THE EFFECTIVENESS OF ICCWL IN REDUCING MISCONCEPTIONS AND SUPPORTING DECISION MAKING AND PROBLEM-SOLVING SKILLS OF FORM 2 STUDENTS

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by

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LIST OF ABBREVIATIONS

AAAS	American Association for the Advancement of Science
ANCOVA	Analysis of Covariance
AR	Acid Rain
AREPDiT	Atmosphere - Related Environmental Problems Diagnostic Test
CCSP	Climate Change Science Program
CFC	Chlorofluorocarbon
DMQ	Decision Making Questionnaire
GDMS	General Decision-Making Style
GHE	Greenhouse Effect
GW	Global Warming
HOTs	High Order Thinking Skills
IBM SPSS	IBM Statistical Package of Social Science
ICCWL	Interactive Climate Change Web Learning
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
MANCOVA	Multivariate Analysis of Covariance
MESTECC	Ministry of Energy, Science, Technology, Environment and Climate Change
NEP	National Education Philosophy
NPCC	New York City Panel on Climate Change
OLD	Ozone Layer Depletion
STEMS	Science, Technology and Environment in Modern Society
UNEP/UNFCCC	United Nations Convention Framework on Climate Change
UPSR	Ujian Penilaian Sekolah Rendah

LIST OF APPENDICES

KEBERKESANAN ICCWL DALAM MENGURANGKAN MISKONSEPSI DAN SOKONGAN MEMBUAT KEPUTUSAN DAN KEMAHIRAN PENYELESAIAN MASALAH DALAM KALANGAN PELAJAR TINGKATAN 2

ABSTRAK

Perubahan iklim adalah salah satu cabaran terbesar umat manusia pada abad ini. Terdapat keperluan mendesak untuk memupuk kesedaran dan pengetahuan perubahan iklim di kalangan orang muda untuk memelihara alam sekitar untuk generasi akan datang. Pendidikan adalah elemen penting dalam reaksi global terhadap perubahan iklim. Tujuan penyelidikan ini adalah untuk mengkaji kesan pembelajaran web interaktif perubahan iklim (ICCWL) bagi mengatasi miskonsepsi mengenai perubahan iklim terhadap Kesan Rumah Hijau, Pemanasan global, Hujan asid dan Penipisan lapisan Ozon serta meningkatkan keupayaan untuk membuat keputusan dan menyelesaikan masalah berkaitan perubahan iklim di kalangan pelajar Tingkatan Dua. Seramai 123 pelajar Tingkatan Dua dari sebuah sekolah pinggir bandar di Malaysia terlibat dalam kajian ini. Sekolah yang terlibat dikenal pasti secara rawak dari populasi 27 sekolah menengah di daerah Kulim. Pelajar-pelajar yang terlibat, dibahagikan secara rawak kepada kumpulan eksperimen dan kawalan. Kumpulan eksperimen terdiri daripada 63 orang pelajar; kumpulan kawalan terdiri daripada 60 orang pelajar. Kajian ini menggunakan kaedah reka bentuk gabungan intervensi dan kajian kualitatif. Kajian ini dijalankan pada tiga peringkat. Di peringkat pertama, temu bual telah dijalankan dengan pelajar-pelajar dan guru-guru dan diikuti dengan analisis dokumen untuk merekabentuk pembelajaran web

interaktif perubahan iklim (ICCWL). Pada peringkat kedua, kesan rawatan terhadap miskonsepsi dan keupayaan membuat keputusan telah dikaji. Untuk tujuan ini, Ujian Diagnostik Berkaitan Alam Sekitar (AREPDiT) dan Soal Selidik Membuat Keputusan (DMQ) telah diberikan semasa pra dan pasca rawatan. Pada peringkat ketiga, temu bual telah dijalankan untuk mendapatkan maklumat terperinci mengenai data kuantitatif terhadap miskonsepsi dan membuat keputusan yang diperolehi diperingkat kedua. Selain itu, pada peringkat ini, kemahiran menyelesaikan masalah pelajar juga dapat diterokai setelah menjalani rawatan melalui jawapan pelajar kepada ujian terbuka. Keputusan kuantitatif bagi kesan rawatan dianalisis dengan menggunakan MANCOVA. Analisis MANCOVA menunjukkan bahawa terdapat perbezaan yang signifikan dalam skor min AREPDiT antara kumpulan kawalan dan eksperimen ((F (1,604) = 361.855; p = 0.00) n2 = 0.751). Analisis univariat susulan menujukkan bahawa terdapat perubahan ketara antara skor min kumpulan kawalan dan eksperimen untuk kesemua empat subskala dalam miskonsepsi (kesan Rumah Kaca, Pemanasan global, hujan Asid, dan penipisan lapisan Ozon). Analisis MANCOVA juga menunjukkan bahawa terdapat perbezaan yang signifikan dalam kemampuan membuat keputusan antara skor min kumpulan kawalan dan eksperimen (F (5,116) = 203,97, p = 0,00 (p <0,05), n2 = 0,898). Analisis univariat susulan menunjukkan perubahan yang signifikan antara skor min kumpulan kawalan dan eksperimen untuk kesemua lima subskala membuat keputusan (Intuitive, Dependent, Rational, Avoidance, and Spontaneous.) Hasil temubual dan analisis dokumen dari tahap pertama menunjukkan bahawa pembelajaran web interaktif yang memberikan pengalaman di dunia nyata adalah tidak dapat dielakkan dalam memahami perubahan iklim. Tema yang muncul dari analisis tematik yang dilakukan terhadap temubual pelajar menunjukkan bahawa para pelajar dapat mengatasi miskonsepsi mereka dan

membuat keputusan berkaitan dengan perubahan iklim. Untuk kemampuan menyelesaikan masalah, keputusan ujian terbuka menunjukkan bahawa pelajar menunjukkan kebolehan menyelesaikan masalah secara analitis dan kritikal setelah menjalani rawatan. Keputusan kajian ini menunjukkan bahawa pembelajaran web interaktif perubahan iklim (ICCWL) adalah pendekatan yang sesuai digunakan untuk mengatasi miskonsepsi dan meningkatkan kebolehan membuat keputusan serta untuk mengajar kemahiran menyelesaikan masalah kepada pelajar Tingkatan Dua.

THE EFFECTIVENESS OF ICCWL IN REDUCING MISCONCEPTIONS AND SUPPORTING DECISION MAKING AND PROBLEM-SOLVING SKILLS OF FORM 2 STUDENTS.

ABSTRACT

Climate change is one of the biggest challenges of humankind in this century. There is an urgent need to foster climate change awareness and knowledge among young people to preserve the environment for the future generation. Education is an essential element of the global response to climate change. The purpose of this study is to measure the effect of interactive climate change web-based learning (ICCWL) in overcoming misconceptions about climate change on the Greenhouse effect (GHE), Global warming (GW), Acid rain (AR) and Ozone layer depletion (OLD), enhancing the ability to make decisions and to solve problems on climate change among Form Two students. A total of 123 Form Two students from a suburban school in Malaysia involved in this study. The participating was school randomly identified from the population of 27 secondary schools in Kulim district. The students were randomly assigned to experimental and control groups. The experimental group consisted of 63 students; the control group consisted of 60 students. The research used both intervention mixed-method design and qualitative methods. The study performed in three stages. In the first stage, interviews were conducted with students and teachers and followed by the document analysis to design the Interactive Climate Change Web Learning (ICCWL). In the second stage, the effects of the treatment on misconceptions and decision-making ability were measured. For this purpose, the Atmosphere Related Environmental Problem

Diagnostic Test (AREPDiT) and Decision-making Questionnaire (DMQ) were administered during pre and post-tests. In the third stage, interviews were conducted to gain insights into the quantitative data on misconceptions and decision making collected in the second stage. Additionally, students problem-solving skills following the treatment were explored at this stage from the responses to the open-ended test. The quantitative responses measuring the effects of the treatment were analysed using MANCOVA. The MANCOVA analysis showed significant differences in the AREPDiT mean scores between the control and experimental groups ((F (1,604) = 361.855; p = 0.00) n^2 = 0.751). The follow up univariate analysis revealed significant changes between the control and experimental groups' mean scores for all the four subscales that constitute misconceptions (Greenhouse effect, Global warming, Acid rain, and Ozone layer depletion). The MANCOVA analysis also showed significant differences in the decision-making ability between the control and experimental groups' mean scores (F (5,116) = 203.97, p = 0.00 (p < 0.05), n^2= 0.898). The follow up univariate analysis revealed significant changes between the control and experimental groups' mean scores for all the five subscales that constitute decision making (Intuitive, Dependent, Rational, Avoidance, and Spontaneous). The outcome of the interviews and documents analysis from the first stage implies that interactive learning that provides real-world experiences is inevitable in understanding climate change. The themes that emerged from the thematic analysis performed on the interview responses indicated that the students were able to overcome their misconceptions and make decisions related to climate change. For problem-solving ability, the open-ended test results indicated that students exhibited analytical and critical problem-solving abilities following the treatment. Findings from this study suggest that Interactive Climate Change Web Learning (ICCWL) is a viable

approach to be used to overcome misconceptions and improve decision-making and to teach the problem-solving skill to Form Two students.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Climate change becomes a widely debated topic around the world in recent years. It poses one of the most serious challenges to achieving sustainable development for the international community. Studies have indicated that climate change is inevitably underway; constant altering of the natural compositions by humans has been identified as the main factor (CCSP, 2008; Intergovernmental Panel on Climate Change [IPCC], 2007). More time and attention have been dedicated to identifying the root cause and finding solutions that do not produce more adverse consequences. Climate change has already changed the magnitude and frequency of extreme weather conditions around the globe. It has also caused a multitude of socioeconomic problems. These are affecting individuals, societies, and businesses at regional and global scales (CCSP, 2008) and undoubtedly will still be here for our children to tackle. Thus, there is an urgent need to develop awareness and knowledge to preserve the environment which is necessary to undertake these issues in the future among young people.

Education is an essential element of the global response to climate change. It helps young people understand the issue and promotes changes in their behavior. It is a powerful tool in shaping them to adapt to trends related to climate change. UNESCO through its Climate Change Education for Sustainable Development program poised to make climate change education an integral part of the international response to climate change. This program aims to increase "climate literacy" among young people through quality climate change education and

advocating innovative teaching approaches to integrate climate change education in schools.

In the 21st century, teaching and learning activities are vastly dominated by electronic media. In the last two decades, information and communication technology and web-based learning have become the main means of imparting knowledge and gathering information in education (Oliver, 2002). This has changed the students' learning behavior, helping to move from content-centered curricula to competency-based curricula. Due to the significant role of web-based learning in the educational context, it has been identified as an appropriate medium to educate issues of high importance that students may encounter in their daily lives such as climate change (Aina, 2013; Desai, 2010).

Nevertheless, climate change remains a misunderstood phenomenon despite its prominence in social and political discourses and its inclusion in various courses within environmental and geographic education (Pascua & Chang, 2015). Climate change is commonly perceived as related to certain environmental issues such as lead pollution, radioactive contamination, and acid precipitation. Misconceptions on the causes, processes, and impacts of climate change are prominent. This misconception hinders efforts to improve climate literacy (Dupigny-Giroux, 2010).

Problem-solving and decision making are integral parts of climate change literacy. Problem-solving and decision-making competencies provide the ability to young people to systematically evaluate possible courses of action in an ethically complex situation like climate change and systematically make a final decision and solve the problem (Helge Gresch, Hasselhorn, & Bögeholz, 2013). Owing to the popularity of computer and communication technologies, studies have shown that

students' problem-solving and decision-making abilities can be fostered by conducting learning activities on the web (O'Brien & Leichenko, 2000). Due to this nature, interactive web-based learning will be a viable platform to deliver knowledge on global issues like climate change that commensurate with our daily lives.

In the face of globalization, the primary goal of the Malaysian Ministry of Education is to ensure the education system of this country is transformed to meet the demands and challenges of the 21st century. In this competitive world, youth requires many sets of special skills to succeed in work and life. Effective teaching and learning need an effective delivery system. As such in this study, the attempt was made to introduce Interactive Climate Change web learning (ICCWL) into teaching and learning of lower secondary science subject. This web-based learning method is specifically introduced in the climate change lesson. This will replace the existing conventional method of delivering the climate change lesson. Subsequently, the effect of this new teaching method in reducing the students' misconceptions about climate change and improvement in their problem solving and decision-making abilities were measured.

1.2 Background of the Study

The drastic changes in the environment, including an increase in the average global and ocean temperature and the sea level due to the melting of icebergs at the Artic, are some evidence indicating climate change is happening (Intergovernmental Panel on Climate Change [IPCC] (2007). United Nations Convention Framework on Climate Change [UNEP/UNFCCC] (2002) has indicated that human activities are the main contributor to the Greenhouse effect that resulted in global warming over the last 50 years. With the increase in global warming the possibilities for the ecosystem

to naturally adapt to the adverse effect of global warming are thinning (Council, 2010).

One way to impart the knowledge of conserving the environment to secure a better future is through education (Kisoglu, Gürbüz, Erkol, Akar, & Akilli, 2010). Children should be educated from an early age on the importance of leading a sustainable lifestyle. Education plays an important role in creating this awareness. Early education on the importance of a sustainable world is the most effective way to reduce human insensitivity towards the environment. Children should be trained to protect mother nature as they are the future leaders (Bradley, Waliczek, & Zajicek, 1999).

The issue of climate change has been integrated to a certain extent into the teaching and learning of science globally. For example, Kisoglu et al. (2010) highlighted that, after recording and predicting the effects of global warming, the interest in educating school children about the problem has increased all over the world. Educational programs are vital tools to deal with global warming and to inform students about its causes and consequences. Taber and Taylor (2009) conceded that global warming has become an issue for discussion in science classrooms in many parts of the world. This shows that many countries have begun to include global warming in their school curricula.

In the Malaysian context, climate change is being taught in Form Two science lessons for the last few years. The issue of climate change has been integrated into the chapter on *the Ecosystem* (Curriculum Development Center, 2016). Currently, climate change lesson is limited to the "*roles of human in maintaining a balanced nature"*. While teaching the topic, teachers will expose the

students to human activities that endanger the ecosystem and the consequences of these activities such as soil erosion, flash floods, landslides, eutrophication, pollution, global warming, ozone depletion, climate changes and loss of biodiversity. The issues of the Greenhouse effect and the thinning of the ozone layer are also part of the discussion.

Past studies have shown that using effective teaching methods is imperative for the students to benefit from the curriculum and to avoid the students from developing misconceptions (Aydin, 2012; Metın, 2011; Treagust et al., 2011). Various teaching models such as the conceptual change model and the 5E model were used by these researchers in addressing the misconception among the students. As for the misconceptions about climate change (Greenhouse effect, Global warming, Ozone layer depletion, and Acid rain) several studies have highlighted that, ineffective methods employed by the teachers have reinforced the misconceptions among the students (Chang & Pascua, 2016; Heng, Mageswary Karpudewan & Kasturi Chandrakesan, 2017). Mageswary Karpudewan, Roth, and Chandrakesan (2015) in a study with 73 form four students identified their misconceptions about Global warming, the Greenhouse effect, Ozone layer and Acid rain. Similarly in another study Mageswary Karpudewan et al. (2015) identified misconceptions among primary school students. The researchers highlighted that misconceptions persist because there is no initiative undertaken to rectify the problem among Malaysian students. In a different study Arslan, Cigdemoglu, and Moseley (2012) have stressed that it is necessary to employ an effective teaching approach to deliver the knowledge about climate change that has been included in the curriculum.

To address the students' misconceptions about climate change it is quite impossible to simply use rhetorical format to present the contents in curriculum specification or textbook. In a related study, Thacker and Sinatra (2019) have successfully conducted a study using a guided online simulation. The purpose of their study was to better understand and enable the students to construct visual representations of the Greenhouse effect from their perceptual experiences.

Several other studies have reported that active participation and involvement of the students during the lesson are required for them to truly understand the climate change phenomena (Mageswary Karpudewan et al., 2015; Lambert, Lindgren, & Bleicher, 2012; Porter, Weaver, & Raptis, 2012). As it is quite impossible to bring the climate change milieu into the real classroom setting, utilization of an interactive learning environment would be an alternative to compensate for the real-world setting.

Teaching about climate change using interactive web learning instruction also would be timely and highly relevant with the 21st-century scenario which emphasizes good problem-solving and decision-making skills. The problem-solving skill has been used as a term encompassing activities requiring critical and analytical thinking as well as the ability to transfer learning to other situations (Kretchmar, 2008). Analytical thinking is related to the students thinking style that enables them to break down complex information and use a step-by-step method to analyze a problem and then come to a solution. Whereas, in critical thinking, the students were expected to evaluate the information and require them to explore possible solutions by looking at alternatives and checking out different points of view.

Several studies conducted on Malaysian students' problem-solving skills highlighted the poor mastery of this essential skill (Ngang, Nair, & Prachak, 2014; Hussain Othman, Berhannudin Mohd Salleh, Syed Muhammad Dawilah al-Edrus Syed Abdullah, & Abdullah Sulaiman, 2008). According to Hussain Othman et al. (2008), students' learning context is one of the factors that contributes to generic skills deficiency, particularly toward critical thinking and problem-solving skills. For example, the teaching and learning process in the classroom which emphasizes rote learning and too focused on the content caused the students to memorize the knowledge learned, rather than analyze and synthesize the exact meaning of the knowledge. Since they do not have a deep understanding regarding the knowledge learned, it leads to reduced ability to think critically and analytically as well as to solve complicated problems (Roselina Shakir, 2009).

Climate change would be best delivered through an interactive learning platform as it provides an opportunity for the students to view the issue from different perspectives. By applying Interactive Climate Change Web Learning (ICCWL), teaching can be done practically anywhere and anytime. Students will learn new information easily if learning is fun, dynamic, and interactive and if it includes different media, especially, a computer. It is also as much helps them to prepare for lifelong independent learning.

Decision-making and problem-solving skills taught in environmental education would help students to become better environmental decision-makers (Arvai, Campbell, Baird, & Rivers, 2010). However various perspectives can influence an individual's opinion in deciding environmental issues. These include the depth of knowledge about the issue; emotional connection with the issues; ethics and arguments that the individual has built about the issue (Halverson, Siegel, &

Freyermuth, 2009). The General Decision-making Style introduced by Scott and Bruce (1995) has identified five decision making styles namely intuitive, rational, dependent, avoidant and spontaneous. These decision-making styles are the learned habitual response pattern exhibited by an individual when confronted with a decision situation (Scott & Bruce, 1995). Several studies have reported the lack of problem-solving and decision-making skills among Malaysian students at various levels (Ahmad Azmi M. Ariffin, Azhar Ahmad, Mohd Suhaimi Ahmad & Mohd Adib Ibrahim., 2008; Mageswary Karpudewan, & Nur Sabrina Mohd Ali Khan, 2017b; Mokhlis, 2009). However, there is no specific study conducted on Malaysian students' decision-making on climate change. These researchers pointed that the existing teaching and learning process in the classroom which emphasizes rote learning resulted in the lack of problem-solving and decision-making skills among the students in general. With these previous findings, it could also be postulated that students' decision-making about climate change is poor (Ahmad Azmi M. Ariffin et al., 2008; Mageswary Karpudewan, & Nur Sabrina Mohd Ali Khan, 2017b; Mokhlis, 2009).

Socio-scientific issues like climate change if imparted using an effective pedagogical approach, (e.g. ICT, computer, web-based platforms) will foster students' decision-making competency (Helge Gresch et al., 2013). Decision-making is pre-requite in education for sustainable development and students' decision-making competency can be enhanced using an ICT or web-based intervention approach (Helge Gresch, Hasselhorn, & Bögeholz, 2017).

1.3 Problem Statement

In making the science content contemporary, various real-life issues have been included in the teaching and learning of science in Malaysian schools. This includes issues on climate change. However, the inclusion is limited to the "role of the human in maintaining a balanced nature" in the Form Two science syllabus (Curriculum Development Center, 2016). Despite being ranked as one of the most contemporary issues that have adversely affected the world, climate change was not given special attention in the syllabus (Eames, Hunter, & Vaioleti, 2020; Heng et al., 2017; Mageswary Karpudewan, & Nur Sabrina Mohd Ali Khan, 2017a).

In responding to the incremental importance and numerous calls from the prominent global organization such as UNESCO and UNEP many countries have taken initiatives to implement climate change education including Malaysian. However, the current way of teaching and learning about climate emphasis mastering the concepts to answer the exam questions (Mageswary Karpudewan, & Nur Sabrina Mohd Ali Khan, 2017a; Mageswary Karpudewan et al., 2015a). This way of teaching created adverse effect on developing pro-environmental behaviors toward protecting the climate (Mageswary Karpudewan, & Nur Sabrina Mohd Ali Khan, 2017a; Yusliza et al., 2020). The poor behavior is informed by inappropriate knowledge or misconception (Mageswary Karpudewan et al., 2015; Mageswary Karpudewan, Ahmad Nurulazam Md Zain, & Chandrasegaran, 2017); poor decision making (Eggert & Bögeholz, 2010; Helge Gresch et al., 2013, 2017) and problem-solving skills (Karyotaki & Drigas, 2016; Surif, Ibrahim, & Mokhtar, 2012; K.-C. Yu, Fan, & Lin, 2015; Zakaria & Ngah, 2011).

Misconceptions about climate change is prevalent among school going students globally also this is a concern among Malaysian students. Mageswary Karpudewan et al. (2015) in a study involving secondary level students explicitly mentioned Malaysian secondary level students hold misconceptions about global warming, greenhouse effects, ozone layer depletion and acid rain. The students unable to differentiate the underlying causes of global warming (Mageswary Karpudewan et al., 2015). Parallel to what Chang, Pascua, and Ess (2017) have said Malaysian students were of the opinion global warming causes skin cancer, carbon dioxide is the main contributing factor towards these environmental problems, the ozone layer helps to keep the earth warm and acid rain occurs because of the Ozone layer depletion or the Greenhouse effect. The findings of the another study conducted by Karpudewan et al. (2017) in later years with another group of secondary level students further heighten the fact that Malaysian secondary students developed concrete misconception about the four phenomena of climate change. Both studies provided explicit evidence that the misconception results from ineffective teaching that takes place is schools. Several other studies by established scholars such as (Chang & Pascua, 2016; Chang et al., 2017; Pascua & Chang, 2015); informs Mageswary Karpudewan et al. (2015) and Heng et al. (2017) in postulating an effective teaching is required to address those misconceptions.

Decision making and problem solving skills are instrumental skills that guide students in making informed decision concerning climate change (Steffensen, 2020) and educate students with possible means to solve problem that climate change possibly acerbated (Eames et al., 2020; Harker-Schuch, Lade, Mills, & Colvin, 2020). Many available studies documented students' ability to make decision and solving problem on various other environmental issues (Bavolar & Orosová, 2015;

Eggert, Ostermeyer, Hasselhorn, & Bögeholz, 2013b; Garrecht, Eckhardt, Höffler, & Harms, 2020; Helge Gresch et al., 2013, 2017; Kretzschmar & Süß, 2015; Middleton, 2009; Ngang et al., 2014). However, studies specifically reporting decision making ability and solving problem concerning climate change issues is not found to the authors' knowledge. Science education research have reported otherwise outcomes such as researchers using climate change issues to inculcate argumentation skills (Carson & Dawson, 2016); knowledge on climate change was used as enabler to solve climate related problem (Richter-Beuschel & Bögeholz, 2019). However, no studies were found using climate change teaching per se as an approach to improve problem solving and decision making skills. This study attempted to bridge the gap. Several studies while investigating high-order thinking skills identified Malaysian secondary level students' problem solving (Hadi, Retnawati, Munadi, Apino, & Wulandari, 2018; Yusliza et al., 2020) and decision making abilities are substantially poor (Jan & Ammari, 2016). The poor skills impose that the possibilities for students having poor decision making and problem solving abilities in regards to climate change.

Since teaching and learning approach has been identified as the profound reasons for students developing misconceptions, and for having poor decision making and problem solving abilities, attempts have been made to transform the current teacher centered to more student centered teaching and learning using varied approaches (Heng et al., 2017; Mageswary Karpudewan & Nur Sabrina Mohd Ali Khan, 2017b; Mageswary Karpudewan et al., 2015a; Mageswary Karpudewan et al., 2015b; Mageswary Karpudewan et al., 2017; Steffensen, 2020). Despite introducing the student centered approaches misconceptions, decision making and problem solving abilities prevail. Studies pointed out that the newly introduce student

centered approaches hindered student from visualizing and experiencing the climate change phenomena for real (Chang & Pascua, 2016; Chang et al., 2017; Eames et al., 2020; Gkotzos, 2017; Heng et al., 2017; Mageswary Karpudewan & Nur Sabrina Mohd Ali Khan, 2017b; Mahaffy, Martin, Schwalfenberg, Vandenbrink, & Eymundson, 2013; Papadimitriou, 2004; Pascua & Chang, 2015; Thacker & Sinatra, 2019). Computer based simulation that allows interactive learning evidence supports learning real world issues such as climate change (Martin & Mahaffy, 2011). Despite computer simulation and online interactive learning evident useful in teaching and learning about climate change, to date every few studies have actually suggested such kind of learning. Particularly, in Malaysia teaching and learning about climate change among secondary school students predominately performed using chalk and talk method (Mageswary Karpudewan et al., 2015a). To the authors knowledge no such interactive web-based learning specifically to teach climate change for local students is available.

1.4 Purpose of the Study

The purpose of this study is to measure the effectiveness of interactive climate change web learning (ICCWL) to reduce misconceptions and to improve decision making and problem-solving abilities on issues concerning climate change among Form Two students.

1.5 Objectives of the Study

1. a) To explore the students' and teachers' views on teaching methods used to teach climate change and the content covered during the lesson on climate change.

b) To identify the content on climate change covered in the textbook and document Standard Curriculum (DSK).

2. To design Interactive Climate Change Web Learning (ICCWL) based on the feedback gathered from the students' and teachers' views from objective 1a and 1b.

3. (a) To evaluate the effect of interactive climate change web learning (ICCWL) in reducing the misconceptions about climate change.

   i. To evaluate the effect of ICCWL in reducing misconceptions about the Greenhouse effect.

   ii. To evaluate the effect of ICCWL in reducing misconceptions about Global warming.

   iii. To evaluate the effect of ICCWL in reducing misconceptions about Ozone layer depletion.

   iv. To evaluate the effect of ICCWL in reducing misconceptions about Acid rain.

   (b) To explore if the students' misconceptions differ before and after the ICCWL.

4. (a) To evaluate the effect of interactive climate change web learning on the students' ability to make the decision on climate change.

   i. To evaluate the effect of interactive climate change education on the students' intuitive decision making on climate change

   ii. To evaluate the effect of interactive climate change education on the students' dependent decision making on climate change

iii. To evaluate the effect of interactive climate change education on the students' rational decision making on climate change

iv. To evaluate the effect of interactive climate change education on the students' avoidance decision making on climate change

v. To evaluate the effect of interactive climate change education on the students' spontaneous decision making on climate change

(b) To explore if the students' decision-making ability on climate change changes with the ICCWL.

5. (a) To explore the changes in the students' analytical problem-solving ability on climate change issues.

(b) To explore the changes in the students' critical problem-solving ability on climate change issues.

1.6 Research Questions

1. a) How the teachers and Form 2 students perceive the existing teaching method and the content on climate change?

b) What are the contents covered in the textbook and document standard curriculum (DSK) on climate change?

2. a) Is there any significant difference in the linear combination of post-test misconceptions mean scores between control and experimental groups after controlling the pre-test scores?

i. Is there any statistically significant difference between the control and experimental groups' Greenhouse effect post-test mean scores after controlling the pre-test scores?

ii. Is there any statistically significant difference between the control and

experimental groups' Global warming post-test mean scores after controlling the pre-test scores?

iii. Is there any statistically significant difference between the control and experimental groups' Ozone layer depletion post-test mean scores after controlling the pre-test scores?

iv. Is there any statistically significant difference between the control and experimental groups' Acid rain post-test mean scores after controlling the pre-test scores?

b) How students' misconceptions about climate change differ before and after the ICCWL?

3. a) Is there any statistically significant difference in the linear combination of decision-making post-test mean scores between control and experimental groups after controlling the pre-test scores?

i. Is there any statistically significant difference between the control and experimental groups' Intuitive post-test mean scores after controlling the pre-test scores?

ii. Is there any statistically significant difference between the control and experimental groups' Dependent post-test mean scores after controlling the pre-test scores?

iii. Is there any statistically significant difference between the control and experimental groups' Rational post-test mean scores after controlling the pre-test scores?

iv. Is there any statistically significant difference between the control and experimental groups' Avoidant post-test mean scores after controlling the pre-test scores?

v. Is there any statistically significant difference between the control and experimental groups' Spontaneous post-test mean scores after controlling the pre-test scores?

b) How students' decision-making ability on climate change changes with the ICCWL?

4. a) How the student's analytical problem-solving ability changes with the ICCWL?

b) How the student's critical problem-solving ability changes with the ICCWL?

1.7 Hypotheses

Based on the research questions, the following hypotheses were formulated.

$H_0$1: There is no significant difference in the linear combination of misconceptions post-test mean scores between the control and experimental groups after controlling the pre-test mean scores.

$H_0$1a: There is no significant difference between the control and experimental groups' Greenhouse effect post-test mean scores after controlling the pre-test scores.

$H_0$1b: There is no significant difference between the control and experimental groups' Global warming post-test mean scores after controlling the pre-test scores.

$H_0$1c: There is no significant difference between the control and experimental groups' Ozone layer depletion post-test mean scores after controlling the pre-test scores.

$H_0$1d: There is no significant difference between the control and experimental groups' Acid rain post-test mean scores after controlling the pre-test scores.

$H_0$2: There is no significant difference in the linear combination of decision-making post-test mean scores between the experimental and control groups after controlling the pre-test scores.

$H_0$2a: There is no significant difference between the control and experimental groups' intuitive post-test mean scores after controlling the pre-test scores.

$H_0$2b: There is no significant difference between the control and experimental groups' dependent post-test mean scores after controlling the pre-test scores.

$H_0$2c: There is no significant difference between the control and experimental groups' rational post-test mean scores after controlling the pre-test scores.

$H_0$2d: There is no significant difference between the control and experimental groups' avoidant post-test mean scores after controlling the pre-test scores.

$H_0$2e: There is no significant difference between the control and experimental groups' spontaneous post-test mean scores after controlling the pre-test scores.

1.8 Significance of the Study

Climate change is a widely debated issue around the world now. Climate change does not happen naturally but a consequence of human activities that are not friendly to the environment (Yakob, Ismail, & Razak, 2012). Educating students about the effects of climate change will help in creating awareness and preserve mother nature for our future generation.

The ICCWL and findings obtained through this study will be resourceful for the curriculum planners and policy-makers. Through the ICCWL, students were able to participate in a more student-centered and independent learning approach which is a preferred learning method in the 21st century. The results would make the stakeholders of science education to be more aware of the misconceptions of the students and taking steps to promote teaching strategies to help the students to overcome misconceptions on climate change.

For instance, as reported in our previous studies, GW is one of the prominent issues that students found difficult to understand (Mageswary Karpudewan & Nur Sabrina Mohd Ali Khan, 2017b; Mageswary Karpudewan et al., 2015a; Mageswary Karpudewan et al. , 2015b). The ICCWL tool used in this study allows the students to picture the GW and at the same time enables them to manage correctly the understanding, parallel to the scientific definition.

Decisions making about socio-scientific issues such as climate change are tightly linked to social, political, and economical concerns. Climate change decision making is complex and involves real-world scenarios at the interplay between science and society and thus can no longer be solved by relying on scientific knowledge only (Eggert, Ostermeyer, Hasselhorn, & Bögeholz, 2013a). The

implementation of climate change lessons into science classrooms also will enhance students' learning outcomes concerning conceptual scientific knowledge as well as decision-making skills (Grace, 2009; Ratcliffe & Grace, 2003). With the ICCWL intervention reported in this, the students were able to make their decisions related to climate change because they overcame their misconceptions and obtained the correct information after using the ICCWL tool.

The development of problem-solving skills in real-world situations is of interest to many professions and the public in general, especially when addressing environmental issues such as climate change (Holder, Scherer, & Herbert, 2017; National Academies of Sciences & Medicine, 2017). Steiner and Laws (2006) suggest that students should be able to theorize complex topics, solve simple and complex real-world problems, and use these skills early in their careers. In this study, a systematic problem-solving approach through ICCWL was introduced. This improved the students' problem-solving ability in a classroom environment on a global issue such as climate change. It is also necessary to facilitate students' problem-solving abilities to adapt to a future society through training concerning information retrieval and reorganization processes. That is, students would enhance their problem-solving abilities via the thinking processes of knowledge organization and reasoning (Goldstein & Levin, 1987; Mayer, 1992).

This study is also significant to science education researchers as they may find teaching methods and techniques used in this study to be helpful in their work. It also may be significant to teachers, teacher educators, and textbook writers as the study probed students' prior knowledge on climate change and how the conceptual change occurs after formal instruction and what misconceptions they still hold. It is also important to find effective methods for teaching and learning science and

hopefully, those methods will be developed and applied in some other areas in science education to improve the results of secondary school students learning and understanding of science.

In terms of the methodology of the study, the mixed-method approach used in this study will provide some insights to other researchers to apply the quantitative and qualitative strategies of data collection and analysis (Creswell, 2015) to come up with a more meaningful study.

1.9 Limitation of the Study

The study was conducted in a suburban school in the northern part of Peninsula Malaysia. The school is a sport excellence school with a good blend of students from nearby urban area. The present study focused on form two students (ages between 13 and 14). As such the findings may not apply to older students beyond this age group or younger students at the primary school level. As such in improving the generalization of the findings to different levels of students and schools in different areas it is suggested to replicate the study at various levels. Since the suggested treatment applies to all Malaysian lower secondary school contexts and globally the content covered is also relevant to students between 13 and 14 years, replicating the study in different schools is highly possible.

Due to the nature of this setting, the intact group selection method was used during the sampling period. Intact group sampling reduces disruptions to the sample. However, to have better control of the external variables and to improve the internal validity, it is advisable to include more schools and more students with diverse backgrounds (Price & Murnan, 2004) to yield the same result. As such it is

recommended for the study to be performed in different school settings to have better control of threats to the findings.

Five weeks were taken to conduct the treatment (week 3 to week 7). Having the treatment for a longer period is advisable because students will need time to get familiarized with the ICCWL tool before they can get exposed to the climate change lessons in it. However, since the intervention has to be conducted within the allocated time for climate change topic in the form two science subject the treatment was planned to be executed in the given 5 weeks' time. Nevertheless, the five weeks treatment time used in this study is within the recommended time of three to six weeks (Brown, Irving, & Keegan, 2008).

One of the limitations of implementing ICCWL in school is the availability of sufficient personal computers or laptops. At times 2 students need to share a computer. Sharing computers in the lab will limit the time given to each student to explore the content for better understanding. This problem was highlighter to the school headmaster. The school acknowledged the need for learning hardware such as desktop or notebook computers for ICT learning in the future. However, as an interim solution, the arrangement was made with From 2 teachers to allow the students to occupy time from the subsequent lesson period to complete their ICCWL session. This arrangement was made for the duration of the treatment.

As ICCWL learning is student-centric, it needs to be done by the students' on their own (solo act). Especially in a sub-urban and rural setting, not all the students have prior experience with interactive tool. As such it will not be easy for all of the students to become well versed when using web learning for the first time. They need guidance from their teachers or instructors. Furthermore, some students need

personal assistance to learn. For this, 2 lab assistants were provided to assist the teachers during the initial stage of ICCWL. The lab technicians will help the students when they have a problem accessing the web tool. Once the students are familiar with the web tool, they can operate it on their own.

In suburban schools (where this study was conducted), in addition to the limited internet coverage, technological barriers, such as limited bandwidth, are issues in learning using web-based tools (Chadha & Nafay, 2003). A similar problem was faced in the course of intervention using ICCWL in this research. When the interactive elements take longer to respond the students tend to lose interest in continuing their exploration using the tool. To overcome this, network boosters were installed at the computer labs. As interactive multimedia needs high speed and wider bandwidth to operate, the network boosters were needed to solve the connectivity problem.

ICCWL is a student-centered learning method, students' with no exposure to this type of learning may feel isolated in the beginning as they have to complete the task on their own. To overcome this, close follow up on the students' progress during the initial stage is recommended. This works for different types of students as well, as some students still prefer their progress to be closely monitored by their teachers.

1.10 Operational definition of terms

Climate change

Climate change appears to be a fact or at least an observable process. Incidents that reflect on climate change include the increase of the average global air

and ocean temperature, the melting of ice, and the rise of the average sea level worldwide (Intergovernmental Panel on Climate Change [IPCC], 2007). Climate change also includes major changes in temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer (USEPA, 2012). Global warming, greenhouse gas effects, Ozone layer depletion, and Acid rain are phenomena that denote climate change. These phenomena were used to present climate change in this study.

Misconceptions on Climate Change

The term misconception is used when referring to students' incompatible ideas with scientific views (Mageswary Karpudewan et al., 2015a; Treagust, 1988). Misconception on climate change happens when students understood climate change differently from how scientists describe it (Chang & Pascua, 2016; Mageswary Karpudewan et al., 2015a). In this study, students with misconceptions about climate change were identified if the students' understanding of the four phenomena that denote climate change appeared incompatible with the scientifically accepted idea. Misconceptions on climate change in this study constitute the misconceptions on Greenhouse effect, Global warming, Ozone Layer Depletion, and Acid Rain.

Misconception on Global Warming

Global warming is the process where atmospheric layers and solid earth temperature rise artificially as a result of the increase in "greenhouse gases" due to human activities (Aydin, 2010). Misconception on GW in this study refers to the incorrect understanding of GW based on Aydin (2010) descriptions. The incorrect understanding includes GW will cause skin cancer, GW can be reduced by setting

limitations on chemical waste released into rivers, GW is the reason for the sudden rise in earth temperature and flood.

Misconception on Greenhouse effect

The Greenhouse effect is defined as the consequence of short wave radiation from the sunshine that after striking the earth's surface, is reflected by greenhouse gases to earth's surface as longwave radiations (Orbay, Cansaran, & Kalkan, 2009). Students misunderstanding about the Greenhouse effect was considered happening when they view GHE differently from what was suggested by Orbay et al. (2009). In this study, some of the incorrect understandings presented are; GHE is not a natural phenomenon, Carbon dioxide (CO2) is the only gas that increases GHE and GHE is a harmful phenomenon for mankind.

Misconception on Acid rain

Acid rain is the term given to increased acidity of rain due to the effects of toxic gases from industrial and natural sources. Acid rain forms when toxic gases (primarily carbon dioxide, sulphur dioxide, and nitrogen oxides) come in contact with water in the atmosphere or on the ground and are chemically converted to acidic substances (Mehta, 2010). In this study, the misconception on Acid rain refers to students' incorrect understanding of AR from what Mehta (2010) described. The incorrect understanding of AR presented in this study are; AR is the reason for Global warming, AR helps some plants and animals to survive and AR can burn everything that it comes in contact with.

Misconception on Ozone layer depletion

Ozone layer depletion is a gradual thinning of the earth's ozone layer in the upper atmosphere caused by the release of chemical compounds containing gaseous chlorine or bromine from industry and other human activities (Chang & Pascua, 2016; Ravishankara, 2015). In this study, the misconception on OLD refers to the incorrect understanding of OLD from what Chang and Pascua (2016) described. Some of the misconceptions on OLD presented in this study are; OLD is caused by excessive oxygen and carbon dioxide in the atmosphere, OLD becoming worse due to Acid rain, and OLD causes an increase in the number of floods.

Decision making on Climate Change

Decision-making refers to the ability to systematically evaluate possible courses of action in factually and ethically complex situations related to sustainable development and systematically make a final decision (Gresch & Bögeholz, 2013). In the context of climate change, decision making involves systematically evaluating the complex nature of climate change in making an informed decision. The systematic evaluation and informal decision making are presented as Intuitive, Rational, Dependent, Avoidance, and Spontaneous decision-making styles. (Scott & Bruce, 1995).

Intuitive Decision Making

Intuitive decision making is characterized by the attention in the flow of information and processing the information by relying on the feelings (Scott & Bruce, 1995; Thunholm, 2004). In this study Intuitive decision-making style is determined when the students tend to rely on their intuition or inner feelings when