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EXPLORING STUDENTS' UNDERSTANDING IN MAKING A DECISION ON A SOCIOSCIENTIFIC ISSUE USING A PERSUASIVE GRAPHIC ORGANISER

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Abstract. *The common use of questionnaires and qualitative assessments revealed that students experience difficulties in visualising the structural complexity of decision making. Thus, the use of scientific knowledge was disconnected while making a preference. The focus of this research was to explore students' understanding of the global warming issue using a Persuasive Graphic Organiser (PGO). This research was conducted among 36 students (Grades 7-9) at a school in Kuala Lumpur, Malaysia. The developed PGO and interviews were utilised as the primary data collection techniques. Meanwhile, a constant comparative procedure was employed in the qualitative data analysis. Results showed that the use of PGO assisted students' visualisation in relating three essential understandings of the global warming issue. The students were able to: 1) identify anthropogenic factor affecting global warming; 2) clarify the effects of global warming in health aspect, and 3) provide alternative solutions regarding green technology and daily practices. It was also found that PGO is operationally workable and can be conveniently utilised as a visualisation tool for promoting students' understanding in socioscientific decision-making.*

Keywords: *decision-making, persuasive graphic organiser, socioscientific issues, understanding of scientific concepts.*

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Introduction

The integration of socioscientific issues in science education is an essential facet of scientific literacy. Socioscientific issues are characterised as controversial in nature, real-world problems and socially relevant, which are informed by science and ethical complexities (Christenson, Chang, Rundgren, & Zeidler, 2014; Sadler, & Zeidler, 2005; Sadler, Barab, & Scott, 2007). More importantly, the socioscientific approach has become a fundamental of developing critical thinking (Kolsto, 2006; Uskola, Maguregi, & Jimenez-Aleixandre, 2010). The expectations of socioscientific approach are centralized on the abilities to reflect on problems, which are relevant to social life (Kolsto, 2001; Sadler & Zeidler, 2009; Holbrook & Rannikmae, 2010), according to a careful examination of knowledge (Albe, 2007; Sadler, Chambers, & Zeidler, 2004; Sadler & Donnelly, 2006). These have been viewed as essentials in producing enlightened students who can participate in decision-making about society (Jime´nez-Aleixandre, 2002; Sadler, Barab, & Scott, 2007; Vesterinen, Tolppanen, & Aksela, 2016) and maintain a democratic way of life (Aikenhead, 1985; Heath, White, Berlin, & Park, 1987). Therefore, students need to be provided with appropriate contexts in order to achieve the objectives set above.

Zeidler and Nicols (2009) highlights that the socioscientific approach requires the use of evidence-based decisions and a contextualized scenario for understanding scientific information. There are no denials on the prioritisation of scientific ideas for decision-making process (Klosterman & Sadler, 2010). The rationale is that it furthers the development of scientific concept and processes and thus develops a sound understanding of particular dilemmas (Sadler & Zeidler, 2009). Sadler and Zeidler (2009) emphasise that students must attain 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,

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as well as decision-making skills. With that being so, it is beneficial to gauge students' understanding so that they can make a sound decision within a socioscientific dilemma.

In this regard, the biggest problem uncovered relates to the difficulties students have in visualising structural complexities in the decision-making process (Ratcliffe, 1997; Zohar & Nemet, 2002). As a result of this complication, they are unable to evaluate scientific evidence, and treat scientific information as uncertain and intolerable (Fleming, 1986). They are also unable to make decisions about the issues and fail to reach a final determination (Grace, 2009). Therefore, there is a need to develop instructional materials for socioscientific issues so as to promote students' understanding and decision-making skills (Choi, Hand, & Norton-Meier, 2014; Jho, Yoon, & Kim, 2014; Klosterman & Sadler, 2010; Ratcliffe, 1997a; Sakschewski, Eggert, Schneider, & Bögeholz, 2014). In fact, it is beneficial if students are provided with a decision-making framework (Acar, Turkmen, & Roychoudhury, 2010; Grace, 2009; Ratcliffe, 1997a) to avoid vague directions in constituting scientific evidence and formulating sound understanding (Walker & Zeidler, 2007).

Previous studies have shown that the use of questionnaires restrict students to prioritise knowledge criteria, based on their personal experiences and values, because selection of the construct is already arranged (Gresch, Hasselhorn, & Bögeholz, 2013). Consequently, students tend to delimit their offers to provide more solutions as a further explanation of the finalised preference. Furthermore, Callahan, Zeidler, and Orasky (2011) utilising the Views on Science and Education survey (VOSE) investigate the relationship between socioscientific issues and science understanding. The results indicate that students are approximately halfway between conventional and contemporary views of science, even after a semester-long socioscientific treatment. The statistical insignificance may arise from two possibilities derived from using the VOSE questionnaire. These highlight the poor detection power of VOSE in discriminating between naïve and sophisticated understanding. Also, there is incompletion of revisiting the same survey, because of students' demotivation parameters. Additionally, Zohar and Nemet (2002) examine the influences of teaching argumentation skills, in the context of human genetics, on the acquisition of content knowledge among ninth-grade students in Israel. It looks promising, particularly for the large samples used, as well as the positive after-effect; however, the main emphasis was on argumentation skills, involving students' ability to recognise unclear key issues of science knowledge.

Recently, Dawson (2015) studied students' understanding of climate change and the greenhouse effects using a designed questionnaire, completed by 438 Year 10 students from six schools in Perth, Western Australia. This was followed by interviewing 20 students to explore their understanding of the issues further. Findings demonstrated that students knew different features of both climate change and the greenhouse effects, although this did not necessarily involve all of them. She also emphasised that the use of clear consequences and solutions for these issues were unclear, because the sciences of climate change, and greenhouse effects or global warming were emerging and subject to change. For instance, the public could hold and oppose views regarding the sciences of factors and consequences. In addition, Khishfe (2015) investigated 10th grade students' understanding of genetically modified food, and river fluoridation using pre-, post- and delayed post-tests. Results showed that the majority of the students reverted to their earlier naive understanding even after they had been exposed to a four-month socioscientific instruction.

In response to the dilemmas in quantitative methods, Choi, Hand, and Norton-Meier (2014) suggested employing a qualitative method, such as the Science Writing Heuristic (SWH) approach, in decision-making process. This method resulted in a very satisfactory outcome for students' socioscientific understanding. However, they challenged the reliability and validity of the approach due to the lack of interview data sources. The use of writing frames might be useful to 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 was necessary because it was vital for tracking students' understanding (Walker & Zeidler, 2007), which importantly symbolised a high-quality skill in decision-making (Toulmin, 2003).

Walker and Zeidler (2007) conducted an inquiry-based curricular unit to promote socioscientific learning among 36 Grade 9-12 students in the Southeast United States. The researchers utilised an online artefact 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 were also not specifically direct in applying their nature of science understanding. The worst condition was that they tended to utilise more factual-based content that led to numerous examples of flawed reasoning and personal attack. The findings recommended a socioscientific approach to exploring aspects of nature of science that represented the science conceptions to be applied within a decision-making context.

Klosterman and Sadler (2010) utilised a multi-level assessment design to explore students' content knowledge which was relevant to science knowledge and the controversies surrounding global warming. Data were collected from 108 Grade 9-12 students using a standards-aligned content knowledge exam (distal assessment) and curriculum-aligned exam (proximal assessment). The analyses from the proximal assessment revealed some stages of understanding of global warming.

Taking a Malaysian context as an example, this acknowledges the importance of integrating socioscientific issues into the science curriculum, as an approach to infusing cognitive competency in various stages. It includes promoting students' understanding in making a decision about socioscientific issues using relevant instructional material. In this framework of study, the issue of global warming was selected, because it is categorised as a major socioscientific area of Malaysian middle school education, relevant to students' daily life experiences, linkable to the formal curriculum and vital for informed citizenship (Hundal, Levin, & Keselman, 2014).{FormattingCitation} It is worth noting that this study is not to determine the depth of global warming content knowledge, but rather to explore what understanding can be detected through the use of a visualisation tool.

Considering the aforementioned problematic area in socioscientific issues, we suggest that teaching strategies about multifaceted issues need to be directed towards, not only promoting students' understanding, but also consolidating the skills needed in each phase of the decision-making process (Böttcher & Meisert, 2013; Hong & Chang, 2004). Grace (2009) adds that the decision-making framework needs to be provided to improve students' understanding when dealing with socioscientific issues. To address these issues, a visualisation tool is believed to be appropriate to explore students' performances, accompanied by an understanding of the processes that precede a decision. This is seen as beneficial, if students are provided with a specific visualisation method (Jonassen & Kim, 2010) and a framework of structural complexity that must be considered in a decision-making process (Grace, 2009; Ratcliffe, 1997; Uskola et al., 2010). Therefore, this research aims to explore students' understanding when making a decision on the global warming issue, using the Persuasive Graphic Organiser (PGO) visualisation tool.

Methodology of Research

General Background

The research design, deemed most appropriate for this study, is a generic qualitative design. This research design emphasises exploring the process, perspectives and worldviews of the people involved in the setting under study (Cooper & Endacott, 2007). This is especially relevant to elucidate students' understanding in making a decision on the global warming issue within a co-curricular context. The researchers act as the "instrument" and their presence, in the lives of the participants of the study, is fundamental to acquire an in-depth understanding of the phenomenon. In other words, the researchers are the instructors of this particular study, driven by the aim of exploring students' understanding in deciding on global warming issue using the developed PGO. This research is conducted for six month period within the co-curricular context.

Sample and Administrative Procedures

This research involved 36 students (aged 13-15) from different backgrounds. They were official members of the Science and Mathematics Society at one Residential School in Kuala Lumpur, Malaysia. The selection of students who possessed a fundamental knowledge of global warming was prioritised. The tone of basic knowledge was indicated via "curriculum mapping" from science syllabuses (Altman, 1989). In choosing the participants and school, so as to get an extensive understanding about the central phenomenon, a purposeful sampling technique was utilised (Creswell, 2007; Merriam, 1998). The relevant criteria for expressing scientific and social perspectives about the socioscientific issue among the students were deemed as the most relevant (Zeidler, Herman, Ruzek, Linder, & Lin, 2013). Further, these students were expected to have the ability to express a higher interest in working with, and discussing, the issue. Initially, a recommendation from Educational Planning and Research Division (MOE) was acquired to suggest a school that was active in co-curricular activities, and also a teacher to suggest the students who were active and responsive. The students who participated in this study submitted consent forms from their parents or guardians.

The administrative procedure in this research commenced with a training session, and then this was followed

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by the actual administration. The one-hour period training session was conducted on day 1 and aimed at providing students with adequate skills in generating a PGO. This session demonstrated the process of developing the PGO, including the essential components and visual examples of a PGO. As a PGO is atypical, the students were provided with a PGO sample (obesity scenario) to get them familiar with a PGO.

A PGO is composed of two components; the "scenario" and the "decision-making graphical organiser." The scenario focuses on the controversial issue of global warming, while the graphical organiser emphasises the main components of the decision-making structure (Ratcliffe, 1997). A combination of these elements enables students to form a writing that includes persuasive and well-defined arguments, which attempt to persuade readers (Stab & Gurevych, 2014) in a structured manner (Gallavan & Kottler, 2007). The PGO is professionally validated using socioscientific and qualitative experts. It is also piloted with students from a different school for the evaluation process. Figure 1 illustrates the format of a PGO.

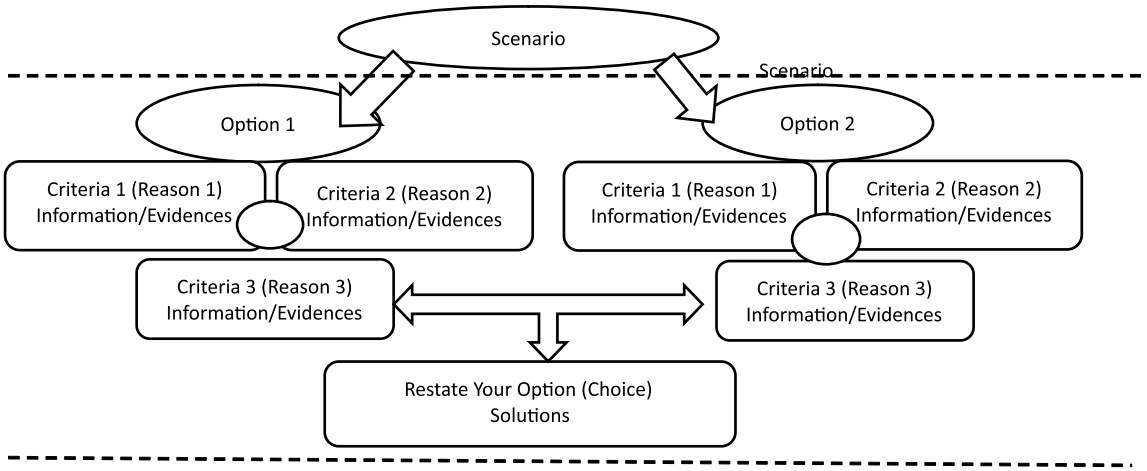

Figure 1: The Persuasive Graphic Organiser (PGO) format.

During the actual administration session (Day 2), a 5-minute video on global warming was presented to highlight the critical condition happening around the world, and in Malaysia in particular. After that, one scenario entitled, "Global Warming: A Silent Killer" (refer Figure 2), was administrated as the first phase, i.e. the contextualisation phase. Holbrook and Rannikmae (2010) pointed out that a socioscientific issue needed to be confined with a relevant scenario as a procedure for contextualisation.

Scenario: "Global Warming: A Silent Killer!"

Global warming is projected to compound the 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. You are an expert advisor and are required to make a decision about whether "to stop or not to stop the developmental activities" so as to reduce the impact of global warming.

Figure 2: The scenario of global warming: A silent killer.

The students were then instructed to work in six groups of three to generate their PGO, based on the skills acquired during the training session. They were allocated in a specially arranged, 90-minute time for discussion and PGO generation. A total of twelve generated PGOs were completed and returned.

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Data Collection

Formal data collection consists of PGOs and interviews. The PGOs are generated through a group discussion, in which justified takes place using PGO. This is followed by a semi-structured interview dealing with a subsample of each group, to determine issues experienced when dealing with PGO creation for global warming decision-making. Steps are taken to ensure that the time intervals between the PGO generation and interview session are not too lengthy, to enable the students to recall their earlier knowledge and skills. During the data collection process, all the students are informed that the PGOs generated in this research are not evaluative. They are assured that their responses to the interview are to be kept confidential and used only for research purposes.

Data Analysis

Data analysis commenced with the analysis of raw data. All the recorded materials were systematically transcribed into text data. The generated PGOs were analysed following the document analysis procedure. Transcription of the interviews and content of PGOs were explored, and analysed rigorously following the inductive constant comparative analysis method (Corbin & Strauss, 1990). A familiarisation process was performed by undertaking an overview of the affluence and diversity of the gathered materials. The whole data were chronologically collected and analysed to the open, axial and selective coding processes in an endeavour to understand both the *structure* (why) and *process* (how) inherent with the paradigm of the students' understanding, using the developed PGO. The final step of the data analysis involved interpretation of meaning of the results. Creswell (2014) emphasised that the interpretation in qualitative research could be described in many forms; research-based, flexible to convey personal and action meaning. The overall tone of this study was the forms of rigor 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.

Trustworthiness

This research employed triangulation and peer review strategies in enhancing its internal validity. For the triangulation aspect, the PGO and interviews were used to increase confidence in the interpretation. The general rationale was that with more sources of information, the more likely it could gain a full perception of the phenomenon under study (Marshall & Rossman, 2014). The peer review included a review of the interview protocol and the PGO task, as well as the evaluation of findings. For example, the categories identified and recognised during the data analysis process were evaluated through expert review. The experts' and scholars' feedback, made over the duration of the study, were scrutinised.

For a transferability sense, Merriam (1998) acknowledged that it was difficult to achieve this in qualitative research, due to the changing nature of human beings. Thus, this study employed triangulation through the use of multiple data sources. Moreover, a process of data abstraction, through the constant comparative method taking place over the entire course of data analysis was identified as a way to set high standards of transferability (Corbin & Strauss, 1990; Merriam, 1998).

Research Results

Based on the analysis, three different categories of students' understanding emerged. These categories represented students' understanding of global warming through the employment of PGOs as the visualisation tool. The categories were:

1) identifying the anthropogenic factors affecting global warming,
2) clarifying the effects of global warming in relation to health aspects, and
3) providing alternative solutions for green technology and daily practices.

Since all PGO entries were in the Malay language (the medium of instruction), the entries were translated. The illustration of PGO generated by the students was initially attached, followed by the translated version for exemplary. For the benefits of readers, only the translated form is presented in the next section.

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Identifying the Anthropogenic Factors Affecting Global Warming

In the context of this research, the students visualised the PGO as a tool in identifying anthropogenic factors affecting global warming. They convinced that *"by using this PGO; we can make a clear investigation, and it helps us in generating a strong statement. The same with the factors of global warming we state here"* (Int-S3:40-41). For instance, the students identified the anthropogenic factors of global warming that were influenced by human activities through deforestation. They acknowledged that *"the first reason we put in the PGO is about forestry. As evidence, people cut down the trees to run some activities related to industrialisation* (cInt-S6:37-39).

Further, they used the PGO to explain about the generation of energy for powering vehicles through fossil fuel combustion. The examples were given *"mostly from petrol produced by cars. Differently, if we want to move the airplane engine, we have to burn kerosene"* (rInt-S5:89-91). They also generalised that *"the energy comes largely from petroleum gasoline. I can conclude that the combustion of fossil fuel, such as petroleum gasoline, resulted in power generation. For instance, we need energy for vehicles, electrical appliances and construction works"* (lInt-S5:92-95).

Figure 3 and Figure 4 detail students' understanding in identifying deforestation and energy supply as the anthropogenic factors associated with the controversy.

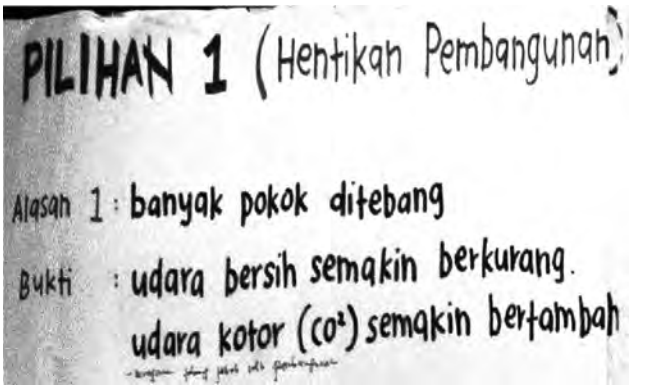

Figure 3(a): Generated PGO drawn by students - forestry factor.

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 (CO2) b comes higher.

Figure 3(b): Generated PGO translated by authors - forestry factor.

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

Figure 4: Generated PGO translated by authors - energy supply factor.

Clarifying the Effects of Global Warming in Relation to Health Aspect

In this particular research, clarifying the effects of global warming was defined as elucidating obvious consequences of global warming to avoid inexactness in making a decision. Informed by the analysis, the students were able to clarify the effects of global warming in term of health aspect. It involved *"minor illnesses such as cracked skin and chapped lips"* (Int-S2:33), which led also to major illness up to *"high risks of diseases including fatal.* Other related examples were *"Carbon Dioxide can damage our lungs and trouble the respiratory system"* (Int-S2:51-52).

The following PGOs (Figure 5 and Figure 6) illustrate the students' ability in clarifying health effects as their justification for the global warming decision.

2) Health will be affected.

- Skin cancer and respiratory problems are likely to occur.

Figure 5: Generated PGO translated by authors - health effects.

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

Figure 6: Generated PGO translated by authors - health effects.

By referring to the generated PGOs, the students could elaborate ideas concerning the effects of global warming further. They revealed *"the use of PGO makes me realize that there is another health effect which might be considered for health category. We can relate general health with the emotional effect because the hotness causes us stress or depression"* (cInt-S6:30-32).

Providing Alternative Solution in Terms of Green Technology and Daily Practices

In the framework of this research, the students were able to provide alternative solutions to present a possible choice between two options of global warming decision. They found the PGO to be a visualised tool providing alternative solutions *"indeed, by generating the PGO, we feel that we can imagine and suggest some solutions for the option taken, as well as the rejected option. Again, we can provide solutions, and maybe we can improve it further"* (Int-S3:141-142). They gave some examples of green technology such as *"hybrid car, magnetic train"* (rInt-S2:148-149), and *"yes, other than that, we can use electric vehicles too!"* (rInt-S2:152). They were able to put forward alternative solutions by stating the significance of "*greening vehicles that have been used in the developed countries will not pollute the environment, thus reduce the Green House Gases emissions"* (rInt-S4:92-93). This could be shown through the application of green transportation as examples of the environmentally friendly products (Figure 7).

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

Figure 7: Generated PGO translated by authors - greening vehicles alternative solutions.

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The revelation of alternative solutions could also be grounded from the next PGO, which demonstrated that the students were able to provide solutions for daily practices that were considered vital in reducing global warming.

SOLUTIONS

Stop the developmental activities.

1. Reducing the usage of electrical appliances which release CFC.

   = Example: Using electrical appliances activities which release HFC.

2. Applying lotion that contains SPF15 and above.

Figure 8. Generated PGO translated by authors - daily practices alternative solutions.

As shown in Figure 8, the students used the PGO as a tool to further clarify the alternative solutions to electrical appliances and cosmetics products. For example,*"by using the PGO, we can visualize related solutions such as HCFC-based electronic devices which contain Hydrochlorofluorocarbon as the alternatives for this decision"* (cInt-S2:70-71). The essentials of the new technology in the cosmetic industry were also suggested; "*the use of SPF lotion, sun protection factor is a UV light cream that can be applied to our skin as our health routine"* (cInt-S2:74-76).

Discussion

This research set out to determine students' understanding in making a decision on the socioscientific issue through the employment of a PGO. The PGO is relevant and workable to recognise the key matters that require relevant science knowledge in global warming deliberation. The findings revealed that the PGO operates as a visualisation tool in identifying anthropogenic factor affecting global warming, clarifying the effects of global warming in term of health aspects and providing alternative solutions regarding green technology and daily practices. The majority of students were able to connect their scientific knowledge when addressing informed decision. They revealed that the use of the PGO helped them to visualize evidence for possible options and judge the sufficiency of proof for the satisfactory and rejected conclusions (Maloney & Simon, 2006).

This is probably due to the method that assists the students in visualising the structural complexity of the decision-making process. Thus, the students can explicitly constitute scientific evidence and conceptualisation when dealing with socioscientific decisions (Walker & Zeidler, 2007). Tishman and Palmer (2005) highlight that the employment of visualised tool enables students to think visibly, hence expresses powerful knowledge. They add that visible thinking refers to any kind of visible representation that documents and supports the development of ongoing thoughts, matters, reasoning, and reflections. In this case, PGO serves as the visualised tool to organise science information when dealing with decision-making situation.

The controversial issue introduced through a global warming scenario was chosen in the context of this research. Klosterman and Sadler (2010) claimed that the combined use of qualitative proximal assessment and quantitative distal assessment offered contradictory evidence for understanding global warming. The findings of the current study were consistent with their qualitative assessment, where students could connect the causes and incorporate the potential consequences associated with global warming. Although the students were not given specific questions, their responses determined the knowledge of science surrounding the factors and consequences of global warming. More specifically, they used the PGO to identify forestry and fossil fuel combustion as the anthropogenic factors. As for the effects, the students considered the health aspect as the consequence of global warming.

The utilisation of the PGO in determining students' understanding, however, is not in agreement with the quantitative studies by Hasselhorn and Bogeholz (2013) and Callahan, Zeidler, and Orasky (2011). The use

of a questionnaire has been shown to be the main issue in which the students are restricted in prioritising their knowledge, and thus fail to offer more solutions for the option undertaken. The poor detection power of quantitative method in identifying the level of understanding and demotivation parameters of revisiting the same instrument can lead to a more serious issue. Moreover, the students cannot reveal their new ideas and the whole phenomenon, because the selection of construct criteria is purposely created. The students in this study, however, reveal that the use of a PGO has helped them in visualising the knowledge for the option taken. The trigger of providing a better solution is also acknowledged because they can visualise the ideas of issues that precede decision.

Further, the students in this research could provide justifications for the solutions to the controversy associated with global warming. In other words, they provided "multiple sources" of alternative solutions as a way to address global warming crisis. For instance, they suggested that citizens would need to alter their mind, attitude, and lifestyle through the exposure to green technology and daily practices. Surprisingly, students were also able to discuss more than one previous issue as the sources of controversy beyond global context.

Evidence from this research gives support and details to similar research like using writing frames for the argumentation process (Choi et al., 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. It includes the means of avoiding mis-evaluation of evidence and inappropriate use of value-based reasoning. This research does not contradict (Choi & Meir, 2014) with the findings that fifth-grade students actively offer more evidence, support claims, and critique and negotiate evidence in making a decision about plant and human health investigation. They postulate that the use of the Science Writing Heuristic (SWH) approach, in an online environment, supports students' understanding. Dawson and Venville (2010) claim that the use of writing frames, which are equipped with guiding questions, plays a significant role in scaffolding students' thinking. Similarly, a PGO, which structures the decision-making framework, acts as a mental prompt for students to convey their knowledge, following the decision- making process. This is because the PGO signifies the enhancement of students' understanding, as they are able to offer a variety of information and connect the relationship between claim and evidence. Otherwise, the PGO offers students a way to identify new and untouched phenomena. Hence, it may provide a deeper understanding of the issues which arise.

In summary, the current research has unveiled merely the tip of the iceberg, that is, the PGO operates as a visualised and structured tool in enhancing students' understanding and decision-making skills. The PGO can be utilised as a mental prompt and visible guidance for promoting students' understanding (Choi et al., 2014), as well as an organiser, when making a decision (Dawson & Venville, 2010; Keys, 1997; Mastura & Rohaida, 2015; Ratcliffe, 1997). Further, the discrimination of students' understanding can be traced, as there are clear justifications provided to determine whether they possess a naïve or sophisticated understanding (Callahan, Zeidler, & Orasky, 2011). Also, the use of a one-time PGO employment can minimise the possibilities of decreased motivation among students and this leading to instability of understanding measures (Callahan et al., 2011).

Conclusions

The functionality of the PGO offers a synergy point for advanced extension, especially in promoting students' understanding in making a decision on a socioscientific issue. Considering these results, it can be concluded that the PGO is beneficial for promoting the didactic structure of students' understanding and decision-making skills, particularly for the global warming issue. The PGO is definitely not seen as a separate entity from the decision-making framework, as it provides the structure in the graphical organiser section. Relevantly, this research confers implications for future research in the methodological implication. These include strategies on how to promote students' understanding, overcome structural complexities and provide flexibility in students' decision-making process.

The PGO allows visible thinking amongst the students. Pertinently, the PGO that contains a graphical organiser allows 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. The messiness of 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. As shown in the findings, the PGO supports students to explain complex information, reduces cognitive loads and con-

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nects the information sources of global warming. The use of PGO as the visual instrument enables students to envisage the physical structure and relationship, and interpret the meaning of the structure when dealing with decision-making process and argumentation.

It is beyond the scope of this study to speculate whether there is knowledge progression or whether misconceptions emerge. The detection of misconceptions exhibited by the students, fallacious reasoning and multiple reasoning can also be explored. It is applicable due to the flexible direction of the PGO which need not be confined to specific questions, as detailed in the quantitative survey. Therefore, it may provide information that may sometimes be revealed by personal experience, which is also converted into numerical form. However, there may be limits to the extent to which the PGO is the only example presented in the context of a global warming scenario. This scenario is, however, "changeable" in nature, or can be replaced by other appropriate socioscientific scenarios and contexts. The familiarisation, change, and stability of the PGO's usability in identifying students' understanding can be explored over time in other localities and educational settings. This study has contributed to some indications for educators and curriculum developers in promoting students' understanding and decision-making skills, especially in the reflexion of socioscientific issues.

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