

College Students' Understanding of Chemical Compounds, Sources of Information, and Risk Perceptions Regarding Environmental Sustainability Issues

Show-Yu Lin

Department of Natural Sciences, Center for General Education, Aletheia University

Email: au4329@mail.au.edu.tw

Abstract—This study explored Taiwanese college students' understanding of chemical compounds, information sources, and risk perceptions regarding environmental sustainability (ES) issues in Taiwan. A total of 51 participants completed three instruments addressing their understanding of chemical compounds on ES issues, information sources on ES issues, and risk perceptions regarding ES issues. The data analysis comprised descriptive statistics. There were three main findings of the study. First, in relation to chemical compounds, all the participants (100%) agreed with the scientific belief that CO₂ affects global warming (GW), 62.75% of the participants were aware that CFCs cause ozone layer depletion, and 52.94% and 56% of the participants, respectively, understood that CO₂ and SO₂ contributed to acid rain. Second, the main sources of information on the three ES issues were teachers (88.24%) in the people category, textbooks (73.86%) in the paper document category, the internet (59.48%) in the electronic document category, and speech (22.22%) in the activity category. Third, the participants' risk perceptions of issues relating to the three ES dimensions of environmental pollution, natural disasters, and resources and ecology were GW, mud flow and landslides, and alien species; by contrast, tsunamis, desertification, and sandstorms were perceived as having the lowest risk. Suggestions for future work include developing effective strategies to improve understanding on ES issues; enhancing environmental, chemical, and scientific literacy regarding the information sourced from teachers, textbooks, newspapers, the internet, TV, teaching, and extracurricular reading; and responding to people's risk perceptions regarding ES issues in terms of how these relate to local societies and culture.

Index Terms—chemical compounds, conceptions, environmental sustainability issues, risk perceptions, understandings

I. INTRODUCTION

Environmental Sustainability (ES) issues are crucial topics in both domestic and international news and are relevant to environmental, chemical, and science education. These issues have become increasingly

important in people's daily lives and represent urgent problems, now and in the future. Authorities need to know how to maintain the living environment and sustain the Earth to ensure quality of living [1]. Three ES issues, Global Warming (GW), Ozone Layer Depletion (OLD), and Acid Rain (AR), are particularly concerning because they have many local or global environmental impacts [2]. Information sources are essential for obtaining both scientific and alternative conceptions of these issues, formally and informally. These issues can be divided into four categories: People (P), Paper Documents (PD), Electronic Documents (ED), and activities (A) [3], [4]. Most environmental impacts relate to three specific dimensions: Environmental Pollution (EP), Natural Disasters (NDs), and Resources and Ecology (RE). This study aims to explore people's understanding of chemical compounds regarding GW, OZD, and AR; sources of information from P, PD, ED, and A; and risk perceptions regarding three ES dimensions, EP, ND, and RE. This study contributes to knowledge on sustainable development in each country [5] to help ensure the environmental sustainability of the Earth. Furthermore, environmental, chemical, and science literacy have become a general goal for school education for children of all ages. Information sources enhance people's understanding of ES issues, and authorities need to respond effectively to address people's risk perceptions regarding these issues.

II. RESEARCH DESIGN

For this study, 51 non-science major undergraduates were recruited as representative of the public. Three questionnaires were administered and completed: "understandings of chemical compounds on ES issues", "information sources on ES issues", and "risk perceptions on ES issues". These aimed to assess participants' understanding of chemical compounds in relation to GW, OLD, and AR issues; their sources of information on GW, OLD, and AR; and their risk perceptions regarding EP, ND, and RE dimensions of ES issues. First, the instrument entitled "understandings of chemical compounds on ES issues" contained items on 14

Manuscript received February 11, 2018; revised May 15, 2018.

chemical compounds that were either scientific concepts or nonscientific concepts. In terms of scientific concepts, the greenhouse gases (GHG) for GW were CO_2 , H_2O , CH_4 , CFCs, O_3 , and N_2O ; the OLD gases were CFCs, and the AR gases were CO_2 , SO_2 , NO_2 , CO , and NO . Additionally, confusing chemical compounds, such as H_2 , N_2 , N_2O , O_2 , and H_2O_2 , were included as nonscientific concepts. Second, the instrument entitled “information sources of ES issues” contained four categories: P, PD, ED, and A. P included parents, relatives, teachers, classmates, friends, and doctors/nurses; PD included textbooks, newspapers, magazines, extracurricular readings, handbooks, posters, clothes, flyers, slogans on cars, and teaching; ED included TV, broadcast, internet, electronic signs, and advertisements before movies; and A included speech, forum, concerts, exhibition, and summer camp activities. Third, the instrument entitled “risk perceptions on ES issues” was structured around three ES dimensions: EP, ND, and RE. The EP dimension included GW, water pollution, air pollution, stratum subsidence, soil pollution, noise pollution, OLD, AR, and the heat island effect; the ND dimension included mud flow and landslides, typhoons, earthquakes, sandstorms, desertification, and tsunamis; and the RE dimension included alien species, natural resources, and ecosystems. The three instruments were drawn from official reports, textbooks, and research and were validated by 7 college teachers who have provided instruction on these topics for more than 10 years. Furthermore, content and additional validation were provided by senior experts, and the readability of the content was verified by college students. All the participants were provided 30 minutes to complete the three instruments. They chose answers to each item that reflected their understanding of chemical compounds and indicated the sources of information they used for all three ES issues. Upon completion, their responses were counted and transformed into a frequency ratio. For risk perceptions, the instrument included 5-point Likert scales addressing 18 ES issues. A higher score indicates higher risk perceptions, and a lower score indicated lower risk perceptions. Finally, the data were analyzed using descriptive quantitative analysis.

III. RESULTS AND DISCUSSION

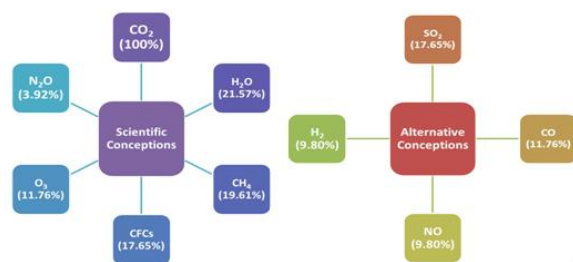
A. Conceptions of Chemical Compounds in Three ES Issues

Fig. 1 shows the participants’ understanding of chemical compounds in relation to three ES issues: GW, OLD, and AR. The scientific conceptions they held were as follows: GW was caused by CO_2 (100% of participants), H_2O (21.57%), CH_4 (19.61%), CFCs (17.65%), O_3 (11.76%), and N_2O (3.92%); OLD was caused by CFCs (62.75%); and AR was caused by CO_2 (52.94%), SO_2 (45.10%), CO (7.84%), NO_2 (7.84%), and NO (3.92%). However, some participants held alternative conceptions of GW, OLD, and AR. The top four alternative conceptions of the causes of GW were SO_2 (17.65%), CO (11.76%), NO (9.80%), and H_2 (9.80%); the top four alternative conceptions of the cause of OLD were CO_2 (25.49%), O_3 (15.69%), SO_2 (11.76%), and

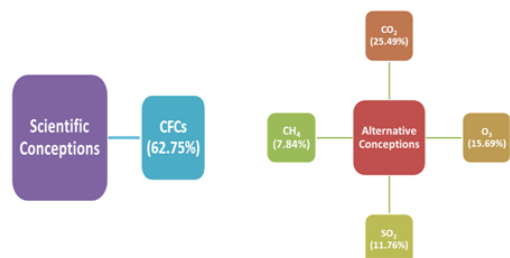
CH_4 (7.84%); and the top four alternative conceptions of the cause of AR were CFCs (7.84%), H_2O (7.84%), CH_4 (7.84%), and N_2O (7.84%).

The participants performed best in terms of understanding that CO_2 causes GW, CFCs cause OLD, and CO_2 and SO_2 cause AR. However, alternative conceptions, such as CO_2 and O_3 cause OLD, were also observed. These findings echo Papadimitriou’s research (2004) which highlighted the fact that GW involves many complex scientific concepts. Studies have also shown that students or teachers hold many misconceptions regarding issues such as GW, OLD, and AR [6], [7]. One of the reasons for these alternative conceptions is that people do not grasp the issue and get confused as to which chemical compounds cause GW, OLD, and AR [7].

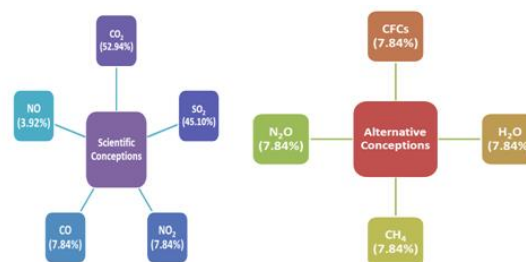
In relation to GW, all the participants knew CO_2 causes GW. The reasons for such remarkable result may be that people are frequently provided information stating that increasing levels of CO_2 lead to GW. However, focusing on the impact of CO_2 means they may overlook other unfamiliar GH gases in the Earth’s atmosphere that are equally damaging. Regarding OLD, most participants understood that CFCs cause OLD. This may be because people have obtained information on how CFCs, such as Freon, which are used in refrigerators or air conditioners, cause OLD. However, they often misunderstood CO_2 as influencing OLD, mirroring Papadimitriou’s [8] finding that teachers confuse GW with OLD.



The scientific conceptions and alternative conceptions of Global Warming (GW)



The scientific conceptions and alternative conceptions of Ozone Layer Depletion (OLD)



The scientific conceptions and alternative conceptions of Acid Rain (AR)

Figure 1. Participants’ understanding of chemical compounds in Environmental Sustainability (ES) Issues: Global Warming (GW), Ozone Layer Depletion (OLD), and Acid Rain (AR)

B. Information Sources on Three ES Issues

Fig. 2 displays information sources on the three ES issues, and these exhibit a very consistent pattern. First, the main sources of information from P on GW, OLD, and AR were teachers (96.08%, 88.24%, and 80.39%, respectively), speakers (35.29%, 29.41%, and 31.37%, respectively), classmates (31.37%, 21.57%, and 29.41%, respectively), parents (27.45%, 23.53%, and 33.33%, respectively), and friends (23.53%, 19.61%, 27.45%, respectively). Second, the main sources of information from PD on GW, OLD, and AR were textbooks (74.51%, 72.55%, and 74.51%, respectively), newspapers (66.67%, 58.82%, and 56.86%, respectively), teaching (54.90%, 58.82%, and 47.06%, respectively), extracurricular reading (54.90%, 49.02%, and 41.18%, respectively), and magazines (39.22%, 37.25%, and 37.25%, respectively). Third, the main sources of information from ED on GW, OLD, and AR were the internet (62.75%, 58.82%, and 56.86%, respectively) and TV (60.78%, 50.98%, and 45.10%, respectively). Finally, the main sources of information from A on GW, OLD, and AR were speech (27.45%, 19.61%, and 19.61%, respectively) and exhibitions (19.61%, 17.65%, and 15.69%, respectively).

Studies have shown that information sources affect people's understanding of environmental issues [3], [9]; moreover, the level of consistency shown in all the three ES issues suggest that certain information sources, such as teachers, textbooks, newspapers, the internet, TV, teaching, and extracurricular readings, may have the highest influence on people's understanding.

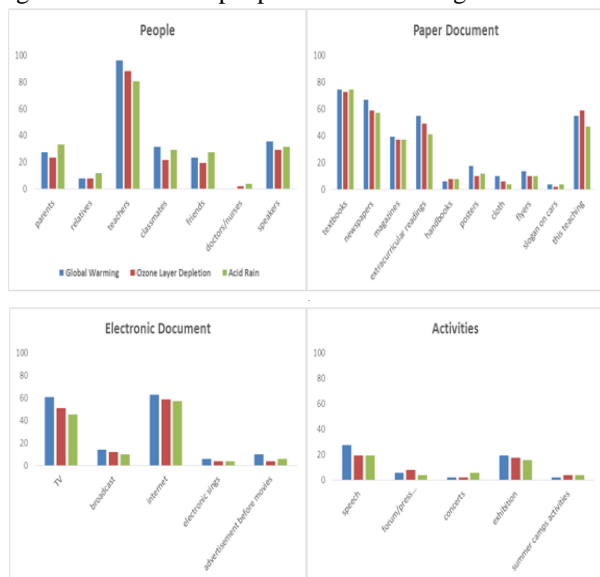


Figure 2. Information sources on three environmental sustainability (ES) Issues: Global Warming (GW), Ozone Layer Depletion (OLD), and Acid Rain (AR)

C. Risk Perceptions Regarding ES Issues

Fig. 3 presents participants' risk perceptions regarding ES issues in three dimensions. It shows that global warming, mudflows and landslides, and alien species were the issues perceived as having the highest risk for EP, NDs, and RE, respectively; by contrast, tsunamis,

desertification, and sandstorms were the three issues perceived as having the lowest risk.

The participants had a higher risk perception of GW than of OLD or AR, but a lower risk perception of tsunamis, desertification, and sandstorms, all of which pertain to NDs. The findings closely echo previous research, which suggested that individuals' relationships to their residential environment and their risk perceptions may differ according to geographical location, society, and culture [3], [4].

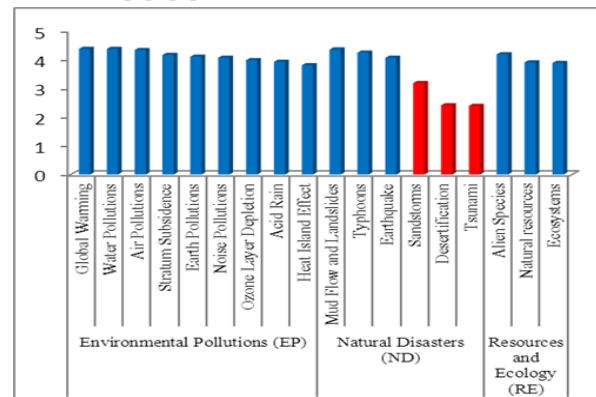


Figure 3. Participants' risk perceptions regarding Environmental Sustainability (ES) Issues

IV. CONCLUSION

The results presented people's understanding of chemical compounds for three ES issues, the sources of information they draw upon for these issues, and their risk perceptions regarding three dimensions of ES issues.

A. Conceptions of Chemical Compounds for Three ES Issues

The participants displayed scientific conceptions of the effect of CO₂ on GW; CFCs on OLD; and CO₂ and SO₂ on AR. However, they also held many alternative conceptions, such as CO₂ inducing OLD, owing to confusion between GW and OLD regarding the contribution of CO₂. Papadimitriou [8] claimed that GW involves complex scientific concepts, and this study has highlighted that both OZD and AR are also understood as involving complex scientific concepts. The confusion of chemical compounds between OZD and GW also echoes research by Dove [10] and Dakolo, and Flogaitis [7], where the relationship between OZD and GW is commonly misunderstood. Moreover, the study also revealed that people were easily confused by the complex contributions these common gases made to all three environmental issues [11].

B. Information Sources on Three ES Issues

Information sources on ES issues are consistent for GW, OLD, and AR. Teachers, textbooks, newspapers, the internet, teaching, TV, and extracurricular readings were all important information sources. These results imply that information sources are linked to learning experiences, not just formal education but also informal education, as previous research [3], [4] suggests.

C. Risk Perceptions of ES issues in Taiwan

The highest perceived risks regarding ES issues are GW, mudflow and landslides, and alien species for EP, NDs, and RE, respectively. Conversely, tsunamis, desertification, and sandstorms were the three issues perceived as having the lowest risk. The results imply that people's risk perception is related to their everyday living environments. This is consistent with Renn and Rohrmann's [12] argument that a range of environmental hazards may trigger people's risk perceptions and is connected to local society and culture. Thus, Taiwanese people's risk perception regarding ES issues may impact their attitudes and actions toward these issues, whereas people in other countries will think and act somewhat differently.

V. IMPLICATIONS AND SUGGESTIONS FOR FUTURE WORK

Environmentally sustainable development has been pursued in many countries [5]. Ethical reflection is required when addressing such issues [13]; however, people's conceptions, information sources, and risk perceptions are underestimated. The findings of this study suggest there are three actions, in the form of education or propaganda, that can be taken to enhance people's environmental literacy, chemical literacy, and scientific literacy [14].

First, an educational program is needed to help clarify understanding of the compounds contributing to different ES issues. Previous research has concluded that conceptual change is needed regarding chemical compounds to avoid any misunderstanding regarding ES issues [11], [15].

Second, effective information sources such as teachers, textbooks, newspapers, the internet, TV, teaching, and extracurricular readings, need to be utilized as propaganda for all three ES issues. The quality and influence of information is dependent on its sources, as these affect people's understanding, scientific literacy, and the policy options that are then pursued.

Third, local society and culture play an essential role in shaping people's risk perceptions and need to be considered by authorities when developing education programs and propaganda. Specifically, Taiwanese people have high risk perceptions for all ES issues except tsunamis, desertification, and sandstorms. Such issues need to be considered in the context of the Taiwanese environment, society, and culture.

In summary, enhancing people's environmental literacy, chemical literacy, and scientific literacy requires a proper understanding of ES issues, communicating through certain information sources, and tackling these issues in the context of local risk perceptions. However, factors such as gender, race, age, education level, and timing (for example, the 921 earthquake in Taiwan, or the 311 earthquake in Japan), may also exert influences on

risk perception regarding ES issues. However, a transnational comparison of risk perceptions in relation to ES issues is yet to be conducted and thus further investigation is required.

REFERENCES

- [1] S. Y. Liu, S. C. Yeh, S. W. Liang, W. T. Fang, and H. M. Tsai, "A national investigation of teachers' environmental literacy as a reference for promoting environmental education in Taiwan," *The Journal of Environmental Education*, vol. 46, pp. 114-132, Feb. 2015.
- [2] O. Badr and S. Probert, "Oxides of nitrogen in the earth's atmosphere: trends, sources, sinks and environmental impacts," *Applied Energy*, vol. 46, pp. 1-67, 1993.
- [3] S. Michail, A. G. Stamou, and G. P. Stamou, "Greek primary school teachers' understanding of current environmental issues: An exploration of their environmental knowledge and images of nature," *Science Education*, vol. 91, pp. 244-259, Feb. 2007.
- [4] A. Ocal, M. Kisoglu, A. Alas, and H. Gurbuz, "Turkish prospective teachers' understanding and misunderstanding on global warming," *International Research in Geographical and Environmental Education*, vol. 20, pp. 215-226, Aug. 2011.
- [5] R. Goodland, "The concept of environmental sustainability," *Annual Review of Ecology and Systematics*, vol. 26, pp. 1-24, Nov. 1995.
- [6] E. Boyes, and M. Stanisstreet, "Children's models of understanding of two major global environmental issues (ozone layer and greenhouse effect)," *Research in Science & Technological Education*, vol. 15, pp. 19-28, 2006.
- [7] M. Daskolia, E. Flogaitis, and E. Papageorgiou, "Kindergarten teachers' conceptual framework on the ozone layer depletion. Exploring the associative meanings of a global environmental issue," *Journal of Science Education and Technology*, vol. 15, pp. 168-178, April 2006.
- [8] V. Papadimitriou, "Prospective primary teachers' understanding of climate change, greenhouse effect, and ozone layer depletion," *Journal of Science Education and Technology*, vol. 13, pp. 299-307, June 2004.
- [9] T. Khalid, "Pre-service high school teachers' perceptions of three environmental phenomena," *Environmental Education Research*, vol. 9, pp. 35-50, July 2010.
- [10] J. Dove, "Student teacher understanding of the greenhouse effect, ozone layer depletion and acid rain," *Environmental Education Research*, vol. 2, pp. 89-100, July 1996.
- [11] F. H. Groves and A. F. Pugh, "Elementary pre-service teacher perceptions of the greenhouse effect," *Journal of Science Education and Technology*, vol. 8, pp. 75-81, March 1999.
- [12] O. Renn, and B. Rohrmann, "Cross-cultural risk perception: state and challenges," in *Cross-Cultural Risk Perception. Technology, Risk, and Society*, O. Renn and B. Rohrmann, Eds., Dordrecht London: Kluwer, 2000, pp. 211-233.
- [13] L. Colucci-Gray, E. Camino, G. Barbiero, and D. Gray, "From scientific literacy to sustainability literacy: An ecological framework for education," *Science Education*, vol. 90, pp. 227-252, Feb. 2006.
- [14] Y. Shwartz, R. Ben-Zvi, and A. Hofstein, "Chemical literacy: What does this mean to scientists and school teachers?" *Journal of Chemical Education*, vol. 83, pp. 1557-1561, Oct. 2006.
- [15] K. Österlind, "Concept formation in environmental education: 14-year olds' work on the intensified greenhouse effect and the depletion of the ozone layer," *International Journal of Science Education*, vol. 27, pp. 891-908, June 2005.

Show-Yu Lin is an associate professor in the Department of Natural Sciences, Center for General Education, Aletheia University, New Taipei City, Taiwan. She obtained his PhD in science education from National Taiwan Normal University. Her research interests include science education, general education, biology education, and medical education.