."
>
> (Int-S2:74-76)

Throughout the study, the use of HCFC and SPF were only emphasised by Group 2 through the PGO in Figure 4.22. The students suggested replacing CFC usage with HCFC to overcome the global warming issue. The use of SPF-15 and above was also encouraged by the group as a method to prevent skin cancer due to over exposure to the UV rays.



SOLUTIONS

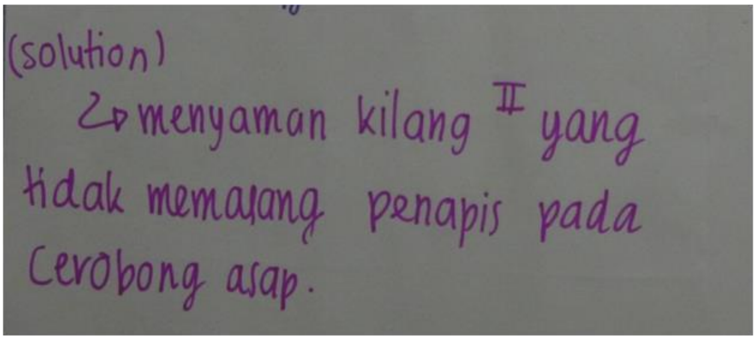
Stop the developmental activities.

1. Reducing the usage of electrical appliances which release CFC.
   = Example: Using electrical appliances activities which release HCFC.
1. Applying lotion that contains SPF15 and above.

Figure 4.22. Generated PGO drawn by students and PGO redrawn and translated by researcher - (G2PGO). (Providing alternative solutions)

Other than that, preventing global warming issues is *"subject to law enforcement"* (Int-S3:233-234). For example, "*maybe IPU controls can be monitored again through legislation and law enforcement* (IntS1:209-201). The students said, *"Malaysia is apparently doing some programme to prevent and tackle this problem. Also the action of enforcing environment acts"* (Int-S5:39-41). Moreover, law enforcement can be implemented in the developmental activity control *"we will be able to say any development approvals may be endorsed from the Ministry of Environment or Ministry of Rural Development"* (Int-S1:159-160). The data from PGOs supported the students' understanding of law enforcement as the alternative means in developing social awareness among societies.

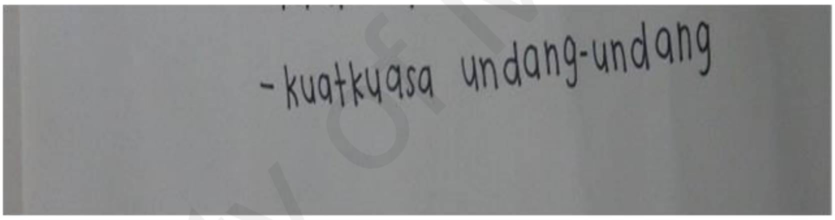
The PGO in Figure 4.23 indicates that the student suggested that a strict legal action should be taken on factories that neglect the order to install air filters in their chimneys. This action may force the operators to take action in reducing the emission of harmful gasses and particles, which may lead to global warming.



(Solution)
Sue the factories that do not install the air filter in the chimney.

Figure 4.23. Generated PGO drawn by students and PGO redrawn and translated by researcher - G4PGO). (Providing alternative solutions)

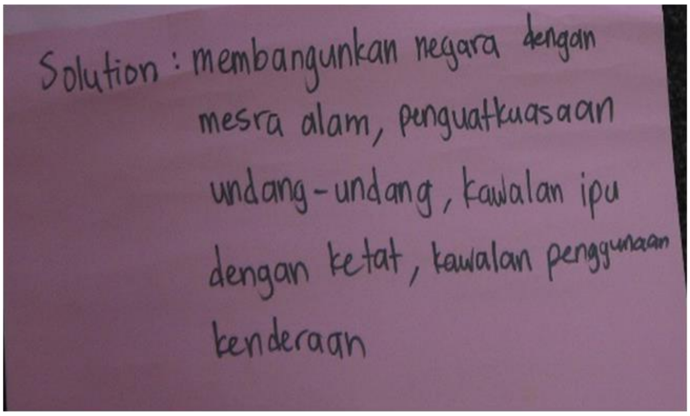
The need to implement law enforcement was also stated in Figure 4.24.



- Law enforcement

Figure 4.24. Generated PGO drawn by students and PGO redrawn and translated by researcher – (G6PGO). (Providing alternative solutions)

Figure 4.25 shows the inclusion of law enforcement as one of the solutions that must be taken in order to control the global warming problem.



Solution: Developing countries with environmentally friendly development, **law enforcement**, control air pollution index (API), control the use of vehicles.

Figure 4.25. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G1PGO). (Providing alternative solutions)

Misconception. In addition, the findings also revealed that the students had some misconceptions or mixed understanding related to this topic. The misconception is an incorrect opinion resulted in misunderstandings the students hold. A student from Group 3 gave incorrect facts that showed a misconception of what the greenhouse effect was. A few of the students in this study claimed invalid understanding when dealing with the global warming issue. For example, Student 4 wrongly explained, *"one of the greenhouse effect functions is that we can use it to filter the smoke or gas from the plant"*. Accordingly, the other student from Group 6 stated, *"each of the ozone layer are releasing heat"* instead of absorbing UV rays.

Another common misconception exhibited by some students was that they assumed that global warming was only a myth. This state of misconception was revealed in which *"global warming is just a myth, the issue that scientist created to scare people, also a strategy to stop us from developing our country!"* (Int-S4:201-

203). Likewise, they commented that global warming issues were only exaggerations made by the scientist. The following excerpt can prove this observation.

> "The last time histories proved that when people have started to develop new technology, they become greedy! Sorry to say, maybe kind of leaders out there view this Earth as an insurgent nature. Kind of developed countries they build up cities so that the devil is coming. Devils really want an iron forest. They consider this Earth should be like a forest of metal, concrete jungle. Because if there is iron forest, then there are many vices and social ills all these things. It's nothing to do with global warming at all."
>
> (Int-S5:171-179)

However, the students' perception and understanding changed after acquiring strong scientific consensus on the global warming information. They admitted, *"when the teacher shows the facts and the alarming global warming statistics, so I realised that global warming does happen"* (Int-S4:28-29). Moreover, another student confessed, *"we ignored this issue previously and assumed that there's nothing wrong with global warming. However, when I reached this stage, then I know more facts about global warming. More concern about global warming or kinda worries stuff"* (Int-S3:27-30).

The misconceptions expressed by the students were mainly related to the misunderstanding about the function of the greenhouse effect and the myth of global warming. Overall, the findings from PGOs and interviews demonstrated that all of the sub-sample groups were able to 1) define the global warming phenomena in terms of temperature and GHG emissions 2) identify anthropogenic and natural factors affecting global warming 3) clarify the global warming effects in the aspects of health, ecological system and climate change and 4) provide alternative solutions for the global warming phenomena in the aspect of sustainable development.

Students' Considerations for Framing Global Warming Decision

The considerations prioritised by the lower secondary students and how they leverage the decision regarding the global warming scenario were characterised in the current study. The students used two different angles of considerations from the scientific and social dimensions when framing their group decision. Figure 4.26 illustrates the two categories of considerations that students used to develop their position which were scientific and social considerations. Each of the categories was further divided into three sub-categories: environment, technological advancements and medical sub-categories were under the scientific considerations and economy, politics and religion sub-categories were under the social considerations. Each of the categories and sub-categories were discussed in the following section.

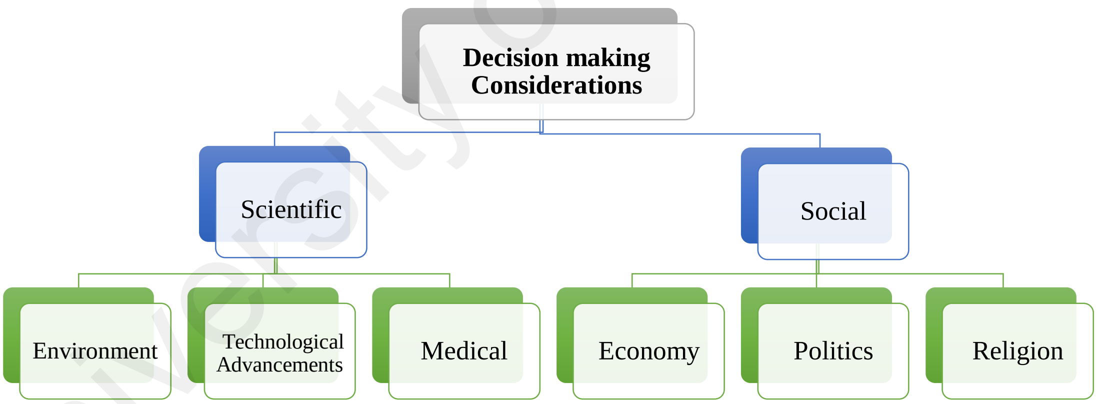


Figure 4.26. Categories and sub-categories of considerations during decision-making regarding the global warming issues

Scientific consideration. In this context of the study, the scientific consideration was defined as an important priority of all science-based knowledge that students used to make a final decision on the global warming issue. Based on the analysis, students made their decision using several scientific considerations such as environment, technological advancements and medical.

Environment. Findings indicated that a majority of the students supported that environmental issues were considered as essential factors in making the final decision. They highlighted that the environmental issues should be considered by *"applying the development control method in managing, planning and controlling the developmental activities"* (Int-S2:110-112). The developmental control involves the process that regulates the development regarding industrialisation, urbanisation, and economic development. This process typically requires a developer to apply for an official permission before starting any developmental work.

The environmental issues seemed important for the students when deciding whether to stop the developmental activities or not. They constantly mentioned about the developmental control in the interviews, *"do not stop the development, and at the same time, we apply a development control method"* (Int-S2:80-81). This method was contemplated *"so we decided that this group made progress for the country but still important: balance-based, it must prioritise the nature, the environment"* (Int-S5:128-129). In general, *"it means we continue the overall development but besides that we want the environment to be always protected. We still think that the environment needs to be maintained. Must equal regarding development and environment"* (Int-S3:200-202).

Some groups considered continuing the developmental activities for certain reasons "*and in the meantime, we will not harm the environment"* (Int-S2:97). They strengthened their position by giving relevant justification on the environmental aspect *"so if we want to pursue what developed countries are there, we must look and control for something that can develop our country in addition to not harm the environment of ours "* (Int-S4:137-139). The example of controlling the development was given so that *"our nation is expanded as environmental-friendly that prioritise plants and nature to be well-developed. Yeah, things [things refer to consideration] like that"* (Int-S5:66-67). The student further elaborated the environmental consideration, as the following excerpt demonstrates.

> "The main thing that I over thought when making a decision is about environment. Why? It is because Malaysia is recognised as one of the 12 mega-diversity countries in the world. So, I feel that Malaysia should maintain the biodiversity and not leave the development."
>
> (Int-S5-78-81)

Technological advancements. Findings showed that various aspects of technological advancements were taken into consideration when making the decision about global warming. It was acknowledged *"so firstly we prefer not to stop the development based on the technological reasons. If we stop it, there is no progress of new technology definitely!"* (Int-S4:85-87). They emphasised, *"we are more focused on advancement of technology because it does help and contribute to solving global warming problems"* (IntS4:99-102). In addition, *"technologies can generate more tools and devices for global warming control"* (Int-S3:130-131).

The students took detailed examples, such as *"if there's no creation of instruments that measure air quality, for instance, we cannot measure and do not know what happened to the quality of our environment now"* (Int-S4:74-77). Other than that, *"if we do not stop the development, then we need to develop it by using the technology* *of environmental-friendly for instance"* (Int-S1:83-84). They also proposed that, *"we must be aware of the innovation and technology used for daily applications"* (Int-S1:65-66). The priority of technological advancement was consolidated as follows.

> "Ok, we chose the same decision, which does not stop the development activities for reducing global warming impacts. Ok, we feel that our country's progression is still not comprehensive in terms of new technology and still faced with many problems. By fully rely on the technology advancement, it might help us solve the case of global warming."
>
> (Int-S3:181-187)

They believed that this aspect should be of concern because *"if there is no technological progress, global warming is likely to be difficult to resolve"* (Int-S4:102-103).

Medical. In the context of the study, medical issues emerged as a consideration that students believed was important when making a decision. For the groups that decided to continue the developmental activities, they admitted that medical consideration became vital in continuing the developmental activities *"yes sure! Ok, at first we decided to stop development because we only think about human life and health that must be protected more than other issues"* (Int-S1:59-62). They justified their preference with *"the decision made because we think that by continuing the development, it does not mean being the main contributor to health problems"* (Int-S1:64). Other related excerpts were shown as follows.

> "For me, it is precisely true for deciding not to stop the development activities. Based on our discussion, continuing development activities promote our country progression in a different angle, isn't? In the meantime, we do not undervalue health aspect."
>
> (Int-S4:73-75)

> "So after we discussed with relevant reasons and arguments, we have to choose our final option not to stop the development activities. For this present age, development is not seen the only factor of global health risk."
>
> (Int-S5:62-64)

The present study detected that the students argued about the importance of the medical aspect although the groups chose to discontinue the developmental activities. The following excerpt indicates the medical consideration that the students regarded as important in making the final decision.

> "Finally, we choose not to stop the developmental activities. We know that the Earth is becoming hotter due to the severe global warming. So if we still continue with this evolution activities, although using green technology but still have side effects. Even though it is small, but over time will become a big problem for us especially for human adaptation and health."
>
> (Int-S6:82-85)

Social consideration. The following section describes social considerations that the students pondered upon in making their final decision. In this study, the social considerations referred to a vital priority of all social-based considerations that the students emphasised on when making a final decision on the global warming issue. The social directions include economy, politics and religion.

Economy. The most common consideration observed across all group was 'economy', which referred to the economic prioritisation in making a decision about the global warming scenario. The country's economic development was the social concern most frequently quoted in the students' interview. This consideration includes elements such as the standard of living, economic power, economic backwardness, unemployment, gross domestic product and unequal distribution of wealth.

For instance, one student in the interview session informed about, *"the decision of not to stop the development are for the public benefits regarding life and standard of living. Their living standards will be maintained and will continue to increase"* (Int-S2:95-97). On the contrary, stopping the development activities will lead to the economic crisis, *"perhaps those who work as a worker with a salary of 5 thousand* *then cut into 3 thousand or 2 thousand. Yes, it will affect their standard of living"* (Int-S3-128-129).

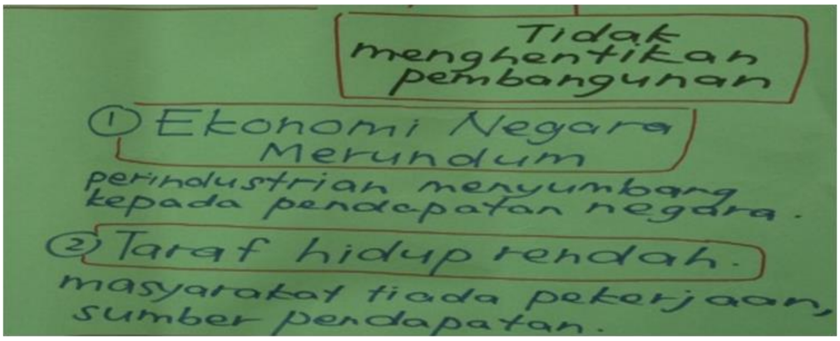
The standard of living emerged dominantly in the students' preferences as they argued, *"because we think and worry about those who are now in a state of poverty. So we could not want to stop development just because of global warming"* (Int-S3:198-199). As a result of the development retention, the unequal distribution of country's wealth may occur where *"the norms and the gap between wealthy and poor is huge" (Int-S3:166-167*). The students listed three examples to the current situation of the living standard that directed them in choosing that decision.

> "We also think about our society. The current standard of living is not possible to feel happy. Let's take one example of how we look at things now. Previously, by 20 cents we can buy nasi lemak but now with the 20 cents, we hardly can buy anything. We also need to pay for the government service tax and so forth."
>
> (Int-S3:129-132)

> "We can see closely via television; they do not like people in Malaysia. People of Malaysia have at least a physical house, at least! However, for those who live in the underdeveloped country, they have nothing, they sleep everywhere. So we thought if the development needs to stop, it will affect people's life as well. Specifically, we say it affects the standard of living!"
>
> (Int-S3:150-153)

> "So if people have no work, there's no sources of income. If no income, how can they survive? The world right now, if you have money you can get everything, if you do not have money then it would be a sad story for you."
>
> (Int-S3:156-158)

The following PGO in Figure 4.27 illustrates the economic lenses comprising the standard of living that might be affected due to the halt of the developmental activities. The student perceived that the activity reduction may collapse the nation's economy as the developmental activities provide the income for the country and will disturb the citizens' standard of living.



Do not stop the developmental activities
1) The country's economy will collapse. Industry contributes to the national income. 2) The standard of living will reduce. As a result, people are out of work and income.

Figure 4.27. Generated PGO drawn by students and PGO redrawn and translated by researcher - (G2PGO). (Economic direction)

In conjunction to this crisis, they were most likely to argue about the economic power. The students mentioned about the consequence of halting the developmental activities where *"if we hack the developmental activities, the most negative impacts such as economic instability will occur"* (Int-S1:86-87). They emphasised the importance of the economic power resulting from maintaining the development, as shown in the following excerpt.

> "Previously, a government is dependent on the strength of political power. However, now, in the modern contemporary world today, a country's strength depends on the economic force of the country. We think that if the country's development stopped, there would be no reform and progress. We will be weak economically.
>
> (Int-S3:119-123)

The following PGO in Figure 4.28 also focuses on the students' justification on why the developmental activity retention must not happen. The students identified that the retention of developmental activity would lead to bankruptcy and disrupt the citizens' essential needs. As a result, economic instability may occur.

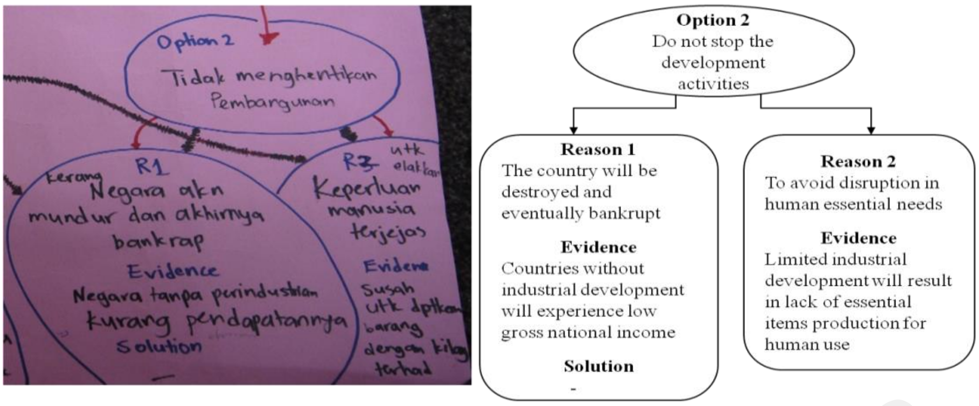


Figure 4.28. Generated PGO drawn by students and PGO redrawn and translated by researcher - (G1PGO). (Economic direction)

The students were most likely to hold on the importance of economic power, where they consider, *"the development of the country should not be dismissed because we want all progress can be made at the level of the whole layer. We want Malaysian's vision to be continued"* (Int-S3:116-117). *In their view,* the specification of the country's vision *"means regarding economic development is the most important, yes about the National finance"* (Int-S5:136-137). They emphasised on the country's national finance produced from *"the economic sector such as export and import businesses"* (Int-S5:131-132).

In making a justification for economic power, a majority of the students preferred to further elaborate by taking developed countries as an example, such as *"Japan is a well-known country because of its economic development in the international arena"* (Int-S4:139-140). One state is considered as economically progressed when they are able to maintain their development. A student stated, *"we know that Japan has a strong economy and tough to be competed economically. It is the factor that Japan has always been at the top ranking. At the same time, Japan was able to control global warming"* (Int-S4:141-143).

The students also highlighted the economic backwardness issue which resulted from the discontinued developmental activities. They listed agricultural dependency as an example of the economic backwardness issue that must not be underestimated. They reviewed the history and stated, *"ok, if we look at our country's economic history, we used to rely heavily on agriculture but ultimately failed! Because what, because the fluctuation of agricultural raw materials price*" (Int-S1:89-90). This circumstance happened *"previously; rubber prices are worldwide demanding. Meaning to say, people always want rubber. However, now it has fallen. Not as high as it used to be"* (Int-S1:91-92). The student again convinced, *"if we do not develop our country for the sake of reducing the global warming effects, this again and finally we will be heavily dependent on the agricultural economy"* (Int-S1:87-89). The following excerpt explains economic backwardness that should be avoided.

> "Say, if the country has stopped its' development, we will face stagnation! So other countries will continue to progress in the economic sector. What is happening to our country then? We will be left out, underdeveloped and even unrecognisable, surely."
>
> (Int-s3:139-143)

For the economic backwardness aspect, most of the students mentioned their worries about the country's progression, where they emphasised, *"our country need to move forward, not only stop until reaching Vision 2020!"* (Int-S4:163-164). The consequences of stopping the development activities were considered as an irrelevant option because it would then *"collapsed our economic sector"* (Int-S2: 57-58). In addition, it may affect the country's currency value *"the economy will collapse and cause the national currency to fall"* (Int-S2:60-61) due to the *"regression in national gross domestic production"* (Int-S2:58-59). Students were also able to relate the economic backwardness that may occur by stopping the development activities regarding the trading sector *"in which aspect they relate? When the economy is down,* *we lost our foreign investors. They are people who come here for trading purposes"* (Int-S3:124-126). Consequently, *"when this happens, the gross domestic product also not much increase"* (Int-S3:126-126).

Equal development in infrastructure seemed relevant for the student as *"we think any country that has developed can provide the infrastructure to serve the people better"* (Int-S3:204-205). The students specified, "*Sabah and Sarawak are the examples of a state that still not gained same progress standard as Kuala Lumpur. Gombak, the city, located in Kuala Lumpur is still not reaching similar development. So we thought, we want to ensure that equal development is applied as a whole. Not just in one point"* (Int-S3:119-121). For example, *"if we stop it just because of that global warming issues, new hospitals will not be built"* (Int-S1:91-92) and *"the schools are limited because we have no capitals to build the new ones"* (Int-S2:128-128). Other than that, *"developed countries always have excellent facilities and services in the business aspect. Surely the economic development is necessarily better"* (Int-S3:128-130). For the aspects of the electricity transmission and water supply, the current local issues were used as an example, such as the one discussed in the following excerpt.

> "We said there are still remote areas that are lacking in water and light support. So we think the facilities still need to be improved, need to progress. Comprehensive progress, the idea should be the equal development of infrastructure thoroughly."
>
> (Int-S3:124-126)

The other economic impact like infrastructure inadequacy would be indirectly influenced, where *"the inadequacy of infrastructure is likely to happen, and surely it will affect life"* (Int-S3:147). This situation would then affect the tourism sector *"due to lack of infrastructure, and also we associate with tourism industry. When there's* *nothing left in our country, there will be no tourists. That is what we think"* (Int-S3:137-139). The following excerpt reflects the students' economic direction in the infrastructure inadequacy in the local and global contexts.

> "If let's say Kuala Lumpur is not developing regarding infrastructure, we have no twin tower, we have no basic facilities, improper facilities; then it can also be categorised as a third world country. Yes, we think of infrastructure inadequacy."
>
> (Int-S3:134-136)

> "Take the example of other country, Sri Lanka and continent like Africa; they are backward in terms of infrastructure and facilities! "
>
> (Int-S3:146)

They also mentioned a neighbouring country as an example of a developed country that not only depends on the development of industrialisation but it has also diversified in strategies in reducing global warming. The relevant excerpt is as follows.

> "For instance, Singapore is one of the rich countries even though industrialisation is not a priority sector. Singapore got much support from outsiders by giving facilities for traders. It is not very advanced in the industry. That is the way Singapore improves its economy. By providing facilities, Singapore can make money through facilities taxation."
>
> (Int-S1:109-113)

This condition automatically affects the human capital for economic development. Human capital is condensed based on the stock of knowledge, habits, social and personality attributes embodied in the ability to perform labour to produce economic value. The students stressed that the aim of providing adequate infrastructure *"will bring a more literate society, the more educated nation yet easy to achieve progress"* (Int-S3:205-207). Ideas from the young generation were considered more noteworthy, *"that is why we do not have to stop developmental activities just for reducing global warming problem because brilliant ideas can't be fully used for other vital development. Avoiding that issue is just a small matter"* (Int-S4:170-172). They were convinced that *"by continuing developmental activities mean we do not restrict the development of constructive ideas among the young generation"(*Int-S4:143-144).

Therefore, more concern should be given to the academic progression because Malaysia is recognised as "*competitive regarding education arenas"* (Int-S5:136-136). This can be done by implementing school and academic upgrading as a means of investing human capital to produce economic value. However, stopping the developmental activities was considered as deactivating this purpose as *"a high dense school is suffered from a lot of damage and capital problems that cause difficulties in upgrading school and academic performance because of lacking in financial resources"* (Int-S2:131-133). Therefore, *"the upgrading of education tremendously decreases"* (Int-S2:128-129).

Not to forget, the public healthcare could also be affected as *"the health of the people or the community as a whole will decrease"* (Int-S2:75-76) due to the *"less modernisation of equipment in the hospitals"* (Int-S1:91). As a summary for human capital development, they stated, *"whenever the country forward, then we will have people who also advanced. We also think that, regarding social development!"* (Int-S3:207-208).

Politics. Students were able to elaborate the political orientation in their arguments for both options: stop or do not stop the developmental activities to avoid global warming impacts. The elements involved in the political considerations were unity, authority, security and military strength.

Some students were able to imagine as they were holding a prime minister's role and took a solid option regarding their political standpoints. The following excerpt shows the example for unity used by the students in framing their decision regarding the global warming scenario.

> "I will not stop the developmental activities just for reducing global warming effects. As a minister, for instance, I will be opposed by people if I am still adamant. People will not united with the leader. There will be the problems of unity and that leader will likely to be sacked."
>
> (Int-S5:76-78)

Furthermore, the political authority also seemed significant with regard to leadership strategy as *"how that leaders think, for example, if we halt the development, the world will see Malaysia's leader as having low leadership skills as they did not believe about economic interest and social benefits. He was only concerned with purely global warming interests"* (Int-S5:168-171). This means *"when stopping the development, Malaysia is considered having poor thinking leaders"* (Int-S5:167-168). They further clarified the authority's importance through the excerpt, *"so we have to think about the consequences, and take the leader responsibilities to bear this situation, we should also think about the benefits of others.* (Int-S3:200-201). This situation showed that responsible leaders must have excellent leadership skills especially in initiating and responding to control the global warming situation in a flexible manner. They also must be able to clarify global warming problems and making logical decision to overcome the issue.

Security issues also emerged, referring to the indirect consequences of stopping the developmental activities. It was considered as an important political aspect that was influenced by the economic development. The student considered that *"the security of the political aspects can also result from stopping the development, may we say that the state is weak politically and militarily, external countries can easily attack us"* (Int-S3:170-172). The security aspect would decrease due to low military power as there were *"no weapons and so on, we have no money, we have nothing to do"* (Int-S3:172-173). According to the student, the security aspect plays an important role in the political agenda, without political stability, multiple impacts such as *"insecurity, people's rebellion, economic collapse, welfare and so forth will be attacked"* (Int-S3:165-166). The student could also offer his opinion in giving a global example related to the security aspect.

> "Ok, let's look into safety term. If the development is stopped, the undeveloped countries such as Afghanistan and Turkistan governments are continuously suffered from peaceful. So other external parties will intervene affairs of the countries; surely that country would not be safe."
>
> (Int-S3:161-165)

The element of country's reputation regarding security emerged where students believed that discontinuing developmental activities for the sake of reducing global warming was just irrelevant which *"then it affect our security position. Other countries assume that Malaysia is dangerous and unsafe country!"* (Int-S3:173-174).

Religion. Students were able to connect their decisions with religious considerations. The religion considerations were one of the spontaneous responses given by the students although they were not probed to do that so. According to the 6th and 7th grade Malaysian Science syllabus, there is no explicit learning objective of global warming connected to the religious aspect (MOE, 2011). However, there were some aspects of religious beliefs present in the students' responses. The selection of these examples denotes reasoning applied to a given global warming scenario. In this context of the study, relating ideas to religious beliefs emerged as a means of expressing their justification about the decisions made, detected through their PGO generated during the contextualisation stage. The PGO in Figure 4.29 denotes the students' ability to relate the current condition to a Quranic verse mentioning about humans who conduct destructive acts on Earth without noticing, which is related to human acts leading to global warming.

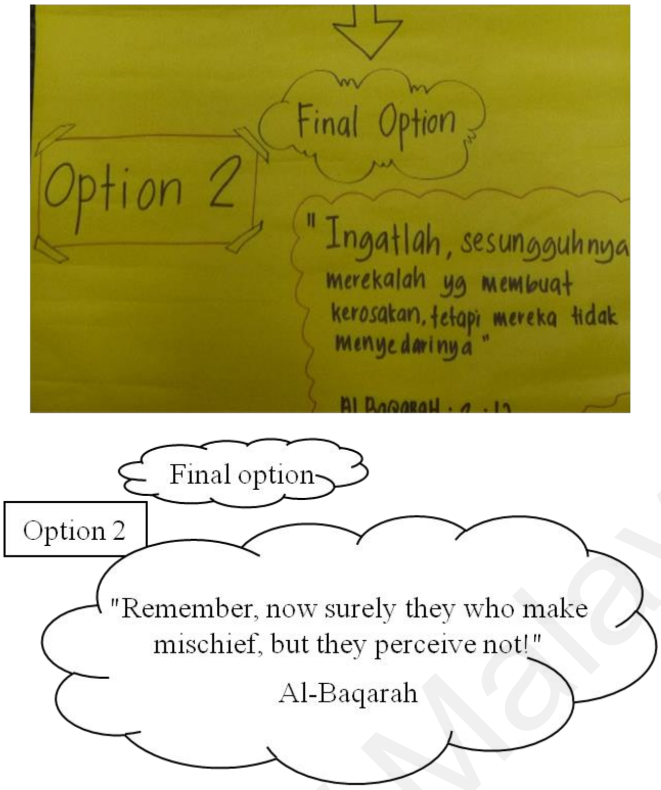


Figure 4.29. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G5PGO). (Religious direction)

Through the PGO, it was noticeable that students held very dynamic perspectives in relating global warming decisions to the religious consideration. They presumed it as necessary justifications for choosing the best option for the scenario given.

> "Ok, we selected option 2, do not stop development and we have put the arguments stated in the Al-Quran. "And remember, they are the ones who make mischief, but they perceive not." Indeed, it is in the Al-Quran, Allah forbids people from making mischief in the land. Allah indeed forbids us to do that. Moreover, in fact, there is a word of God for humanity, "Do you notice that Lord took them with punishment for what they used to earn"."
>
> (Int-S5:213-219)

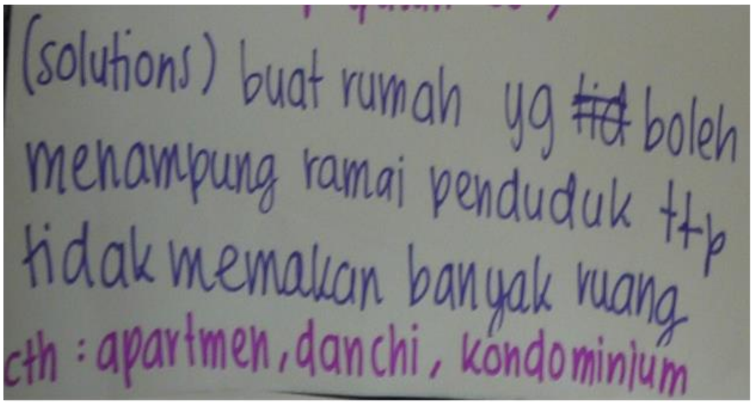
They were further convinced, *"many aspects such as religion concerned us before making conclusion"* (Int-S5:180-181). Extreme global warming issues affect the whole Earth as *"Earth is just a temporary place from God. If we ruin it, perhaps it is too late because of the depletion of Earth's speciality. It cannot be replaced and will* *be a big problem for the world's population"* (Int-S3:81-884). They showed their despair by connecting global warming effects to the religious principles, as shown in the excerpt below.

> "Another one, we are afraid that if we act later, Lord will send down something or misfortune that we do not know. We are aware, that if one area that has too many sins so that God will inflict punishment. The guilty and innocent society remained punished by Lord."
>
> (Int-S5:380-383)

Furthermore, one student could mention about the specific verses in Surah Al-Baqarah, stressing on human factors that could damage to the Earth.

> "When your Lord said to the angels, "Indeed, I will make upon the Earth a successive authority." They said, "Will You place upon it one who causes corruption therein and sheds blood, while we declare Your praise and sanctify You?" Allah said, "Indeed, I know that which you do not know"."
>
> (Int-S1:190-194)

In a different episode, the students tried to relate the ideas with Chinese beliefs by providing alternative solutions that could reduce the deforestation activity. The student explained, *"so the second idea stated here is what I am saying just now, future house must be considered in incorporating many families in one house, following Chinese style"* (Int-S4:75-77). A similar suggestion was also expressed through the presented PGO in Figure 4.30, where the group suggested housing plans using limited spaces but would still be able to accommodate a large number of residents.



(Solutions) Create a home that can accommodate many people but does not take up much space. Example: Apartment, Danchi, condominium.

Figure 4.30. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (G4PGO). (Religion direction**)**

The Factors that Influence Students' Understanding in Making Decision about SSI within the Co-Curricular Context

The analyses revealed four factors explaining the influences of the co-curricular context towards promoting the students' understanding in making a decision related to the global warming issue. The four factors identified have either facilitated or inhibited the students' learning within this context. The fundamental factors were categorised into learning flexibility, socioscientific instructional resources, integrative activities, and students' readiness. The factors for the four contradictory categories are suggested, as shown in the following Figure 4.31. The third research question of how do the factors influence students' understanding in making decision about the global warming issue will be discussed shortly.

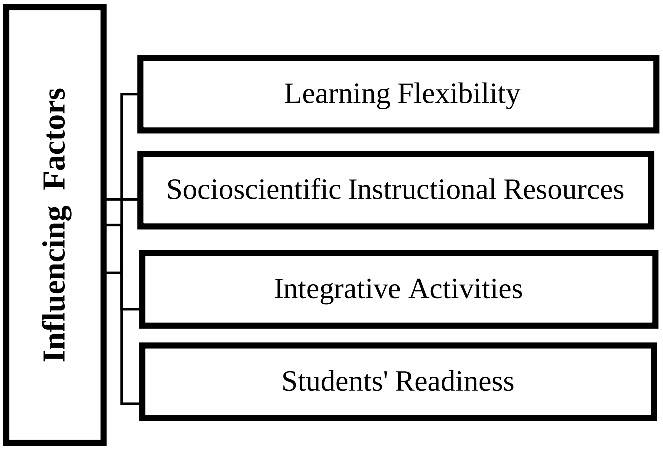


Figure 4.31. The influencing factors for learning SSI within co-curricular context

Each category was further divided into various sub-categories. Figure 4.32 illustrates the details of each factor that influenced the students' understanding in making a decision about the global warming issue. The first category, 'learning flexibility' was further divided into two sub-categories, which were 'physical and digital infrastructure' and 'strategies of learning'. On the other hand, the second category, 'socioscientific instructional materials' were subdivided into 'visualised decision-making tools' and 'printed and digital materials'. The 'integrative activities' category was subdivided into 'relevancy' and 'multidisciplinary', while the final category, 'student readiness' was subdivided into 'prior knowledge' and 'basic digital skills'.

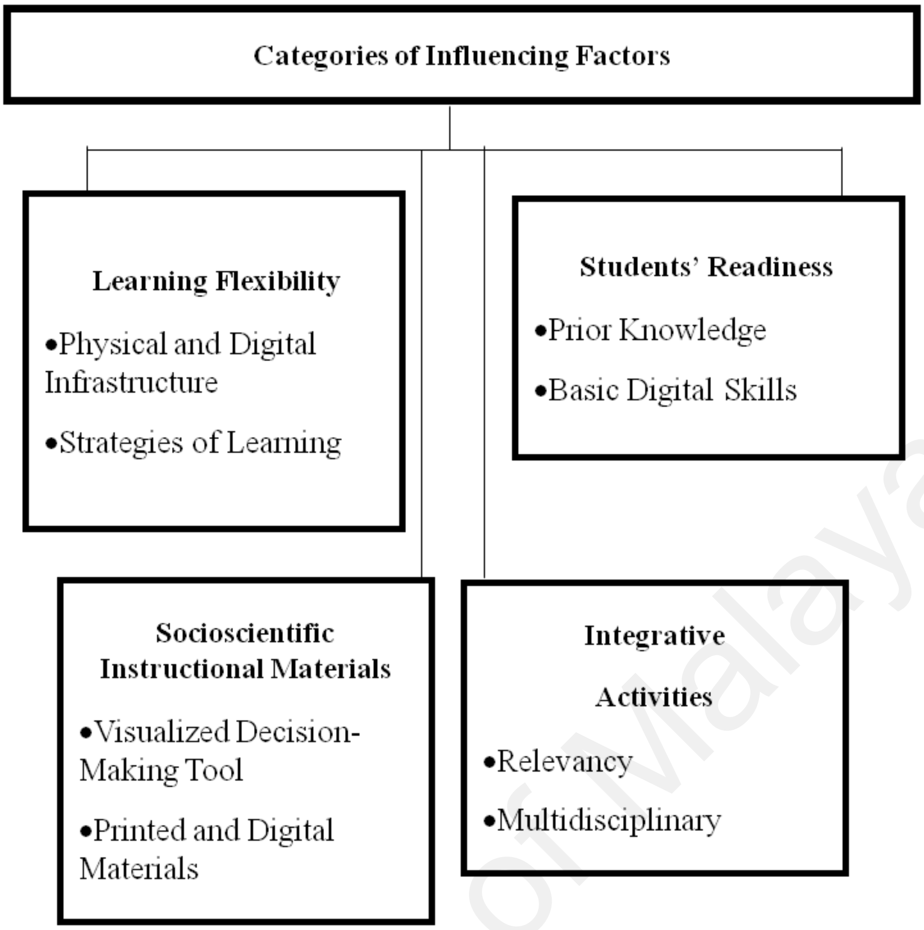


Figure 4.32. Categories and sub-categories for influential factors when learning SSI within the co-curricular context

Learning flexibility. Based on the analysis, learning flexibility in the co-curricular context supported the students' understanding in making a decision related to global warming. The associated sub-category such as 'physical and digital infrastructure', and 'strategies of learning' were seen highly important in learning flexibility in the context studied.

Physical and digital infrastructure. Within the framework of the current study; physical infrastructure was referred to the physical arrangement, functionality and openness of the space. From the observation episodes, the students responded with the arrangement and functional sense, which influenced their group decision-making task, where *"one student mentioned the arrangement of infrastructures such as teaching aids and physical setting were in an orderly manner and suitable for us to generate PGO"* (Act2Obs-S13:95-97). This sub-category seemed effective for the process of discussion, as one student claimed *"ok, the tables and chairs were grouped quite far away from one to another following the tagged group. So, they will not listen what we discuss about"* (Act1Obs-S14:15-16).

The physical infrastructure also detailed about the space openness that was required when the students had to do the group work: *"I'd like to learn here, its physical condition is quite spacious"* (Int-S5:331). The students were also observed to be working comfortably: several groups were able to move around with their preferred angle to complete the task given and *"this situation is clearly reflected in the student body movements and verbal when executing the task of PGO. Ok, you stay here, and we choose that corner to complete this part"* (Act1Obs-S22:102-106). The current study also observed, *"some students were standing and some sitting for the purpose of generating PGO. There are also some groups that have changed their position over the counter and grab an extra table: hey friend, let's go and take that table and put it over here."* (Act4Obs-S28:65-68).

Parallel with the space openness, one student had distinguished the spaces for the formal classroom and the co-curricular setting, emphasising on the open environment provided.

> "Ermm, I think co-curricular context provided more spacious spaces than a formal classroom. I feel comfortable. For instance, if we are in the formal classroom, its space is small, and we need to sit closer to our friends. My friend always conquered the space. I feel that co-curricular provide a more spacious and openness environment for me."
>
> (Int-S6:87-88)

Informed by the analysis, the digital infrastructure also supported the students' learning in the study. Internet usage and connectivity were listed in the description of the digital infrastructure. From this atmosphere of study, the internet prioritisation among students was enormous where the current study *"noticed that students widely explored the knowledge through the network websites such as academic journals, NASA, National Geographic Environment, Wikipedia, BlogSpot and Infosihat from the Ministry of Health"* (Act2Obs:52-55). Even though they had been exposed with posters from the DOE, *"the students preferred to use the notebook as the main medium to search for appropriate information; we better search the scientific facts through certain webs first"* (Act2Obs:48-49).

The findings on internet connectivity were also prevalent in the students' diary entries where they repeatedly stated, *"I like this activity because I can use the school's notebook that has not been used all this while. Some more, the internet connection functions well"* (DAct2-S24). Another student also stated, *"this task was divided through a web search, and this simplifies and accelerates all of our work"* (DAct2-S27). Furthermore, *"I can find related information via the internet easily and quickly"* (DAct2-S19) and surely *"the use of chrome book allows me to interpret the data and information as soon as possible"* (DAct2-S4). Therefore, the stability of internet connectivity was acknowledged as essential in exploring relevant knowledge before making a decision on the global warming issue.

> "Notebook and fast internet accessibility facilitated our group in finding scientific information on the state of worldwide. We have divided the information search tasks among the group members. For example, I find the global warming consequences, "A" finds for energy production, "B" finds something else and so forth. So we can find lots of information before making a final decision."
>
> (Int-S6:221-116)

Strategies of learning. Strategies of learning refer to the system of behaviours and psychological processes, which occurred in the groups' social learning within the co-curricular context. The strategies of learning which emerged within this framework of the study were based on the data representing students' capability, peer discussions between same or different group members, heterogeneity and group familiarisation.

Delegating tasks based on students' capability. For this sub-category, the students overcame the difficulties in completing the decision-making task by assigning the group members following their different talents and roles. The task was delegated appropriately as one student confessed, *"I admit that I am not into the drawing. So if there were students who are good in drawing, giving an explanation, surely it helped us to complete the task"* (Int-S5:287-289). Another student explained, *"about putting this into pie chart, Shasya did it. Her advantage is over the visual. She was good at drawing*" (Int-S2:94-95). Accordingly, *"we assigned one student to do that writing task. Everybody asked her to write because she has a beautiful handwriting"* (Int-S6:121-122).

Based on the current study's observation, the students also completed their task by delegating tasks among the group members according to the roles. For instance, *"the leader of Group 5 describes the tasks that must be done and divide the questions to the other group of friends; Ok, you complete the first part and I will complete the third part. It's because third part is kinda little difficult"* (Act2Obs-S5:37-40). Another group's members also delegated the task according to gender, where *"initially, boys and girls groups were assigned to search for the first and second information respectively. However, we changed the roles when we have encountered difficulties in thinking the appropriate reasons. Finally, we did it!"* (Int-S6:48-50). The cooperation between the group members showed that they played remarkable roles when a girl gave a sigh and expressed, *"Idieza shouted to Amir, make it goodly. We are about to finish!"* (Act2Obs-S14:45-46)

Peer discussions between same and different group members. Findings revealed that the discussion between same and different group members also involved the strategies of learning. In the case of creating discussion among group members, the students revealed, *"yes, all groups' members helped to get the information through discussion"* (Int-S6:108). They admitted, *"group discussions added new ideas and it is more academic and scientific. I learned a lot about what is global warming and how to stop it"* (Int-S2:110-111)**.** For example, *"some ideas of SPF came from me and some from my group members"* (Int-S2:78-79). They later confessed, *"the delegation of task scope was given to all members to ensure that everybody contributed relevant ideas"* (Act4D-S5).

The findings from the students' diary entries supported the peer group discussion emerged in these sub-categories. The approach for completing the task was different from one group to another. Some groups preferred *"initially asking all relevant facts from all members of my group"* (Act4D-S24) and some group tended to *"listen to suggestions from all members while preparing PGO"* (Act4D-S23). The other group would rather *"complete the tasks by asking each person to produce their ideas and explain it to group members for deep clarification"* (Act1D-S2). All strategies that had been employed were aimed to ensure that the students *"reach* *consensus about the scenario discussed, thus produce a high-quality PGO"* (Act1D-S2).

Additionally, the strategy of learning through different group members was a part of the factors that supported the student learning in the co-curricular context. For example, students from a different group were taking the opportunity to discuss and gain appropriate information related to the issue studied.

> "While taking annotation from the posters provided, Taufiq explained the facts to one of the students from a different group named Uwais. Taufiq explained 'cleaner production as a preventive cleaner; it reduces risks for humans and environment. Uwais was writing the note while nodding. This situation showed that he understood Taufiq's explanation. After that, both of them explained it again to the juniors from a different group."
>
> (Act2Obs-S5:59-60)

The dynamism of learning strategies within this context allowed some discussion to be conducted by different group members where *"one female student joined another group and asked about the correct fact of the GHG from her friend; Idieza, CO is categorised as GHG isn't?"* (Act2Obsv-S13:57-58). The social interaction between peers could have contributed to the individual cognitive development that gave impact on the decision- making task as this co-curricular setting permitted the coaching session between capable students with weaker students during the learning process.

The findings from the diary entries revealed the emergence of this sub-category where students disclosed, *"like the presentation session because it can increase my understanding. I've got something valuable from all groups through the arguments they put forward"* (Act4D-S26). They included additional comments on the presentation session, stating, *"the presentations of other groups can make me think outside the box. It really helped me!"* (Act4D-S24). They continued to express their feeling such as, *"I like being able to learn from other group members. But I prefer if* *there is a disagreement that arose contention for the best way to solve this problem"* (Act4D-S19). The effectiveness of the presentation session was admitted by the students, where one of them stated that *"I love it so much! I can take advantage of other groups to serve as an example or a better understanding of myself"* (Act4D-S5).

In the group discussion, the students preferred to work with peers from different backgrounds such as grades, age and gender. The findings from the diary entries revealed, *"working in groups of various backgrounds facilitates in solving the problem"* (Act4D-S4). For instance, a student claimed, *"I like working with individuals from different grades because it can reduce stress and simplify the work"* (Act1D-S21). The students also expressed their feelings where *"I really enjoy working in groups from different grades"* (Act4D:S21) because *"there are two levels of achievements (grade 7 and 8), so that I can add certain knowledge and experience working with senior students"* (Act1D-S21). Consequently, *"we will have more constructive ideas and can work collaboratively"* (Act1D-S2).

Due to the diverse experiences from personal backgrounds, students preferred *"to work with juniors and seniors! They may have different experiences that can help"* (Int-S6:100). They confidently expressed their eagerness in working with friends from different backgrounds, where they stated, *"yes, very comfortable, I'm comfortable when learning with friends of the opposite sex and age"* (Int-S2:94-95). The relevant excerpt below indicates the student's positive perspective in learning with peers from different backgrounds.

> "There is some benefits acquired from the co-curricular activities. For example, we can work in group that consisted of boys and girls. Maybe the views of the opposite sex are different, so we can see the global warming problem in different perspectives."
>
> (Int-S1:76-77)

The findings for this sub-category were also grounded from the observational field notes. The students spontaneously reflected their learning session after they had completed the task : *"while switching off the fan, one female student told her friend about the attitude of her group members; that boy who always sleep in our class, but his opinion sounds great during our discussion"* (Act2Obs-S22: 108-110). In a different episode of instruction, *"one senior student has borrowed Tafsir Al-Quran from a junior student; let me borrow this for a while, I want to find something, and later I pass it to you!".* (Act4Obs-S14: 64-65).

These notes indicate that working with students from different background was not an issue for the students, as the observation noted, *"two representatives for Group 4 (grade 7 and 8) volunteered to explain their decisions"* (Act4Obs-S4: 80-81). In another occurrence, the students had complimented their group member, as observed in Activity 4, *"while Amir is presenting his group arguments, a female student stood up and interjected; even if the justifications we made are not as great as Group 4, but we believe it is a rational decision"* (Act4Obs-S2: 88-91).

It is worthwhile to emphasise that the emergence of negative strategy for the group discussion between the group members was detected especially during early instruction. The negative roles, for instance, may influence the dynamics of group work where one group leader revealed, *"honestly speaking, sometimes it becomes difficult to discuss. My group was fairly quiet"* (Int-S2:44). This situation might distract the group work especially *"when there was no collaboration happened at certain time, might as well I work with people from different group who want to work at the time. I need the support of everyone"* (Int-S1:95-96). The atmosphere seemed gloomy and silent due to the inactivity of some group members.

Furthermore, gender and age heterogeneity could create some tension between group members. The notion was evident in the following excerpt:

> "Usually, group work will be organised into boys and girls group following their grade level. Students at grade 7 will never be exposed to work with students in grade 8. No combination at all! So when I entered this co-curricular programme, I was the only girl from grade 7 that need to work with seniors from different gender and grade. Frankly speaking, there was a kind of fear especially in contributing ideas."
> (Int-S4:282-286)

Some factors may prove to inhibit students' understanding in making a decision about SSI.Group familiarisation was the inhibiting factor that could decrease the importance of peer group discussion where the students confessed that they were *"feeling stressed and depressed because there is a communication barrier, the task is relatively heavy. But in this case, it's more to the communication barriers among group members"* (Int-S1:81-83). This situation occurred due to the *"heterogeneous factor, so there is no bond. In contrast, when in formal classroom, we are with our friends with the same age. Easy to describe the contents of discussion"* (Int-S1:74-76). To solve this problem, the students revealed, *"we talked casually to reduce awkward atmosphere in our group"* (Act1D-S24). However, the group familiarisation became better at the end of the instruction as the students admitted, *"group members are very helpful at this time. This is because the interaction is closer and better than the previous encounter"* (Act4D-S5).

Socioscientific instructional resources. In the context of this study, socioscientific instructional materials refer to two aspects: 1) the visualised decision-making tool and 2) printed and digital learning materials. The visualised decision-making tool, known as the PGO, relates to the instrument structured with the decision-making framework. The printed materials include newspaper, books, posters and flyers while the digital materials include video and slide show presentation prepared using Microsoft Powerpoint from the DOE. The above-mentioned resources refer to related materials which were identified as essential in supporting students' socioscientific learning.

Visualised decision-making tool. The aspect of visualised decision-making tool was prevalent when the students spontaneously acknowledged that they were able to visualise the decision-making framework suggested in the PGO. The findings revealed that the use of PGO helped them in the aspect of comparing and analysing both options while monitoring the visualised PGO generated. This can be clearly proven through the task accomplishment of Student 3:

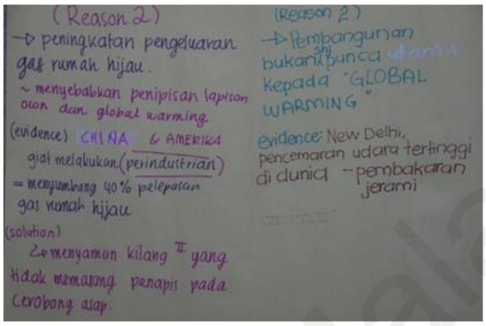
> "PGO is actually acts as a systematic tool. We can make a comparison by using it. Ok, if we really do not know what to choose, we can always read and monitor about the reasons and evidences for each alternatives. And surely we can compare them."
>
> (Int-S3:313-316)

While comparing the options, students were able to apply the compensatory strategy, which has been acknowledged as the most complex strategy in decision-making. The following corresponding excerpt provides the proof for this observation.

> "Usually if people want to make a decision, they just look at the option they preferred and for sure they do not look at the other option. So they cannot see the strength of both option as portrayed in PGO. With that, they cannot make a good decision. But in this case, PGO helped me in comparing these options simultaneously."
>
> (Int-S1:98-100)

In the process of comparing options, students were observed to undergo the most complex compensatory strategy for decision-making where they were able to monitor both options together with the details considered, without eliminating certain options preferred.

Other than that, the students agreed that the PGO facilitated them in sequencing the structure of decisions, where *"the strength of PGO is something like we know about* *option 2 for instance, we must have reasons, evidence and maybe solution before making the decision"* (Int-S6:128-129). The generated PGO supported the ability of students in structuring the sequence of making a decision as illustrated in Figure 4.33. The inclusion of reasons, evidence and solution was clearly structured in order to make a final decision for the option taken, as well as the oppositional option.



Option 1
<u>Stop the development</u>
(Reason 2)
-Causes the increase of GHG
~causes ozone depletion and global warming
(Evidence)
CHINA & AMERICA are actively involved in industrialisation
=contributes 40% GHGemission
(Solution)
~sue the factories that do not install filters on chimneys

Option 2
<u>Do not stop the development</u>
(Reason 2)
- Development is not the only primary source of GLOBAL WARMING
(Evidence)
- New Delhi,
is an underdeveloped capital of India that suffers from high index air pollution in the world due to the straw burning activity

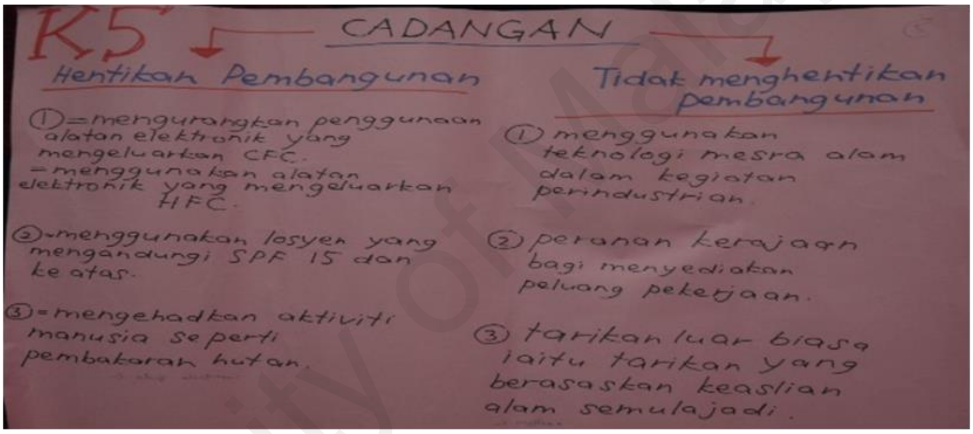
Figure 4.33. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (Sequencing the structure of decisions

When dealing with socioscientific decision-making, students encountered certain difficulties such as creating a set of alternative solutions. However, the difficulty in offering some logical alternative solutions related to this ill-structured nature of socioscientific scenario could be overcome in the generated PGO. By using it, students would identify and imagine the appropriate alternative solutions pertaining to the global warming scenario. The existence of appropriate solutions was a characteristic attribute of the SSI. The relevant excerpt was given below.

"By generating PGO, we feel that we can predict and suggest some solutions for the option taken. Even though the other option contains more reasons, but we can recognise and deduce it as weak justifications. Very fragile sometimes! Although the finalised option contains less reasons, we highly confidence about the firm reasons and evidences justified. Again, we can come out with solutions and maybe we can improve it more."

(Int-S3:G3)

In Figure 4.34, the findings clearly outlined that PGO can support students in identifying and imagining the appropriate solutions related to the reasons stated in the respective columns generated by Group 5. The solutions were brought forward for both options as a clarification for the decision made and also the rejected ones.



SOLUTIONS

Stop the development

1. Reducing the usage of electrical appliances which release CFC
   = Using electrical appliances which release HFC
2. Applying lotion that contains SPF15 and above
3. Delimit human activities such as forest burning

Do not stop the development

1. Using green technology in conducting industrial activities
2. The government must provide job opportunities
3. Providing extra attraction for tourism field with nature basis

Figure 4.34. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (Identifying and imagining the alternative solutions)

By visualising the structure of decision-making, the students were also able to estimate and evaluate both options before making the final choice. *"The decision should be evaluated on a global basis. Alternatively, we look from above. Therefore,* *when we look from above, we find that some aspects concern the world situation, society, and individuals. We consider the importance of all aspects!"* (Int-S3:111-116). The following relevant excerpts supported the importance of evaluating knowledge through the PGO utilisation.

> "Yes, we can visualise the positive and negative alternatives and then we can directly opt the best one. For instance, if the reasons for option one is weaker, we can just choose the second option. From there, we can see the strength of the reasons given for our group preference."
>
> (Int-S5:132-134)

> "After concluding all the points given, we try to find the evidence that supports the reasons stated. After that, we attempt to provide some solution for it. If we are unable to provide its solution, then we try to evaluate the next reason following the same procedure."
>
> (Int-S1:50-53)

The ability to estimate and evaluate knowledge was strengthened when the student admitted, *"I can see and evaluate what I'm thinking about"* (Int-S4:30-31). This can be demonstrated further by a student's interview response in which the student was convinced that he had engaged in the evaluation process of knowledge before choosing the final option:

> "PGO can help us make a transparent investigation and evaluation, thus possibly directing us to generate stronger statements. When we prefer a particular decision, we initially evaluated it based on our social and scientific knowledge. We are confident with all of the justifications discussed; we have extracted all of the analysed knowledge by juxtaposing it in this PGO."
>
> (Intv-S5-7-9-2015:77-80)

Printed and digital materials. Printed materials were one of the relevant learning materials for learning an SSI in this context of the study. The infusion of relevant knowledge was deemed necessary when the students responded, *"according to my friends, they got this information from the newspaper"* (Int-S6:43-44). One of the leaders also suggested, *"I think it's better if we do the same thing provided with* *some resources such as books for searching information sake. Because otherwise I do not know what to write or decide"* (Int-S1:58-60).

Posters and flyers distributed by the DOE had also facilitated the students in making a decision on the global warming issues. The content, as well as the context of the knowledge described on the posters, played a remarkable role in providing relevant information as the students offered the e-waste management as one of the solutions to reduce global warming.

The e-waste management was not an ordinary understanding for the students and it was claimed as *"an unknown fact of the e-waste management"* (Int-S2:46-47). However, it was explained in the posters and flyers provided by DOE, *"for example, we must dispose of the waste of electrical goods properly, through the e-waste management. That is the new information that I acquired from the posters* (Int-S2:45-46). The following excerpt elaborates on the influence of printed materials, which the students regarded as important in enhancing their global warming understanding.

> "However, when we are exposed to many activities such as administration of posters and flyers, we realised actually there are many ways for us to run for green development. Which means that the development efforts is not extremely detrimental to human health."
>
> (Int-S1:63-64)

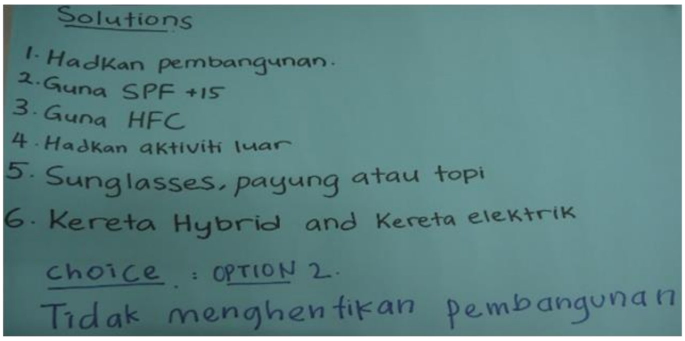
As for the digital materials, the students revealed that the inclusion of video session in the science talk provided new knowledge on the decision-making demands. For instance, the integration of video animation for the global warming added some knowledge, thus, strengthening their understanding before making a decision. They revealed, *"the video session from science talk did trigger me to understand the most. Which at that time, the video portrayed more clearly about the linkage between global* *warming and ozone layer depletion"* (Int-S1:26-29). The following excerpt clearly explains the influence of the video session that provided a positive impact on their understanding before making a decision.

> "This has increased my knowledge. For example, the video session presented cartoon illustrations that show the function of the ozone layer in filtering UV light. The small bubbles representing ozone layer while the bubbles with a purple colour are representing UV light. So at that time, I can only imagine the exact situation. I was like ohh, it seems like this, the function and concept of the ozone! The ozone may be depleted due to the CFC release. I can see the chemical reaction clearly!"
>
> (Int-S5:51-56)

The slide show presentation prepared by the DOE was also related to the students' understanding for the alternative solutions to overcome the global warming as commented by Student 2 in the following excerpt.

> "The second info that I know from the power point slide is about the effect. The depletion of the ozone layer can affect our eyes. The UV rays can damage the eyes. So how to overcome and prevent it? Just wear the sunglasses!"
>
> (Int-S2:35-37)

Figure 4.35 exhibited the specific solutions gained by the Group 2 students from the posters, including the suggestion to use sunglasses as a method to prevent eye problems and the use of sunscreen with SPF-15 to prevent skin damage due to dangerous UV rays.



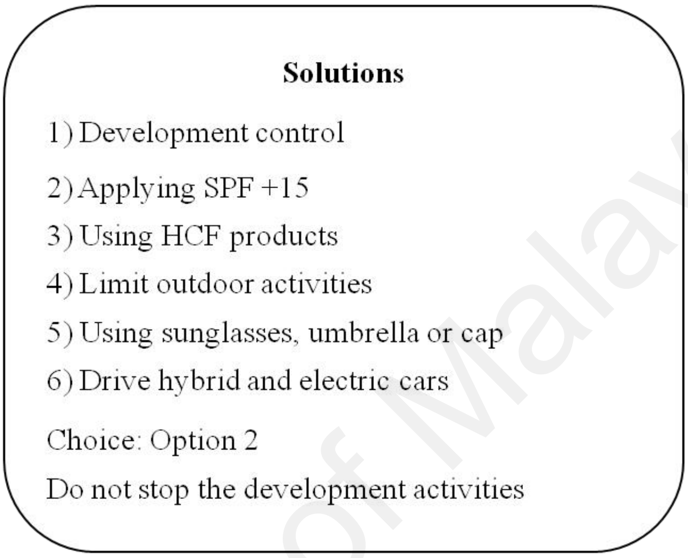


Figure 4.35. Generated PGO drawn by students and PGO redrawn and translated by the researcher - (Providing alternative solutions gained from posters)

From the findings of this study, some considerations must not be undervalued. The PGO familiarisation was detected as the aspect that delayed the decision-making process when the students confessed to being *"a bit stressed, and maybe it is because it is my first time generating PGO"* (Int-S1:37). Consequently, the student admitted, *"actually there is some important reasons that should be stated in PGO. But we were like blank and not familiar with PGO at that time. I did not know what to write. We feel agitated!* (Int-S1:35-36).

In terms of printed and digital learning materials, the students confessed that the inadequacy of global warming understanding was rooted from the lack of information source, as commented by Student 3 in the following excerpt.

> "Yes, we must have some sources of knowledge, and surely it become easier for us to give the reasons for the issue studied. I felt that I possessed a lack of knowledge. The best way is about getting the facts directly from certain sources. Maybe books or television documentary!"
>
> (Int-S1:144-145)

Integrative activities. Integrative activities were attributable for the students' socioscientific learning. For this to happen, it must be complimented or fitted with the multidisciplinary and relevancy sub-categories.

Multidisciplinary. **'**Multidisciplinary' refers to a combination of several academic disciplines and specialisations in an approach to SSI, particularly in global warming. In this framework of the study, the multidisciplinary sub-category provides details about the integration of science and social fields, research and development and informative activities.

The students talked about the science and social disciplines that must be taken into account *"I must consider socioscientific is the issue which comprises science and social dimension"* (Int-S4:76). They constantly mentioned, *"these activities add to my knowledge of science and social aspects such as environmental friendly practices and social awareness respectively"* (DAct4-S20). The importance to integrate several fields was clarified, where the student stated, *"Activity 4 triggered me to utilise a different understanding of social and scientific terms. For example, global warming causes heat stroke and agriculture breakdown"* (DAct4-S26). The notion of the multidisciplinary essentials was evident in the following excerpt.

> "Previously, I assumed that science and social are separate disciplines. It seemed like science and social knowledge cannot be integrated. However, my perspective was changed after being exposed to socioscientific instruction. For example, field 'A' can explain field 'B'. Now I can see that they actually can be combined and SSI explain more detail what is happening in a particular problem."
>
> (Int-S4:53-56)

The details of other disciplines were also mentioned, such as *"Shinkansen is a magnetic train. I know this evidence from the Japanese language lessons. In Japanese language classes, we were introduced to the cultures of Japan too. So we put this evidence as an example for this eco-friendly transportation"* (Int-S4:178-181). Moreover, they explained, *"air pollution or global warming issues that we discussed that has to do with facts of Geography and Science"* (Int-S6:111-112). The specification of areas were connected *"in terms of environmental science and human geography"* (Int-S5:310-311), as portrayed below.

> "To be specific, this co-curricular programme assists me on how to relate science and geography. It characterise about the municipality, global warming phenomenon, its factors and consequences. So when we discuss this scenario, we can actually understand more of the both, hence led us to be open-minded."
>
> (Int-S3:401-405)

In this atmosphere of study, research and development were also categorised under the multidisciplinary sub-category. It was the component of the activities that linked learning to research design activities and innovation. The students shared their experiences about local and internal competition concerning innovation that could help them in dealing with this issue. Abundant data emerged based on the students' research *"this statistic may be all we can know when we do research using the laptop on a second activity that day"* (Int-S4:161-162). The students were able to articulate their ideas according to their group research activity *"I studied more in respect of this SPF. Based on the research of cosmetics fields, SPF is often contained in beauty creams. It can parry this UV light from penetrating and avoid direct effect to our skin!"* (Int-S2:38-41).

The students also admitted that they actively participated in the research design competitions at local and international level. *"I went for a competition under the Ministry Of Education. Luqman, Taufiq and I represented this school and we* *introduced about the herbal products that can be used to avoid pollution. So we won gold medal"* (Int-S1:72-74). They further explained other schools' justification in introducing innovation as a way of preventing global warming crisis. *"There is another example of innovation produced by other school. They established mice repellent herbs. In order to say no to the insecticides, they introduced a mouse repellent that does not use chemicals but substitute with herbs"* (Int-S1:77-80).

At the international level, *"we presented our project to several international competitions before. In Korea for example, we won gold medal for the innovation project"* (Int-S1:75-77). They continuously emphasised, *"based on the discovery findings, we think that there are many more things we can create to reduce environmental pollution or global warming"* (Int-S3:268-270). The following excerpts describe the essentials of research and development aspect that facilitated them in learning SSI within the co-curricular context.

> "Thank God that our school successfully bring the project up to the international level. I'm not involved in that project. From what I know, we introduced the brick produced from the waste materials that widely used in engineering field. It was generated based on the organic composite that is strong in structure."
>
> (Int-S3:266-268)

> "We can use the technology to study about the materials used in the engineering field. For instances, concrete and materials such as bricks. The upper secondary students are now implementing the research activities conducted during co-curricular hour. They produced the basic bricks which are red in colour by using other eco-friendly composites."
>
> (Int-S3:262-265)

Furthermore, the element of informative activities seemed attributable when working with SSI in the co-curricular context. In this framework of the study, informative activities refer to the activities that take place during the co-curricular instruction. Specifically, these activities can certainly engage students to discover certain information about global warming in order to make a decision. Throughout the corresponding discussion of the students' understanding, selected excerpts from their activity diary entries indicated that some of the students' understanding had been gained from the activities conducted during the instruction.

> "Yes, science talk activity can improve my scientific understanding. Among the scientific aspects of the new I get is about the fact that the Earth temperature increase should happen 10,000 years in future. Also, on how to tackle global warming by checking the tires before travelling."
> (DAct3-S14)

> "Yes, I can improve my scientific understanding regarding global warming. As we know, the CFC is not harmless to humans. However, when it is hovering in the air, it thinning the ozone layer. The function of the ozone layer is to prevent UV radiation. When the ozone layer is destroyed, automatically we are exposed to its effects such as haze, skin cancer and so forth."
> (DAct3-S10)

> "Yes, this science talk activity did add my scientific understanding.
> - CFCs are not dangerous to humans but yes to the ozone layer.
> - Ozone layer takes 50 years to recover.
> - There is an e-waste disposal centre for the disposal of electrical goods."
>
> (DAct3-S28)

> "I love when these events enable us to share the information that we were looking for from a variety activities provided."
> (DAct2-S15)

> "The experience of reading scientific journal via internet helps me to improve my scientific understanding that I didn't know before."
> (DAct2-S14)

The oral presentation session was recognised as an influential factor when many of the students conceded, *"yes, the presentation phase was very informative"* (Int-S2:190) as *"the oral presentation from other groups has increased my understanding of global warming. It is because I can learn a little about the technology used by the Japanese to reduce global warming"* (DS5Act4). The students gave the example on transportation, which corresponded with the above-mentioned technology: "*this activity can add my scientific knowledge. It* *reformulates my understanding on environmentally friendly products like hybrid vehicles; Nissan Leaf and Toyota"* (DS5Act4).

The related findings from the interview session also demonstrated that an informative activity like the group discussion was rarely applied in both classroom and co-curricular settings, *"so this type of science talk, surfing internet and group discussion are no longer the kind of activities that we do in this school"* (Int-S4:241-243). However, the comments on the activities achievement were acknowledged, where *"this co-curricular instruction brought me some experience of enhancing knowledge through science talk, group presentation and discussion"* (Int-S6:175-177). The examples of additional knowledge were revealed, where one of the students claimed, *"the new information I got is on how to dispose refrigerators. That's my first knowledge! Before this I did not know about that. Thank God"* (Int-S5:417-419).

It is imperative to mention that stereotyped or oversimplified activities seemed irrelevant and made no sense for the students to call upon prior knowledge. In an example from the direct observation, two students *"put their head on the table. One of them made the graffiti left blank on the paper while another student took a short nap during the science talk activity"*. The non-verbal gestures indicated that frustrations might have set in among them. These occurrences were indirectly affected by the stereotyped events presented during this instruction. The notion of the students' frustration was evident when some students admitted, *"the facts that being delivered by the speaker were right, but I already knew it. It's a bit boring. At one time I feel disappointed. I was like escaping that session*" (Int-S4:221-222). Certain information had not been clarified deeply. They offered their frank opinion accordingly *"I'm not satisfied with the way that speaker delivered the information. Her voice was a bit slow.*

Slow and the explanation of the facts were not that detail. Unsteady!" (Int-S4:221-222).

Another inhibiting factor discovered from the students' comments was the time-consuming activities because *"time management is recognised as very hard and limited"* (Int-S5:318). They added some additional comment on this issue as follows.

> "Just for me it would be better if you take the time on Saturday or even Sunday morning. The reason for me is when thinking about all this complicated issues, I felt tired doing in evening time, so prefer do it in the morning. We are more energetic as compared to after school hour."
> (Int-S4:209-212)

Relevancy. Relevancy refers to any activities that reach the quality of being 'real'. It also relates the issues to the daily experiences connected to the formal learning. It becomes an aspect of the integrative activity that facilitates students' understanding in making a decision related to global warming.

In this context of the study, the global warming issue was considered as relevant or real to the students as this issue was connected to their daily life experience. *"Yes, of course, global warming is close to me, real and relevant to daily living. This is a topic or issue that ignored by many of us. We do not realise its effect even though it is connected to our daily lives. It happened every day!"* (Int-S1:167-169). They mentioned that everyone could discuss global warming issue as it *"could indeed relate to every life in every human life"* (Int-S3:362-363) such as *"the actual effects of health aspect are well-known"* (Int-S1:170-171). It was also recognised as a global issue *"and anything related ideas can be adopted and accepted, we can just use the idea appropriately"* (Int-S2:248-249). Further global relevancy aspect was strengthened through the students' excerpt, as portrayed below.

"In terms of difficulty, it depends on the issue chosen. If it is difficult maybe it will be difficult to discuss! Referring to this case, global warming is a well-known issue that must be concerned, the issue of the world. So it was not too hard to think because it's a global issues."

(Int-S2:245-248)

The close relation between global warming issue to the students' daily life triggered their active engagement in the scenario and they claimed, *"it's quite easy to discuss, so for me global warming issue should be taken seriously, everyone should care about this issue"* (Int-S3:364-366).

Relevancy should also aid the activity to be connected and linked to the formal learning. This was efficient as students revealed, *"yes, the PGO generation session and knowledge that I gained are usable in many things. For example, it is useful in the decision-making process, or in the formal examination shall be. Wide bar, I had to adhere with justifications and solutions when making decision"* (Int-S2:169-171). Other than that, the structural complexity of the decision-making process was acknowledged as useful. *"Although it's quite difficult, but we satisfied with the PGO we made. It is because we have done a detailed study on the issue. PGO may be beneficial for students' use and career later"* (Int-S3:111-114).

In understanding the corpus, the students specifically confessed that this instruction could have assisted them in enriching their formal knowledge related to global warming. *"As I said, this issue helps us in describing what we learn in the classroom"* (Int-S4:142-143). They considered their content knowledge as the basis of the justifications for the decisions made. For instance, *"as referred to science curriculum in Form 1, the fossil fuels is categorised into three; petroleum, natural gas and coal. So we consider the burning fuels as one of the causes of global warming* (Int-S5:87-88).

Learning global warming in the co-curricular context also played a role as the additive and transformative elements. *"By right, global warming is the issue that has* *been exposed previously. However, this issue was scrutinised and discussed thoroughly so that it can increase understanding, thus acted as a revision context"* (Int-S5:29-31). The other relevant excerpts extracted from the sources of students' interview and diary entries were shown below.

> "As I said, this activity helps me in elaborating further on what we have learnt in the classroom. So in the yesterday's examination, I have also able to substantiate this ideas, what descriptions we have used during the discussion in this co-curricular activity. I used a global warming description discussed in this activity to explain what's going on in answering the examinations questions."
>
> (Int-S4: 142-146)

> "Yes, this science talk from DOE can help me understand more especially in Science and Geography in my formal classes. This knowledge can also be used for my Malay and English essay writing too."
>
> (DAct3-S6)

Student readiness. There are two aspects of student readiness, which consist of prior knowledge and basic digital skills. In this context of the study, the prior knowledge was acknowledged as the knowledge about the global warming scenario that the students already hold from the beginning of the instruction. The knowledge may be multidisciplinary in nature ranging from scientific and social considerations. It also refers to the knowledge that is connected to a particular theme or topic consolidated in the formal science syllabus.

For the basic digital skills, these focus on the essential skills to equip students to explore relevant knowledge via the internet usage. The following sections describe the aspects of student readiness in detail.

Prior knowledge and digital skills. In this context of the study, student readiness refers to the students' prior knowledge towards a topic of global warming and basic digital skills. The students have a tendency to work independently without referring to the teacher as the source of information. The factor of prior knowledge can be clearly proven when two members of Group 4 were still fuzzy about the principle and function of hybrid cars for global warming solutions. However, one student expressed his prior understanding by clarifying, *"hybrid means two! Hybrid cars used a combination of two engine systems that controls GHG emissions. We cloned between lion and tiger, yeah, that's the example of hybrid animal"* (Act4Obsv-S4:48-51). As the global warming issue was also linkable to formal curriculum, this encouraged the students to use their prior knowledge for an effective discussion towards making a decision.

> "We have learned about fossil fuel in "local research" subject during primary school, and it is also being consolidated in Form One Science syllabus. Moreover, now it is described further in this activity throughout the co-curricular instruction. So, even a bit usual to it, but I've still got to learn to think again."
>
> (Int-S5:96-99)

This proved to be an inhibiting factor; the limited prior knowledge of the global warming was most probably due to the fact that these students had limited scientific knowledge. This was proven when the students assumed, *"maybe we have a limited science understanding, err yes I think it's about limited science understanding and it is not strong enough!"* (Int-S1:61-62). The students revealed, *"at that time maybe we can give different ideas. It seems that everybody had their own ideas. But perhaps, we have lack science understanding on the issues discussed"* (Int-S1:80-81).

Digital skills seemed to be attributable when *"majority of the students used credible information sources such as Google and Wikipedia as part of the search* *engine medium on global warming*" (ObsvAct2:119-121). They commenced the learning session *"without delay, and started their exploration by typing keywords and searching for appropriate information on the web through the credible sources of global warming information such as Environmental Department official web"* (Act2Obsv-S14:117-119).

Furthermore, they applied other digital skills during the information retrieving process when one student admitted, *"I get a bit difficult information by simply "copy and paste", then I managed to explain the info to my friends"* (Act2D-S4). Moreover, students had the skills in troubleshooting internet connection. The notion was evident through the following observation.

> "Taufeeq repeatedly tried to reconnect the interrupted internet connection. He pressed the internet connection icon and press right click, and then try to resume the connection by pressing the "Connect" button. The connection was still not working. However, he changed to another tablet, which is used in turn to start the process of finding relevant information."
>
> (ObsvAct2-S4:113-117)

Chapter Summary

This chapter had answered the three research questions, providing the findings which explained how the designed activities about SSI were conducted within the co-curricular context. It led to an in-depth clarification on students ‘understanding in making a decision about global warming issues within the co-curricular context.

To conclude, most of the evidence showed that the majority of the students had responded positively toward the socioscientific learning carried out in this phenomenon. Their global warming understanding was considered sophisticated, thus, this enabled them to consider the multiple considerations of decisions ranging from scientific and social dimensions. This accomplishment could be achieved by concerning the four factors such as learning flexibility, socioscientific instructional resources, integrative activities and student readiness. Chapter 5 presents further discussion pertaining to the findings.

Chapter 5 Conclusion, Discussion, Implications and Recommendation

Introduction

This final chapter encapsulates the main issues that concern lower secondary students' understanding in making a decision on an SSI within the co-curricular context. The first section gives a brief account of conclusions, discussion and implications to further deal with the SSI conducted within the co-curricular context. The findings from the previous chapter are interpreted to explore its magnitude in the current literature context while addressing issues of concern, which functions as a critical assessment of this study. Towards the end, the acknowledgement of the limitations in conducting this study is discussed, followed by the further research recommendation for advancing the line of investigation for future work.

Summary of the Study

Recent developments in the field of science education have led to a new interest in introducing SSIs, a movement that primarily emphasises empowering students to be rational in connecting science-based issues and the decisions made (Zeidler et al., 2005). It requires students to be concerned and reflect on the moral principles and the qualities of their lives physically and socially (Ekborg et al., 2009; Zeidler et al., 2005). Dealing with SSI confronts students with decision-making situations which require factual and ethical complexities (Sadler & Zeidler, 2005). The complex nature of SSI demands multidimensional perspectives which support the students' knowledge; then it is meant that they are influenced by the SSI within informal learning circumstances (Rose & Barton, 2012; Walker & Zeidler, 2007) including the co-curricular context (Burley, 1990; Hofstein & Rosenfeld, 1996).

Until now, there is a lack of certain structures and guidelines that can be used by school organisations, emphasising on the integration of informal learning facilities and school content-related learning. This is prominent, especially within the co-curricular environment. An issue of backwardness or gap in research on the SSI and co-curricular context exists from the global perspective (Burley, 1990; Jarman, 2005) and local contexts (Pereira et al., 2013). These problems need to be examined further and analysed in detail. Hence, scientific research needs to be carried out together with an appropriate methodology as guidelines for the stakeholders and practitioners in the local education context. Thus, the purpose of the study was to explore the students' understanding in making a decision about the global warming issue as well as the factors that influence their learning within the co-curricular context.

A qualitative study was employed as the paradigm-setting of this research. To obtain better insight of this phenomenon, I have selected the qualitative research design following the constructivist world view. The methodology of this research was primarily guided by the literature review and analysis of the previous researches in the field of SSI specifically in understanding and decision-making corpuses. The professional opinions of the SSIs, co-curricular and qualitative experts were also taken into considerations aiming at acquiring a proficient academic view according to the whole principles of context, rigour analysis and validation purposes. A preliminary study had been conducted before the actual study aiming at familiarising the researcher with the phenomenon and data collection techniques. More importantly, it acted as the key features to be addressed in the actual study, emphasizing on research feasibility.

The selection of the school and participants for the actual study were primarily based on the rationales of purposeful sampling. It is because the purposeful sampling is always relevant for a qualitative study following the needs of the study corpus (Coyne, 1997). The participants were the members of Science and Mathematics Society from one Fully Residential School located in Selangor, which is a state in Malaysia. They consisted of thirty 7^{th} (n=15) and 8^{th} grade (n=15) students, and they were grouped heterogeneously regarding gender, race and age. The obvious needs for effective practice in the co-curricular context served a strong justification for the researcher to select a group from one Fully Residential School. In addition, a Fully Residential School is acknowledged as the best type of school in implementing efficient practice by the school principals (Ghani et al., 2013). Further on, these groups of students were expected to have the ability to express a higher interest in working with and discussing the issue. The researcher initially requested for a suggestion from an officer from the Educational Planning and Research Division (MOE) for a school that is active in co-curricular activities as well as a teacher to suggest the students who are active and responsive.

The principle of the constant comparative method (Corbin & Strauss, 1990) was utilised as a basic procedure for data analysis. All recorded materials were systematically transcribed verbatim. The analysis of PGOs, diaries, transcripts, and field notes were coded based on the open, axial and selective principles of qualitative analysis criteria. They were then triangulated in search of the students' understanding, the considerations of the decision and the factors for learning the global warming issue within co-curricular settings. The data analysis ended with the interpretation of the findings.The researcher did not predetermine these findings, but the findings naturally emerged as appropriate categorising descriptions to the co-curricular context studied, thus representing the entirety of the data sets. The reliability and validity of this research were established through the application of triangulation, peer review, and prolonged engagement.

This study had employed a broad scope of science education areas, particularly in the SSI and co-curricular context. It was aimed to explore the lower secondary students' understanding in making a decision related to global warming issue. However, the findings had been beneficial in identifying the potential of the co-curricular context in promoting the students' learning about SSIs. The first Research Question addressed about the students' understanding during the socioscientific instruction within the co-curricular context. Four categories emerged when exploring the students' understanding of global warming issue. The findings described the students' ability in 1) defining the global warming phenomena in terms of temperature and GHG emissions, 2) identifying anthropogenic and natural factors affecting global warming, 3) clarifying global warming effects regarding health, ecological system and climate change and 4) providing alternative solutions for the global warming phenomena regarding sustainable development. Most of the evidence showed that their understanding had reached a sophisticated level when dealing with the global warming issue within the co-curricular atmosphere.

The Research Question 2 addressed the considerations that the students used when making global warming decisions. The findings showed that students had applied the scientific and social considerations ranged from various dimensions.

The Research Question 3, on the other hand, emphasised on the connecting factors that should be considered when conducting SSI within this co-curricular platform. Most of the evidence reflected that the four factors should be provided: 1) learning flexibility 2) socioscientific instructional resources 3) integrative activities and 4) student readiness. However, some categories such as learning flexibility, were identified as having inhibiting factors in the students' learning process within this context.

The gap of learning SSI had been widely discussed in the literature such as the structural complexity of the decision-making process. Therefore, the researcher had developed a visualised tool that could assist the students' decision-making process, namely the PGO. The researcher had briefly discussed the development and validation of the PGO, which functioned as a visualisation tool in making a decision pertaining to the global warming scenario. The development and validation of the (PGO) followed the qualitative paradigm. It consisted of five developmental phases, which reflected the fundamental processes involved during the entire period of study. The five developmental phases of PGO involved the designing of the PGO framework, the process of getting the initial feedback and the experts' reviews on the PGO, the PGO revision and the PGO evaluation. The main objective of developing the PGO was to provide an impetus on the visualisation particularly in exploring the students' understanding and promoting the students' decision-making skills. This current study suggested that the PGO picked up competencies for the didactical structure of understanding and decision-making skills, which was influenced by the uniqueness of the flexible graphical tool.

Conclusion and Discussion

Overall, three conclusions can be drawn from the study. First, socioscientific understanding can be identified through the students' ability in recognising relevant scientific knowledge. Second, socioscientific decisions can be drawn upon multi-dimensional considerations according to the specificity of context. Third, the co-curricular setting can be used to complement the socioscientific learning. The particular conclusions are described and emphasised in detail in the following sections.

Socioscientific understanding can be identified through the students' ability in recognising relevant science knowledge.

Cognitive domain involves the recognition of specific facts and procedural concepts which fulfill the development of intellectual ability and skills (Bloom, 1956). However, the review of the literature (e.g. Hundal. et.al; 2014, Rose & Barton, 2012) detailed in Chapter 2 stipulated that very few research investigations had focused on the students' understanding of making a socioscientific decision, particularly in the co-curricular context. The outcomes of this study demonstrated that socioscientific understanding is heavily contextualised in light of the students' ability to recognise the relevant science content knowledge. The students performed the discussion and tasks by the capacity to acknowledge the relevant science understanding. In details, they were able to define the global warming phenomena in terms of temperature and GHG emissions; identify the anthropogenic and natural factors affecting global warming; clarify the global warming effects regarding health, ecological system and climate change and; provide alternative solutions for the global warming phenomena in the aspect regarding sustainable development.

These findings further support the idea of Dawson (2015) and Lewis and Leach (2006) which suggested that the success of discussing SSI was very much associated with the students' scientific knowledge. The majority of the students were able to recognise the key matters that required some understanding of relevant science. However, there was also a loose relationship between the numbers of science knowledge criteria utilised to justify the final view. They concluded that although the scientific understanding was essential, the science justification infrequently emerged in justifying their opinions. Indeed, the requirement of having some understanding of the basic science was not a compromise for making a decision on SSI.

This also accords with the researcher's earlier observations, which showed that applying the global warming scenario in daily occurrence as well as global context revealed that the students were able to connect their scientific ideas at the most sophisticated level. These findings are consistent with Klosterman and Sadler (2010), who claimed that students who could describe global warming regarding the accumulation of GHG demonstrated the highest level of understanding. Informed by the findings of this study, the students' understanding were beyond describing and connecting global warming to temperature increases and possible effects. Specifically, they were able to link global warming to the greenhouse effect, connect the anthropogenic factors and incorporate the potential consequences associated with global warming. Although they were not specifically provoked with the greenhouse effects questions, the students' response indicated their knowledge on the underlying consequences of temperature rise.

Accordingly, the students in this study were found to possess the most accurate level of understanding as they could provide the justifications of solutions to the controversies associated with global warming. In other words, they were able to provide multiple sources of alternative solutions as a way to address global warming. For instance, they suggested that citizens would need to be exposed to education and social awareness to alter their mind, attitude and lifestyle. They also suggested that development control solutions prevent biodiversity and habitat destructions. Surprisingly, the students were also able to discuss more than one previous issues as sources of controversy beyond the global context. This category was considered as the most accurate understanding of global warming because of the students' ability to discuss the multifaceted controversy surrounding global warming. Furthermore, the use of ‘complex trade-off’ demonstrated that the students could describe the series of challenges between personal comfort, political and economic change.

However, the findings are contradictory with Dawson (2015) who asserted that students were confused about the main GHG and assumed that CO_2 was the only GHG that causes global warming. Referring to the issues that surround global warming, Dawson specifically emphasised that the consequences and solutions for the issues that surround global warming were unclear. In this context of the study, it is noteworthy to mention that the students were able to give other examples of GHG such as methane and CFC. They were also capable of providing many consequences of global warming, for instances, on health and ecological system. To further complement their understanding, they clearly offered eco-friendly development, transportation, education, social awareness and preservation as the alternative solutions for this controversy.

The misconception about the issue that surrounds global warming such as the greenhouse effect are commonly noticed (Gautier, Deutsch, & Rebich, 2006). Although the majority of the students were identified as having sophisticated understanding, a few showed some misconception at the early instruction. The existence of misconception in this study was consistent with the reports by Dawson (2015) and Sadler and Klosterman (2010). They mentioned that some students were not able to offer a correct or partially correct definition of the greenhouse effect and climate change surrounding the global warming issue. They also had misconceptions on five categories such as the greenhouse effect and the ozone layer, types of GHG, types of radiation, weather and climate and air pollution. The students in this current study, however, exhibited some misconception such as the greenhouse effect and pollution as myths. The misconception in the fundamental science can elicit a failure to discern vital and relevant issues. It also leads students to draw inaccurate reasoning and undergo inappropriate decision-making process (Aikenhead, 1985; Lewis & Leach, 2006).

The incorporation of global warming issue is one of the alternatives that refine the nature of science understanding. Similar to this context of the study, the detection of the students' ability to recognise and utilise precise conceptual nature of science proves that the students perceived global warming as tentative and relied on the role of subjectivity and creativity in science. For example, they supported their position by giving appropriate solutions in reducing global warming impacts such as the application of conservation and preservation as well as the use of technological advancements. The current study findings, however, are contradictory with Walker and Zeidler (2007) who found that the students did not divulge much of their understanding when making a socioscientific decision. They also did not apply their nature of science understanding as they debated on the issue, for example, genetically modified food. Half of the students relied on either an erroneous consideration of the evidence and subject matter knowledge. The worst condition was that they lack additional knowledge or evidence to support logical arguments when making a decision. They also did not reason their position with a sound premise but gave justifications based on the wrong facts, extreme instances and hasty deductions to personalise the dilemma. Hence, they tended to utilise more factual-based content that led to numerous examples of flawed reasoning and personal attack.

The present study findings are also in contradiction with a report by Khishfe (2015), who found that the majority of the 10th grade students reverted to their earlier naive understanding even after they had been exposed to a four-month socioscientific instruction. Although the present study was not intended to determine the instruction's effectiveness, the findings clearly showed that the students' understanding was sophisticated, as they were able to elaborate more relevant science knowledge within the co-curricular context.

In this present study, the sophisticated understanding was identified from the students' ability in complying all categories emerged. More importantly, the students' global warming understanding had exceeded the expectation of the formal Malaysian Science Curricular Standard for Form One and Form Two (MOE, 2011; 2016).

The observation on sophisticated understanding is also in agreement with Bloom (1956) who proposed the level of difficulties in cognitive learning. The first level of difficulties showed that the students were able to define global warming according to the temperature and GHG emissions. The second level determined the students' ability in identifying anthropogenic and natural factors affecting global warming. These two levels of difficulties were grouped under basic understanding. The next higher level of difficulties was the application. Students in this present study context reached the application level where they were able to clarify the set of principle ideas of global warming that should be applied or interpreted. They clarified the problem or scenario by clarifying its effects in detail. In this particular study, the students were able to provide alternative solutions regarding sustainable development (e.g. the use of green transportation and intelligent sensors to minimise global warming effects). This ability could be categorised into a synthesis level of the Bloom's Taxonomy where it is described as the highest level of difficulty in cognitive learning. From the findings, the students at this level of difficulties were identified to continue towards the complete solutions.

Socioscientific decisions can be drawn upon multi-dimensional considerations according to the specificity of context.

Most of the research conducted in socioscientific decision-making employed quantitative methodology (e.g. Sakschewski et al., 2014; Gresch, Hasselhorn & Bogeholz, 2013; Jho & Mijung, 2010). However, the best alternative to explore students' decision-making is through the qualitative method as proposed by Choi et al. (2014), Rose and Barton (2012), Marrero and Mensah (2010), Dawson and Venille (2010) and Uskola et al. (2010). The use of the qualitative method in the present study clearly demonstrated the students explicitly used multiple considerations when making a decision.

Specifically, the findings from the interview and the PGO document strongly indicate that the students used scientific and social considerations in making a decision on the global warming issue. The findings are parallel with the observation by Marrero and Mensah (2010) and Callahan et al. (2011). The investigators had found that the students were having a high capacity to apply the scientific concepts towards making a societal decision if they were equipped with relevant science knowledge. However, the current study could not generalise that a sophisticated understanding would drive students to make a decision, entirely based on scientific consideration.

The results of this study are also in line with Jho et al. (2014) where they found that scientific understanding did not show connection or any significant relationship to decision-making. It could not be assumed that students with better understanding would choose the option which was supported by the only scientific evidence. However, the students had a tendency to consider scientific together with social considerations according to the specificity of the context.

In this framework of the study, the specificity of the context refers to the complexity of issue presented. Some SSI topics were complicated and sensitive. Hence, the science considerations became less important in the students' decision compared with social considerations. For instance, a pregnant lady had to deal with abortion when carrying a baby diagnosed with genetic disorders (e.g., Down's syndrome, haemophilia, Klinefelter syndrome, thalassaemia major) or if human values and dignity could be in a humiliating situation for the biotechnological research; scientific considerations may be not in concern to the final option. If the issues are paradoxical to values, interest or religious beliefs, people tend to prioritise the religious value considerations (Mikulak, 2011; Zeidler, Walker, Ackett & Simmons, 2002). For instance, the topic of global warming in this present study is one of the problematic issues in Malaysian society. Economic, political and religious beliefs were valued in the students' social consideration when making a decision. In this complicated context, they opted for social and scientific aspects as their balanced considerations when making a final decision. Due to the different level of complexities in SSI, the considerations that students used when making a decision might be dissimilar. Therefore, the relationship between scientific understanding and decision-making considerations might be different according to the specificity of context.

The present study further supports the idea of Jho et al. (2014) and Lewis and Leach (2006) who proposed that instead of having sufficient scientific knowledge, the ability of students to engage in reasoned discussions is influenced by the specificity of the socioscientific context. Similar to the present study findings, students who are having sophisticated understanding tend to finalise their global warming decision using multiple consideration ranges from scientific and social consideration, including moral and ethical importance. For the scientific consideration, they gave priorities on the environment, technological advancements and health aspects. As for the social considerations, they preferred economic, political and religious belief. The findings recommend that the sufficient knowledge empowers the students' perspectives concerning scientific and social consideration as their preferences.

A detailed justification was given on the option chosen. The students demonstrated well-supported evidence by drawing scientific and social considerations for their final decision. For instance, they were able to consider the economic situation and provide a prediction of the global warming effects on certain aspects. According to Sadler and Flower (2006), this level of decisions was reserved for students who were considerate, able to provide flooring justifications and also acknowledge positions contradictory to their own. The ability to justify an issue beyond one's own or manage to counter evidence is considered as essential but a difficult element in making a decision (Kuhn, 1991). The findings of this study proved that students were not only able to finalise their decision but expressed the furthest solution on the option they preferred or adopted.

It can be deduced that the students adopted balanced considerations in making a global warming decision. This situation acknowledges science as a dynamic discipline and should not be trained as a hard body of knowledge; it signifies the incorporation of scientific and social considerations underlying a decision-making process (Hughes, 2000). The students revealed that they were able to appreciate a diversified opinion, as there was no correct or wrong answer for the socioscientific decision. Therefore, they were able to think about various considerations for their decision. In addition, the co-curricular activities were not exam-oriented. Thus, they had more flexibility as there was no pressure from any test scores. Some other factors influenced students' learning in the co-curricular setting, and this will be further discussed in the next conclusion.

Co-curricular setting can be used to complement socioscientific learning

Most of the studies in SSI utilised formal learning environment (Callahan et al., 2011; Ideland et al., 2011; Jho et al., 2014; Keskin et al., 2013; Klosterman & Sadler, 2010; Lewis & Leach, 2006; Uskola et al., 2010) while very few studies were conducted within an informal learning environment (Hundal, Levin, & Keselman, 2014a; Rose & Barton, 2012). The informal learning environment provides a significant outcome for socioscientific learning, but there has been little research on the direct learning contribution they make.

Based on the findings, co-curricular context can serve as a platform for learning SSI. Four influential factors should be concerned to assist learning SSI through this platform: 1) learning flexibility, 2) socioscientific instructional materials, 3) integrative activities and 4) student readiness. To supplement the discussion, a schematic diagram (Figure 5.1) is presented to illustrate the connections of factors (red boxes) and its peripheral sub-factors (uncoloured boxes) that influence students learning within the co-curricular context.

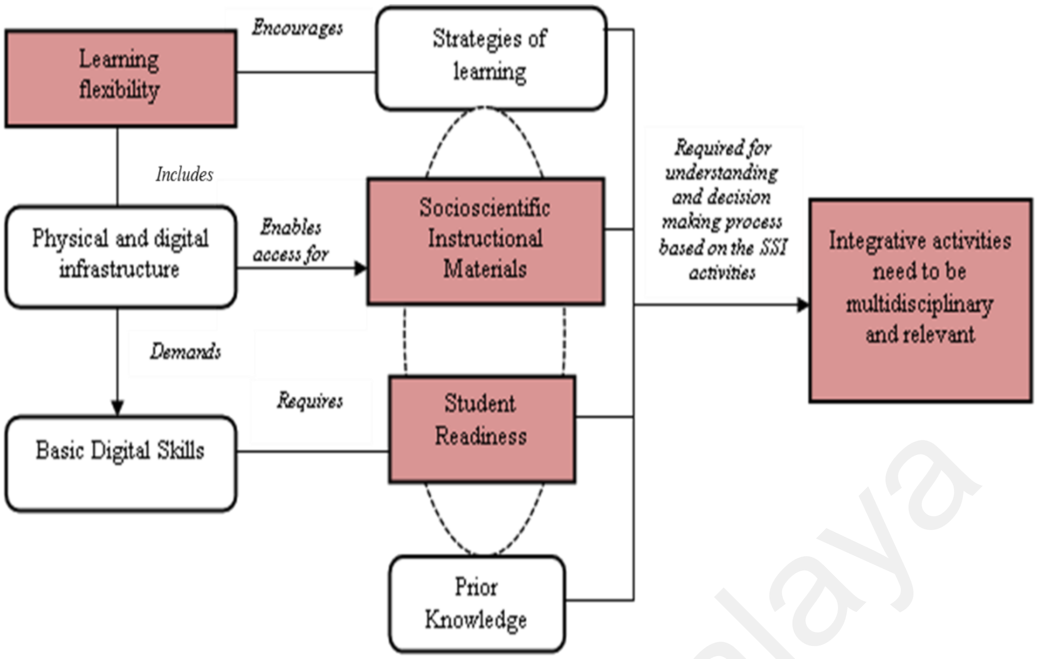


Figure 5.1. Schematic diagram of the influential factors for socioscientific learning within the co-curricular setting

First, the students' understanding in making socioscientific decisions is associated with the learning flexibility. They maintained and refined their understanding with the input received from the flexible learning environment. Lewis and Leach (2006) claimed that the ability to deal with issue demands multiple understanding. Thus, the students cannot be restricted to explore the issue within the casual learning environment.

This study showed that flexible learning environment in the co-curricular settings, which involved the physical infrastructure was required for socioscientific learning. The arrangement, functionality and space openness of physical infrastructure is critical to achieving the successful output especially for learning that involves a large number of students. Referring to this context of the study, the group stations were arranged distant from one another and they were provided with the functional basic facilities. This enables a smooth discussion and flexible movement for students to work, as it involved thirty students in total.

Furthermore, the digital infrastructure seems beneficial for socioscientific learning. Findings of this study are consistent with Callahan et al. (2011) who claimed that digital infrastructure could be an effective means to engage students in socioscientific learning, particularly with the students who had a difficulty in basic concept in the past. Importantly, the qualitative results reported in the current study findings section presented the detailed aspects of digital infrastructure vital for learning SSIs. For instance, this attribute is not only confined to the existence of computer but goes beyond the prioritisation of internet usage and the stability of internet connectivity. The requirement of student-centred learning in this context of study supports the above-mentioned suggestion of providing digital infrastructure as an optimal way to lead students to have better understanding towards making a reasoned decision. Relevantly, it is beneficial to provide a context in which scientific activity is mediated by cultural tools such as technology which assist the emergence of scientific reasoning (Morris, Croker, Masnick, & Zimmerman, 2012), especially when dealing with SSI.

The features of the co-curricular learning environment matched the suggestion postulated by Osborne (2013). He proposed that the characteristics of the modern learning environment are centralised to the flexibility, openness and access to resources including technology. He emphasised that flexible learning environment is better than a single classroom where it can support learning as inquiry and collaborative instruction implementation, hence lead to a more meaningful learning.

It is therefore essential to support the students with flexible learning spaces to reflect the peripheral educational functions performed by sophisticated 21st-century new learning environments (Brown, 2006; Osborne, 2013). The peripheral functions of learning flexibility encourage multiple learning strategies. Based on the findings, it can also be inferred that the co-curricular setting that employs student-centred instruction through discussion with peers could have influenced students' understanding in making a global warming decision. This happened due to the guidance acquired from a more knowledgeable person such as peers. Figure 5.2 visualises the influence of peers who assisted students in refining their global warming understanding within the ZPD. The example is taken from the student's response that acknowledges guidance from more knowledgeable peers in Group 4. He revealed that he had assimilated the knowledge acquired during the group discussion. Hence, he developed his understanding by refining the existing arguments regarding the solutions of reducing global warming.

Contextualization Stage	**Decontextualization Stage**	**Recontextualization Stage**
	Zone of Proximal Development	
Existing argument	Guidance from a more knowledgeable person (Peers or experts	**Refined argument**
• Planting • Build factory with no smokes	• Planting • Law enforcement • Air quality index control • Cloud seeding • Eco-friendly development • Synthetic ozone layer	• Planting • Law enforcement • Air quality index control • Cloud seeding • Eco-friendly development • Synthetic ozone layer

Figure 5.2. The guidance from more knowledgeable peers

The main emphasis of this learning instruction (student-cantered learning) is grounded on the expectation that social interaction between peers will allow capable students to guide weaker students in acquiring knowledge or skills independently (Vygotsky, 1980). This statement undoubtedly reflects the decision-making task to be maximally facilitated when discussion occurred among peers: they are able to cope with the complex scenario. Perhaps, it contributes to individual cognitive development regarding evaluating, comparing and contrasting the strengths and weakness of various viewpoints (Marttunen, Laurinen, Litosseliti, & Lund, 2005). Driscoll (2000) acknowledged, "that the social interactions they encounter could lead to developmental delays or abnormal development as well as to normal or accelerated development" (Drisscol, 2000, p. 250). In addition, more positive interactions regarding verbal interaction emerged where the students in the current study actively presented their ideas in helping the group to achieve a goal (Conwell, Griffin, & Algozzine, 1993; Kim, 2016). Their reasoning and ideas develop collectively in a shared space, which might be impossible in an individual realm.

This is in agreement with Callahan et al. (2011) who demonstrated that the strategy of learning in a group is essential for socioscientific learning as it can assist peers who are incompetent in certain basic concepts of the issue discussed. However, the results of the present study are not consistent with Ideland, Malberg and Winberg (2011) who demonstrated that students are not familiar working with problem-based learning and autonomous group in the formal classroom. In contrast, students who worked in this present study in the co-curricular context could handle their job without depending on the teacher's instruction. For example, they were competent in collaborating with the same and different group members (intragroup and intergroup dynamics) to examine the valid sources of information before making a decision. They were also able to manage their work by delegating tasks, giving roles and using group members as resources in a collective meaning-making discussion. These consequences might happen due to the instructional strategy that was not confined by specified rules and the teachers' authority.

The next factor is socioscientific instructional resources. The instructional resources for socioscientific understanding and decision-making are earnestly discussed among researchers (e.g. Sakschewski et al., 2014; Gresch et al. 2013; Jho et al., 2014; Klosterman and Sadler, 2010). It is crucial for science instructors to recognise the instructional materials that could aid the students to improve and develop their learning. This enables them to structure lessons in an appropriate manner. Klosterman and Sadler (2010) pointed out that many researchers have focused on cognitive and social factors, but similar emphases have not been directed toward the development of framework and instrument that support the objectives of socioscientific instruction.

The results of this study support the needs on socioscientific instructional materials in aiding socioscientific learning, especially in the students' understanding (Callahan et al., 2011; Choi et al., 2014; Walker & Zeidler, 2007) and decision-making skills (Böttcher & Meisert, 2013; Grace, 2009; Hong & Chang, 2004; Ratcliffe, 1997b; Ratcliffe, M & Grace, 2003; Zohar & Nemet, 2002). These findings corroborate the ideas of Ratcliffe (1997), Zohar and Nemet (2002) and Uskola et al., (2010) who suggested that students must be provided with a specific instrument, to enhance their decision-making skills. This includes the methods with clear visualisation framework to assist the students in describing the structural complexity during the decision-making process. It would be sophisticated if the students were provided with a decision-making framework (Acar et al., 2010; Grace, 2009; Ratcliffe, 1997a) as it could avoid vague directions in constituting scientific evidence and formulating sound understanding (Walker & Zeidler, 2007).

Based on the analysis, a majority of the students showed improvement in their decision-making skills. The students revealed that the use of PGO enables them to visualise their thoughts during the decision-making process. The decision-making process can be difficult due to the students' inability to visualise the complex process of comparing options before choosing the final determination. However, the use of PGO helped them to compare and analyse both generated options. According to Ratcliffe (1997), the students who are capable to compare the options when making a decision are considered to have excellent decision-making skills. The result is in agreement with Ratcliffe (1997) and Uskola, et.al (2010) where the students in these previous and current studies were able to compare the options using the decision-making structure. They were able to analyse the problem systematically by considering both advantages and disadvantages of their choices. This includes the awareness to incorporate relevant information in clarifying the pros and cons of the available options. The utilisation of a great variety of criteria to support the decisions resulted in well-reasoned decisions.

Furthermore, this study is also in line with the previous findings by Choi and Meir (2014) which showed that the 5^{th} grade students actively offered more evidence, supporting claims and critiquing and negotiating evidence in deciding on plant and human health investigation. They postulated that the use of Science Writing Heuristic (SWH) approach in an on-line environment supports students' understanding. Dawson and Venville (2010) claimed that the use of writing frames provided with guiding questions plays a significant role in scaffolding students' thinking. Similarly, the PGO that structured the decision-making framework acted as a mental prompt for students to convey their knowledge following the sequences of the decision-making structure. This is because the PGO provides a visible structure where the students can offer a variety of knowledge and be able to evaluate the relationship between the claims and evidence. They also can convey evidence, which they believe relevant for the decision preferred. Other than that, the PGO helps the students to identify new phenomena. Hence, it may provide a deeper understanding of the arising issues.

Because of the uncertainty of evidence related to SSI, students could hardly estimate and evaluate the data provided, thus making them confused about assessing knowledge which encompassed scientific and social evidence. The utilisation of PGO in determining students' knowledge is not in agreement with quantitative studies by Gresch et al. (2013) and Callahan et al. (2011). The use of questionnaire was proven as the main limitation where the student's view on the issue is restricted when estimating and evaluating the knowledge. The students could not reveal their new ideas on the phenomenon because the selection of construct criteria was purposely created. However, the students in this present study showed that the use of PGO helped them in visualising the importance of evaluating knowledge of the options, both accepted and rejected. The ability to evaluate and analyse both types of knowledge for both alternatives is important because it symbolises the high quality of decision-making skills (Böttcher & Meisert, 2013).

Relevantly, PGO allows visible thinking among students. Palmer and Tishman (2005), emphasised that visible thinking expresses the power of knowledge. The PGO that contains graphical organiser enables ongoing annotation, evaluation, addition, and revision. By visualising the knowledge, the students can reveal the key relationships between the decision and evidence, facts and questions and certainties and uncertainties. These complexities can be overcome because the PGO can change and interlock visible relationships. It helps students to offer authentic knowledge instead of just memorising facts.

Evidence from this study supports and refines other similar investigations using writing frames for the argumentation process (Choi, Hand, & Norton-Meier, 2014; Dawson & Venville, 2010). According to Acar, Turkmen and Roychoudhury (2010), the incorporation of decision-making findings may help students to overcome some problematic areas in the argumentation field. This includes the means of avoiding misevaluation of evidence and inappropriate use of value-based reasoning. The use of the argumentation structure is necessary because it symbolises high-quality skills in decision-making (Toulmin, 2003). The results of this present study showed that PGO facilitates students in estimating and evaluating knowledge. They were able to judge and appraise the value of knowledge, which they had offered in the PGO.

Regarding the abilities to evaluate knowledge and to provide alternative solutions, the results of this present study contradict the observation by Gresch et al. (2013) and Callahan et al. (2011). They pointed out that the incompetence to evaluate knowledge resulted in the students' failure in offering more solutions for the option undertaken. From the findings, the students in this study could also discuss the justifications for the solutions to the controversies associated with global warming. In other words, they provided 'multiple sources' of alternative solutions as a way to address the global warming crisis. For instance, they suggest that the citizen would need to alter their mind, attitude, and lifestyle through the exposure of green technology and daily practices. In addition, the students were also able to discuss more than one previous issue as sources of controversy beyond the global context. The trigger of providing a better solution was also acknowledged because they could visualise the ideas of the issues that precede the decision.

In addition, a variety of resources including printed and digital materials could have facilitated the students' learning. This study discovered that the students reflected on the information originating from the printed materials such as posters and flyers distributed by the DOE. They also made use of the digital materials from the digital academic journals, credible websites and the DOE's video and slide show presentation. The supports of the digital infrastructure discussed earlier are one of the fundamental criteria that enable access to digital resources. However, some data from the current study revealed that the unfamiliar learning materials (PGO, printed and digital materials) could distract students' learning.

These findings are in agreement with Witzig, Halverson, Siegel, and Freyermuth (2013) who created a new model of the interface of opinion, understanding and evaluation while learning about SSI. This model emphasised that students' content knowledge and opinions could be influenced by the sources provided. The evaluation criteria and the evaluation of the sources are among the influential factors that encouraged the students to provide evidence for the decision they made.

It is somewhat surprising that integrative activities were found to be advantageous for socioscientific learning within the co-curricular context. Integrative activities refer to a movement towards the integrated disciplines assisting students to make relation across the curriculum. To be specific, the infusion of integrative activities emphasises on making connections within a major, between fields, between curriculum, co-curriculum or between academic, knowledge and practice (Huber, Hutchings, & Gale, 2005). This concept is in agreement with K-12 outcomes, acknowledging the interdisciplinary curriculum potential to support students' engagement and learning.

Similar to the above-mentioned concept, the exploration of the co-curricular context encourages integrative activities to be one of the possible factors that cannot be undervalued. In this learning setting, integrative activities are emphasised on the activities focusing on the nature of multidisciplinary and relevancy.

The researcher is taking 'relevancy' as an example, where the students could relate their existing knowledge resulting from the familiar scenario given in the introduction phase. It provides them with experiences of daily life which are linked to the understanding of the context undertaken (Lewis & Leach, 2006). The complex situation of global warming, which consists of scientific and social frames are authentic in nature. Thus, it can be categorised as real-life contextualisation, open-ended, relevant to the students and having the capacity to develop possible responses (Jimenez-Aleixandre, 2008). The results of this study accentuate the importance of incorporating global warming issue into informal science education such as after school and co-curricular programmes (Hundal, Levin and Keselmen, 2014).

The findings also support the observations by Rose and Barton (2012) and Marrero and Mensah (2010) where they indicated that the scientific knowledge the students possessed and acquired over the course of informal instruction clouted their sensibility of the issues. The sensibility in considering various disciplines when making a decision on global warming issue was positively influenced by broad considerations of how and why the issue mattered. It is evident when the students in this particular study could frame their understanding and were able to connect the multidisciplinary considerations when making a decision.

The final factor was the student readiness. Predominantly, readiness refers to the capability of the learner to undergo learning based on their prior knowledge (Ausubel, 1980; Driscoll, 2000). The findings from this co-curricular context could also demonstrate that student readiness influenced students' learning in the aspects of prior knowledge and digital skills. When dealing with an ill-structured issue, the students must be able to cope with the uncertainties of different knowledge to make a final decision. According to Ausubel's (1980) perspective, students were recognised to undergo meaningful learning when they were able to integrate and connect existing knowledge, thus, making new meanings to themselves.

The contextualisation stage in this instruction was the initial stage where one complex situation is introduced to trigger readiness as well as the students' scientific understanding or prior conceptual knowledge (Vygotsky, 1980). This stage is also parallel with the Vygotskian views that emphasised on the intrinsic motivation and scientific knowledge to be the key learning focus which must be recognised as a starting point in conceptual science learning which evolves within the ZPD. For example, incorporating an overarching issue into the introduction of activity can assist students to connect the science content knowledge and the issue being studied (Lenz & Willcox, 2012) and to detect students' prior understanding in making a decision about the issue. During this stage, students will determine their prior knowledge related to the scenario given, thus, enable them to work further on the issue. The prior knowledge is recommended to be the crucial factor determining problem-solving in all science context (Duit & Treagust, 1998). Students' readiness could also be narrowed down to digital skills. The digital skills that the students have could help their learning when dealing with digital devices.

Parallel with the aforementioned justifications, this study suggests that the facilitating factors play a notable basis that influences the students' learning. Thus it can be viewed as a systematic guideline for the respective practitioners especially educators, policy makers and informal agencies. In light of the issues highlighted by the study design, practitioners could consider various aspects to ensure success regarding the practical and methodological significance.

Implications for Practical and Methodological Significances

The present study, however, makes several noteworthy implications to the practical and methodological aspects. The findings suggest the relevant aspects to consider when teaching SSI.

Practical implications in science teaching. A basic understanding of the key concepts in science is compulsory to enable students to function effectively in dealing with science issues and it is indeed the fundamental aim of functional scientific literacy (Ryder, 2001). The outcomes of the study suggest that the ability of students to engage in reasoned discussion of SSI was very much associated with the content knowledge. Furthermore, they could use multiple directions to make a relevant justification for the decision they made. This study provides a support for the approach of using SSI as a context for science learning. It benefits educators looking for a concrete meaning to integrate this issue into the Science curriculum with direct or indirect touch within the formal and informal context of learning. The integration must be aligned with the Science curriculum standard that allows students to gain evidence of the content knowledge and skills about the decision-making process. The findings are in line with Zohar and Nemet (2002) who concluded that the integration of explicit argumentative-based learning into teaching SSI increases the performance in both scientific understanding and decision-making.

In reality, students generally failed to connect the Science content gained from the formal classroom to their decision-making (Sadler, 2004; Zohar & Nemet, 2002). Moreover, there are also some advanced skills pertaining to SSI that students may not have learned in a formal classroom setting. These difficulties may be rooted from the challenges and circumvention of SSI within formal context (Hughes, 2000; Ratcliffe, Mary & Grace, 2003; Zeidler, et al., 2011). In conjunction with this issue, this study supports the findings by Dawson (2015) and Zeidler et al., (2015) who demonstrated that grappling the SSI demands sufficient knowledge of the underlying scientific concept. Therefore, students could utilise various directions ranging from different perspectives in making justified decisions.

The level of sophisticated understanding and capability in using multiple considerations in this study might have emerged due to the exposure the the students obtained from informal and personal experiences. For example, most of the students claimed that they acquired knowledge via informal ways through parents, reading and surfing the internet, not only from the formal classroom. It would be fruitful if the activities might imply various learning strategies that encourage inquiry-based implementation (Holbrook & Rannikmae, 2010).

Socioscientific activities should be conducted in a well-designed and contextualised scenario. Not to forget, explicit instruction for the socioscientific curriculum context influences students' learning rather than the length of the treatment (Callahan et al., 2011). It is imperative to note that the principal had informed the researcher that the school's active involvement in the co-curricular achievement up to the international level had helped them in expanding students' potential.

One important implication of this study is that educators should consider utilising socioscientific case-based activities in the co-curricular context to narrow the gap between formal and informal setting. It is evident that the content knowledge could positively affect the students' capability in drawing scientific and social considerations on decision-making.

Ordinarily, the socioscientific instruction is conducted without the factors that influence its effectiveness especially in the co-curricular platform. This study provides a clear evidence of co-curricular programmes as a social fabric context that contributes significant impact on the students' understanding and decision-making related to SSI. The findings of this study may serve as a guideline to promote students' learning within this informal context. As reported by Anderson, Lucas and Ginns (2003), Hofstein and Rosenfeld (1996) and Burley (1990), formal and informal learning are complementary as informal learning can also occur in the formal school curriculum and vice versa via informal ways. It is advisable for educators to evaluate the co-curricular programme design that emphasise on the effective engagement of the co-curricular programme following the desirable outcomes.

Ensuring co-curricular effectiveness by implementing systematic development programmes. The principal outcome emerged from this study is to maximise co-curricular effectiveness to stimulate the students' potentials. One of the possible results which can be practised to overcome the difficulties in learning multifaceted issues is to initiate collaboration between schools and related organisations to design meaningful programmes that enable students to develop their understanding and skills.

In accordance with the socio-constructivist principles, individual learning is reliant on the organisational programmes and settings in one's social milieu (Vygotsky, 1980). The design of the co-curricular programmes has been developed in view of the learners' background knowledge and heterogeneous connectivity so that the students experience an in-depth enculturation into being informed citizens in the globalisation era. The present study has tried to promote the collaboration between school organisation and the DOE through the infusion of informal activity that can support students' understanding in making a decision about global warming issues. Apparently, this activity has scaffolded the students' ability in learning global warming issues.

The shift towards teaching SSI which incorporate ethical dimensions challenge some teachers about the focus of scientific rigor (Nielsen, 2013; Ryder, 2015). In the framework of this study, a collaboration between the school and informal learning agency provides numerous evidence on how such cooperation can be integrated within the co-curricular context. An existing strategic network between the school and informal learning agencies should be improved and strengthened to establish a relationship between the two complementary contexts, whether in formal and informal learning. Reis and Galvao (2009) recommended that the implementation of multifaceted SSI must be supported by professional development such as new guides, experiences and expert guidance in order to minimise its challenges.

Exposing students to the informal learning environment such as the co-curricular context may be helpful in connecting students to a variety of science topics. However, linking the formal science learning with the co-curricular experiences with a basic understanding of certain subject matter challenges the nature of science education historically (Falk & Storksdieck, 2010). Zeidler et al. (2011) pointed out that offering students to work and discuss relevant SSI has been proved as an effective method of teaching content knowledge in which they provide a space for students to introduce argumentation, hence strengthening the students' understanding before making a decision. If the aim of scientific literacy is about understanding complex scientific issues and decision according to their knowledge, then it is meant that they are influenced by SSI within the informal learning circumstances such as co-curricular context (Walker & Zeidler, 2007).

Within this framework of the study, the use of the global warming issue that is linkable to the formal curriculum helps the students' learning. The strategic collaboration between schools and other agencies should be designed meaningfully, as an effort to optimise the contribution of this informal education institutions and to support formal learning in schools (Birmingham & Calabrese Barton, 2014; Bozdogan & Yalcin, 2009). The implementation of SSI within informal learning settings has the ability to create scientifically literate citizens by enhancing the students' understanding of how science works outside of the classroom (Zeidler & Sadler, 2009).

Findings from this present study revealed that the resources supplied by the DOE provided an effect on the students' understanding in making a decision for the presented scenario. The support of global warming posters, for instance, helped teachers in dispersing knowledge effectively. These materials appeared supportive for controversial socioscientific discussions as educators and students could become unenthusiastic due to the difficulties they expected during such discussion (Zeidler, Applebaum & Sadler, 2011). The common complication is the students possessed limited knowledge (Jho et al., 2014; Khishfe, 2015; Sadler & Zeidler, 2009) and mixed understanding in circumnavigating the SSI (Dawson, 2015).

A socioscientific instruction such as introduction to the socioscientific decision-making should also be taken into account, considering as an initiative to facilitate classroom science learning. This instruction is best conducted during the co-academic courses as it serves as a suitable platform for the co-curricular context. In this framework of the study, the integration of the global warming issue was used as the principal learning method over the three stages of socioscientific instruction. The instruction was systematically designed based on the literature following the contextualisation, decontextualisation and recontextualisation stage. The lower secondary students who participated in this current study came from eight mixed classes of 7th and 8th grade of one Fully Residential School. The instruction used in this study was beneficial for the lower secondary science education, as there were limitations in integrating SSI within the formal classroom activities.

Effective socioscientific learning has to be implemented in an after-school programme as an avenue to provide opportunities for students to discuss relevant issues as suggested by Rose and Barton (2012), Jarman (2005), and Birmingham and Barton (2014). To fully appreciate how the co-curricular context and the SSI-based context differ from formal classroom learning and how SSI are systematically contextualised as a learning framework, an illustration of the proposed guideline is recommended. The guideline should comprise the four above-mentioned factors that influence the students' understanding in making a decision on SSI: learning flexibility, socioscientific instructional resources, integrative activities and student readiness.

Since there are no specific objectives being documented for the club or society activities within the co-curricular context, it is not mandatory for the practitioners to adhere to all factors stated above. Importantly, the guidelines are the main concern to ensure the successful learning within this context. In the co-curricular platform, students must play a major role in making this happen. However, the effectiveness relies on a significant part of devotion and creativity from everyone involved (Huber et al., 2005).

The role of teachers is also crucial in the implementation of the co-curricular activities. They are the facilitator and planner for the socioscientific instruction. The guideline provided aims to facilitate teachers in planning and implementing socioscientific learning within this co-curricular context. With the appropriate mechanisms in line, co-curricular context can be a dynamic and complementary platform for science learning. It could also serve as a catalyst for formal classroom learning (Burley, 1990; Hofstein & Rosenfeld, 1996; Jarman, 2005; Livingstone, 1999).

Methodological implications. This study confers the implications for future research in the methodological aspect. The development of the decision-making instrument is in line with Ratcliffe, (1997), Zohar and Nemet (2002), Dawson and Venille, (2010), Gresch, Hasselhorn, & Bögeholz,(2013) and Choi et al., (2014) who recommended numerous strategies in dealing with decision-making difficulties. This includes some suggestions on how to overcome the structural complexities, tracking knowledge in decision-making and provide flexibility in the students' decision-making.

In this study, the researcher has presented a rich description of PGO that operated as a visualisation tool for making a decision related to global warming issue. Notably, the findings from the evaluation and actual studies revealed that the PGO has detected competencies for the decision-making process, which has been influenced by a flexible graphical tool. The data from this present study has led to an in-depth understanding that the lower secondary students preferred a visual tool (PGO) in their attempts to understand and make a decision on the presented issue. In addition, they preferred to utilise PGO to better understand the normative and descriptive rules of decision-making.

The findings indicated that the PGO is relevant and workable to recognise the key matters that require relevant scientific knowledge in deliberating issues related to global warming. It also revealed the considerations the students used when making the final decision. The main contributing factor is the PGO enables the students to visualise the structural complexity in the decision-making process. Thus, the students can explicitly organise scientific evidence and conceptualisation when dealing with the socioscientific decisions (Halim & Mohd Saat, 2017; Walker & Zeidler, 2007).

Tishman and Palmer (2005) highlighted that the employment of visualised tool enables students to think visibly. They added that visible thinking refers to any kind of visible representation that documents and supports the development of ongoing thought, matters, reasoning, and reflections. In this case, PGO serves as a visualised tool to organise information when dealing with the decision-making situation. Similar to this context of the present study, the decision framework facilitates collaborative discussion to keep students on track and to aid balance on the consideration of science and social (Ratcliffe, 1997). If the guidance on appropriate ground rules for decision-making is flexible, it may increase spontaneity and it is valuable in helping students to organise their discussion.

The use of PGO proves that the qualitative assessment enables students to connect the causes and incorporate the potential consequences associated with global warming (Klosterman & Sadler, 2010). In this particular research, every group was not given with specific questions related to global warming. However, their response determined the knowledge of science surrounding the factors, consequences as well as solutions to global warming. In detail, they used the PGO to identify anthropogenic and natural factors affecting global warming and clarify the global warming effects regarding health, ecological system and climate change. For the alternative solutions, they conceptualised sustainability development as the best way of reducing global warming. The considerations of scientific and social aspects were also relevant to the issue discussed.

It is worth noting that the employment of PGO can be simultaneously used to identify both didactical structures of students' knowledge and decision-making skills.

In the aspect of decision-making skills, PGO operates as a visualisation tool to compare options, structure the sequences of decisions, identify and imagine appropriate solutions and estimate and evaluate knowledge. Based on the literature, students failed to visualise the complexity of the decision-making process with regard to monitoring and analysing the options (Grace, 2009; Zohar & Nemet, 2002) and failed to structure the sequences of decisions (Ratcliffe, 1997). Pursuant to the complexities, students also lacked the capability to weigh the options (Böttcher & Meisert, 2013; Eggert & Bögeholz, 2010), struggling to offer alternative solutions (Acar et al., 2010; Jonassen & Kim, 2010) and barely recognising or evaluating scientific evidence (Sadler et al., 2004). Nevertheless, the development and validation of PGO contributed a new role for the socioscientific visualisation method about overcoming such complexities in the decision-making process (Halim & Mohd Saat, 2015, 2017).

The development of PGO is a flexible alternative to assist students in monitoring their decision-making processes. By using PGO, students are expected to systematically control and reflect upon their decision-making process (Böttcher & Meisert, 2013; Eggert & Bögeholz, 2010; Eggert et al., 2013; Gresch & Bögeholz, 2013; Sakschewski et al., 2014). Students should be exposed to these decision-making steps to create a sophisticated strategy, especially when discussing SSI (Grace, 2009; Zohar & Nemet, 2002). Perhaps this synchronisation of competencies should be considered a vital part of enhancing the quality of decision-making (Aikenhead, 1985) associated with SSI(Aikenhead, 1989). It would be advantageous to make students' thinking visible by giving a direct visualization tool regarding the structural complexity (Gallavan & Kottler, 2007; Tishman & Palmer, 2005).

Overall, the students' decision-making skills can be stimulated and engrossed much further via the use of PGO. The lack of competencies was probably rooted from current practices that neglect the infusion of systematic methods of a socioscientific decision-making framework within the formal curriculum. This might also be attributable to the lack of a visualisation tool for decision-making in which students failed to understand and control their decision-making process. Moreover, this was due partly to the fact that the students nowadays are stimulated with more visual than written information in their daily lives. The above-mentioned complexities can hinder students' progression in polishing and practising their skills of decision-making. The utilisation of visual framework, however, is ineffective until it has been practised and reflected in the teaching and learning activities (Erduran, Simon, & Osborne, 2004; Simon, 2008). Therefore, the students must be familiarised with the new method to make their learning more efficient.

According to Ausubel's (1980) view, the instructional materials must be potentially meaningful to learners, organised so that the connections are easily made between new information and that which is already known. Providing an advance organiser that activates prior knowledge is one way of making learning more meaningful. It becomes an impossible or a hard task to complete if there are no meaningful instructional materials provided for the students (Driscoll, 2000). It is also consistent with a constructivist theory, which proposed that students must be provided with appropriate instructional materials that represent content and structure information so that they could more easily develop appropriate skills.

It is beyond the scope of this study to speculate the extent of the knowledge progression. Nonetheless, the PGO has functioned as a total qualitative tool that can be revisited to determine students' knowledge progressions for socioscientific decision-making task. Sakschewski et al. (2014) recommended that future studies pertaining to socioscientific decision-making must take important consideration on the development of a specific instrument to monitor the students' prior knowledge progression. It would be fruitful to explore the need of prior knowledge for the decision-making instrument as prior knowledge does play a vital role in the decision-making competency. The progression of students' prior knowledge indicates their understanding about a specific context. The use of PGO may be relevant due to the flexible direction of PGO that is not confined to specific questions like the quantitative survey. Therefore, PGO may provide information that sometimes is only revealed through personal experience. The information may also be converted into a numerical form in which it could explain knowledge progression that consists of a broad range of knowledge, concepts and abilities.

Recommendations

According to the limitations, delimitations and also the discovery of influential issues during the research process, some recommendations are suggested for future studies in this area. As an initial recommendation, the specific focus of the research should consider the following aspects:

1. This study focused on one Fully Residential School type. It would be engrossing to explore a similar research in a different type of schools, which will provide similarities and differences in the findings of the students' understanding and decision making of SSI within co-curricular context.
2. Due to the limitation of this context of the study, it can only be conducted among lower secondary school students. Future potential research focus could select students from the primary or upper secondary students in relation to exploring their socioscientific understanding and decision-

making. It could be worthwhile to take a different target group from various level of schools in which it may represent a different state of outcomes.

3. It can be engaging to replicate the study with a variety of learning environment. Although the main aim of this research work was to explore the socioscientific learning in the informal environment via the co-curricular setting, it is recommended that this kind of activities is suitably conducted within the formal classroom learning. The infusion of knowledge and skills may be enriched since there is no explicit learning instruction being documented in the formal Science syllabus, especially in the Malaysian context.
4. Replicating the study with researchers acting in different positions could shed some light into the body of knowledge. In this study, the role of the researcher is mainly as a researcher-participant who primarily acted as an instrument of a qualitative study. Future research could see researchers acting in a different role. If possible, the researchers may serve more than one role during the entire study to have a better ability in collecting meaningful data essential to answer the research questions. Furthermore, it is one alternative of avoiding biases that might be obtained by a single role researcher.
5. Due to the limitation of this study, it was only conducted to explore the students' understanding. Future research focus could study on students' knowledge progression. Then, it would be advantageous if their knowledge is explored during early and late instructions. Indirectly, the effectiveness of socioscientific instruction could also be studied.

6. The study can be replicated using a different scenario that fits the context of the study. There may be limits to the extent to which PGO is the only one example presented along with the global warming scenario. However, the scenario is changeable in nature, where another appropriate socioscientific scenario can replace it, thus, fitting the aspects of content-related, relevance and neutrality.
7. The SSI can be applied in various disciplines. Therefore, the changes and stability of the students' understanding could be explored in other subjects, such as English, Civic and History and not confined to the Science subject.
8. The investigation of socioscientific learning in the co-curricular context may employ the use of a quasi-experimental research design, which uses a control group and experimental groups. This strategy can be used to generalise the results to a larger population.

Chapter Summary

Providing an opportunity for a flexible discussion in the social fabric of school is one of the alternatives to assist the students in dealing with SSIs. The flexible learning environment is indeed relevant to rekindle their potentials. The co-academic co-curricular platform could be the peripheral medium to enlighten students' potential in the aspects of cognitive, affective and psychomotor. Once this potential is activated, it can only enhance and generate an additive outcome. Although abundant ideas and approaches are forwarded to increase the standard of Science, the role of co-curriculum should not be circumvented.

The complete overview of this study shows that informal learning through co-curricular context could stimulate the students' learning. Specifically, there is a linkable continuum between the formal and informal context, deemed at students' understanding and decision-making related to SSI. Hence, the journey towards facilitating socioscientific learning in the co-curricular setting commences with the mindset to think unconventionally following the dynamism of the learning phenomena. To begin with, the strategy for learning is not ruled by authority but by initiative and flexibility; the designed programmes are not merely teacher-centred but formulated with integrative activities which promote student-centred directions and the co-curricular outcomes do not rely on specific rules but guidelines that assist them. It is hoped that the co-curricular setting benefits students through their successful or not so successful learning experiences. The experiences gained in this medium could eventually develop the students' knowledge and skills in general. Indeed, the co-curricular platform provides a synergetic path between formal and informal learning continuum.

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