Research in Science & Technological Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/crst20

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To cite this article: Yuh-Yuh Li & Shu-Chiu Liu (2022) Examining Taiwanese students' views on climate change and the teaching of climate change in the context of higher education, Research in Science & Technological Education, 40:4, 515-528, DOI: 10.1080/02635143.2020.1830268

To link to this article: https://doi.org/10.1080/02635143.2020.1830268

Published online: 22 Jan 2021.

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RESEARCH IN SCIENCE & TECHNOLOGICAL EDUCATION
2022, VOL. 40, NO. 4, 515–528
https://doi.org/10.1080/02635143.2020.1830268

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Examining Taiwanese students' views on climate change and the teaching of climate change in the context of higher education

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ABSTRACT

Background Although higher education continues to pay great attention to teaching climate change, relatively little is known about how university students understand and perceive climate change and its teaching and learning, and how their understanding and perceptions may change over the course of climate change instruction.

Purpose The study was embedded in the context of a Taiwanese public university which has been actively integrating a climate change agenda into the curriculum. The purpose of the study was to examine students' knowledge of and views on climate change and its teaching, and the influence of climate-related instruction on their knowledge and views.

Sample A total of 146 university students were solicited through four semester-long general environmental studies courses, all of which included some climate change instruction.

Design and methods Participating students completed both pre- and post-course surveys including Likert-type, multiple choice and open-ended questions for the purpose of examining their views about climate change and the teaching of this issue.

Results The vast majority of students demonstrated a high level of certainty about the reality of the happening of global warming as well as concern about this issue. However, their actual knowledge about its causes was alarmingly poor, and action-related perceptions were rather negative. Participating in an environmental course had only a limited impact on their views; significant improvement was only observed in their subjective knowledge and concern about the issue. Nevertheless, students' responses regarding university teaching about climate change exhibited a strong interest in and support for their university to take an active role in combating the problem.

Conclusion These findings raise questions about the focus of, and approaches to, climate education in higher education, and serve as important basis for promoting curricular and instructional innovation in the field of climate change education.

KEYWORDS

Students' views; climate change; higher education; environmental studies courses

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Introduction

Climate change is one of the greatest challenges faced by the world today, and as such is an extremely important environmental education topic (UNESCO 2012; IPCC 2014). In recent years, interest in education about climate change has been growing, which is likely partly due to the mounting awareness of unusual weather patterns and the deepening concern surrounding the social, economic and environmental consequences of climate change (Monroe et al. 2017). Reflecting this overall growth of interest in, and need for, climate change education, higher education institutions have expanded the curricula explicitly focused on climate change and sustainability (O'Byrne, Dripps, and Nicholas 2015; Fahey 2012). In 2011, an evaluation of the sustainability performance of a sample of 178 universities from 42 countries showed that climate change was the most prevailing indicator achieved by many universities (Suwartha and Sari 2013).

It need hardly be said that higher education has a critical role to play in responding to the overall challenge of climate change (Wachholz, Artz, and Chene 2014; Cortese 2003; Leal; Filho et al. 2019) and, more specifically, in increasing the chance that graduates feel empowered to take effective action to combat climate change not only on a personal but also on a professional level (Sebastian and Tonia 2017; Aksit et al. 2018). In Taiwan, an increasing number of universities and colleges are incorporating climate change agenda into their educational programmes. By year-end of 2017, an estimated 360 climate-related courses had been offered in general education programmes (Taiwan Ministry of Education 2018). Although higher education continues to pay great attention to teaching climate change, relatively little is known about students' views toward climate change; how their views evolve as the result of teaching and learning; and how students perceive university efforts in response to climate change. While many national and international surveys of the general public's awareness and perceptions of climate change and global warming have been undertaken and continue to be undertaken (Feldman et al. 2010; Leiserowitz 2005; Lorenzoni and Pidgeon 2006; Reser et al. 2012), research has not provided sufficient information on how university students perceive and respond emotionally to this issue, and how these perceptions and feelings may change over the course of their study (Santos et al. 2016; Wachholz, Artz, and Chene 2014).

The present study

This study seeks to fill the above knowledge gap. Understanding what university students think and feel about climate change, and in what way their participation in environmental courses may make an impact on their thoughts and perceptions are highly relevant given the likely role they will play as future decision makers. In addition, student opinions on teaching and learning about climate change will enable educators to more fully understand the challenges and opportunities presented by climate change education. Therefore, the aim of the present study was as follows:

- to examine Taiwanese university students' knowledge of and views on climate change,
- to examine their views on teaching and learning about climate change in higher education; and
- to assess possible changes in their knowledge and views over the course of semester-long environmental instruction.

We conducted this study in a research-oriented public university in Taiwan. This university is located by the coast, and is justly famous for its marine education and research. In the past decade, it has been actively involved in integrating environmental education, including climate change education, into the curriculum. Since university graduates have become the major source of future professionals and experts in Taiwan, with nearly 70% of 18–21 year olds enrolled in higher education (Taiwan Ministry of Education 2016), the results of this study should have important implications for future national and international climate change policy-making, as well as the inevitable and ongoing adaptations to university curriculums in response to student perceptions.

Students' knowledge and views regarding climate change

A number of studies have indicated that students often approach climate phenomena with misconceptions. These misconceptions include: (1) confusing weather and climate, such as using local or recent weather information as evidence of global climate trend (Papadimitriou 2004; Read et al. 1994); (2) regarding stratospheric ozone depletion as a major contributory factor to global warming (Read et al. 1994; Rye, Rubba, and Wiesenmayer 1997), in the mistaken belief that the ozone hole allows more solar energy to reach the earth (Österlind 2005; Andersson and Wallin 2000); and (3) linking unrelated environmental damage or pollution (e.g., littering, acid rain, general air pollution, and nuclear waste) to global warming and climate change (Boyes and Stanisstreet 1993, 1997; Shepardson et al. 2009). Although most of these studies looked at primary and secondary school students, a small number of studies conducted with college students have showed similar results. One recurrent theme is that many students believe that global warming is caused by increased penetration of solar radiation, which is connected with holes in the ozone layer. For instance, in Jeffries, Stanisstreet, and Boyes' study (2001) of students' knowledge of the greenhouse effect, 67% of first-year biology students at a British university (n = 267) believed global warming is caused by holes in the ozone layer and 58% thought that the greenhouse effect is made worse because more of the sun's rays penetrate the atmosphere to reach the earth's surface. In another study with general chemistry students in the US (Walz and Kerr 2007), 40% of the 91 students in the pre-assessment held the idea that global warming, due to the greenhouse effect, resulted in ozone destruction, and only 33% identified the correct relationship between the greenhouse effect and ozone depletion. While environmental knowledge is a necessary, but not sufficient, rational precondition for pro-environmental behaviour, misconceptions or erroneous beliefs are a concern.

As reported in previous studies, multiple factors may increase the knowledge associated with climate change action (and general pro-environmental behaviour), or alternatively, create the widely reported knowledge-action gap (Ortega-Egea, García-de-Frutos, and

Raquel 2014). For example, two different knowledge types – subjective (self-rated) and objective (actual) knowledge – may have different effects on specific pro-environmental behaviour (Vicente-Molina, Fernández-Sáinz, and Izagirre-Olaizola 2013). Also, while a lack of knowledge is a barrier to conscious engagement (Lorenzoni, Nicholson-Cole, and Whitmarsh 2007; Semenza et al. 2008), an excessive amount of knowledge or very detailed technical information concerning highly complex and far-reaching issues such as climate change may also hinder pro-environmental behaviour (Kollmuss and Agyeman 2002; Whitmarsh, O'Neill, and Lorenzoni 2011). Researchers have also found that domain knowledge is correlated with sourcing skills – noting and evaluating the source of information, which are important skills for tackling climate change (e.g., Iding et al. 2009; Rieh and Hilligoss 2008). In Bråten, Strømsø, and Salmerón's study (2011) of 128 Norwegian undergraduate students, those with little knowledge of climate change were more likely to put more stock in less trustworthy sources such as oil company presentations and to base their trustworthiness judgments on superficial features such as text type and publisher than were those students with a broader and deeper knowledge of climate change issues.

Several US-based studies that explored university students' views of climate change showed a similar trend, in that the majority believed climate change is occurring, and identified it as basically a human-induced environmental problem (Feldman et al. 2010; Cordero, Todd, and Abellerra 2008). The students were generally concerned about this problem, but their worry did not translate into mitigation action (Wachholz, Artz, and Chene 2014). A previous survey compared US and Chinese college students' opinions about climate change and found that Chinese students were more likely to believe human-induced climate change is occurring compared to US students; over 84% of Chinese college students (n = 773) believed that climate change is occurring compared to just over 75% of their US counterparts (n = 826). Nearly all Chinese students that reported climate change is occurring also believed the causes are primarily due to human activities, compared to just 59% among US students (Jamelske, Barrett, and Boulter 2013). While there exists a small number of studies conducted to understand students' views in the higher education context, even fewer studies were found that looked into how students perceive university efforts to teach climate change. One exception is the study by Wachholz, Artz, and Chene (2014), which investigated perceived satisfaction levels and ideas about how to improve climate change teaching among a representative group of US college students (n = 338). This study seeks to provide some new insight into climate change education in a higher education context by examining Taiwanese students' knowledge of and views on climate change and its teaching and learning, as well as possible changes in their knowledge and views over a semester of environmental instruction.

Methods

Participants and procedure

The participants in the study consisted of 146 students (45% female and 55% male) solicited through four elective environmental studies courses. All these courses were semester-long, taught in general education, and intended for all students attending the university. As mentioned above, this university, like many others in Taiwan, has been

actively engaged in integrating climate change agenda into their curriculum for a number of years, particularly in general science education. These four environmental studies courses can be regarded as part of this movement and representative of the university's curricular efforts. The major common feature of these courses is that, while focusing on different environmental subjects (biodiversity, the marine environment, nature conservation, and life science), they contained some climate change instruction in relation to their specific subjects. The climate-related content was typically limited to the understanding of risks and challenges global warming posed for, as an example, biodiversity. Among the four courses, only one introduced some basic science of climate change, such as the greenhouse effect. The climate-related instruction time varied among the courses, ranging from two to six hours. Another common feature of the instruction is the lecture-based teaching mode, which is commonly used in large-enrolment classes.

The participating students included second to fourth-year majors representing a wide range of disciplines in humanities, sciences, technology, management, and social sciences. The reason for no freshmen is that a typical freshman-year schedule is very tight and focuses on required courses.

We distributed a survey instrument to assess students' perspectives on climate change at the beginning and end of the semester. Students who completed the post survey represented 68% of those who participated in the pre-survey (n = 214). Duplicate data were removed from further analysis.

Instrument

A survey questionnaire consisting of 21 items, including Likert-type, multiple-choice, and open-ended questions, was adapted from previous studies (Wachholz, Artz, and Chene 2014; Feldman et al. 2010). The adapted survey was reviewed by a panel of three science and environmental education experts to ensure its content validity and appropriateness for the student population. This instrument was designed to measure students' knowledge and views in the following components: (1) their concern over climate change, (2) the impact of climate change, (3) social norms, (4) the reality and causes of global warming, (5) outcomes of actions (6) openness to new information, (7) subjective knowledge, (8) objective knowledge, and (9) perceptions of teaching. Within the first six components measuring students' views on climate change, two action-related components – social norms and outcomes of actions- are included. The seventh and eighth components measure two types of students' knowledge of climate change. The last component, perceptions of teaching, consisted of two Likert-type questions to explore students' satisfaction with the amount of education regarding climate change currently taught at the university, and one open-ended question, which was included only in the post survey, about how to improve student learning of the issue. Table 1 shows the item probes used to measure each construct.

Data analysis

Data was analysed using univariate frequency distributions and bivariate analysis to compare pre and post results and to identify possible relationships among measured constructs. Student responses to the open-ended question regarding teaching were content analysed by two researchers for the purpose of identifying major themes that address students'

Table 1. Questionnaire constructs and item probes.

Construct	Item number and probe
Concern about climate change	1. Perceived importance of global warming
	2. Worry about global warming
Perceived impact of climate change	3. When climate change will impact people in Taiwan
	4. When climate change will impact people around the world
Social norms	5. Whether or not friends act to reduce global warming
Perceived reality and causes of global warming	6. Whether global warming is occurring
	7. Whether or not most scientists agree that global change is occurring
	8. Whether global warming is caused by human activities
Perceived outcomes of actions	9. Expected outcomes of human action to reduce global warming
	10. Impact of personal behaviour change on quality of life
Openness to new information	11. Whether more information is needed in order to make up one's mind
	12. Willingness to change one's mind about global warming
Subjective knowledge	Items 13–16 (e.g., How informed do you feel about the causes of global warming?)
Objective knowledge	17. a-f. Whether each of the following contribute to global warming: toxic waste, the hole in the ozone layer, acid rain, etc.
	18. What 'the greenhouse effect' means
Perceptions of teaching	Items 19–20 (e.g., whether the university was providing enough climate change education)
	21. How to improve student learning of climate change (post survey only)

curricular or instructional suggestions. Some of the results were specifically compared with those in a US-based study (Wachholz, Artz, and Chene 2014) where a similar survey was used for a representative sample of college students (n = 338). We do not presume that the respondents in this study and in Wachholz et al. are equivalent groups, but the comparison nevertheless allows us to understand the results in a larger context.

Results and discussion

The results were divided into three parts. The first part discusses students' knowledge of and general views on climate change, including concerns, openness to new information, and perceptions regarding the reality, risk, causes and impact of climate change. In the second part, students' action-related views, including social norms and perceptions about actions, are reported. Results concerning the students' views on climate change teaching are presented and discussed in the final part of this section. In each part, the overall results from the pre-survey are outlined, followed by comparison of pre- and post-survey results.

Knowledge of and general views on climate change

Students' concerns over climate change, openness to new information, and subjective knowledge were measured using four-point Likert items with a higher score denoting a greater degree of the specific construct. To measure the perceived impact of global warming, students were asked to rate how soon Taiwan and the world will start to feel the harmful consequences on a scale of 1–5. Multiple-choice items were used to measure students' perceptions about the reality and causes of global warming (with possible scores ranging from 0 to 3) and objective knowledge about the different causes of global warming (with possible scores ranging from 0 to 6). Once again, a higher score indicates a higher level of perception or knowledge.

The pre survey results showed that the students' levels of concern about the issue was high: the vast majority said that they believe global warming is happening (97% in the pre survey) and that they are 'very' or 'somewhat' worried (94%) by this. Similar to previous results (Feldman et al. 2010), these students tended to believe that the problem is worse elsewhere, and will worsen over time: 38% understood that climate change was currently harming people in Taiwan, while 52% understood that it was currently impacting others around the world. Unlike previous generations, these university students grew up with increasing scientific certainty on the reality of climate change, more exposure to formal and informal climate-related instruction, and easier access to information about climate change through online resources. They have also been the first to really experience the consequences of climate change. Therefore, it is not so surprising that an overwhelming number of our students prior to instruction believed in the reality of climate change, and expressed their concern about this issue.

Despite a consensus among students over the occurrence of global warming, considerably fewer students (66% in the pre-survey) believed that there is a general agreement among scientists, and even fewer (38%) identified global warming as basically a human-induced environmental problem. Compared to the US college students in Wachholz, Artz, and Chene (2014) (approximately 75% identified human activities as the main cause of global warming), our students were strikingly less informed about the true causes of global warming. Such poor understanding may seriously affect their future actions since they do not really blame humans for climate change. Moreover, in response to the basic question (with multiple true-false items) as to what contributes to global warming, the students revealed alarmingly low levels of knowledge: 56% of the students received total scores of 0–2 out of a possible maximum of 6, and among the response items, the hole in the ozone layer was taken by many students (73%) as one of the causes of global warming. These results also align with those found by Stevenson et al. (2014) among middle school students that those with lower levels of climate change knowledge were more unlikely to accept anthropogenic activity as the major source of global warming. What is surprising to the authors is that, compared to Wachholz et al.'s US sample (2014), there is a greater gap between comprehension and awareness of climate change among our students. Our students appeared to be very aware of the seriousness of this issue, but rather unsure about why and how it has come about.

The pre- and post-survey comparison using *t*-test showed that there was no significant improvement after a semester of environmental learning (Table 2). A large number of students continued to hold well-documented misconceptions that contemporary global warming is mainly caused by a mixture of natural changes and human activities, and that ozone depletion is one major cause of global warming. In the post surveys, a considerable number of students believed that global warming was caused by the hole in the ozone layer (68%), aerosol spray cans (71%), and volcanic eruptions (62%). Even the sun (63%) was believed to contribute to global warming.

Despite these unsatisfactory levels of actual knowledge regarding the causes of global warming, the students seemed nevertheless to be rather confident in their knowledge about the causes and effects of global warming. With regard to the students' self-perceived (subjective) knowledge, the vast majority believe they were either 'very well' or 'fairly well' informed about climate change, including how the climate system works

Table 2. Results of the pair sample *t*-test analysis before and after instruction.

	Pre Mean (SD)	Post Mean (SD)	*t*	*p*	Cohen's *d*
Concern about climate change	3.27 (0.488)	3.37 (0.458)	2.493	.014	0.21
Perceived impact	3.98 (1.031)	4.11 (1.051)	1.618	.108	–
Perceived reality and causes of global warming	2.01 (0.814)	2.01 (0.733)	0.000	1.000	–
Openness to new information	2.91 (0.478)	2.72 (0.572)	−3.427	.001	0.36
Subjective knowledge	2.97 (0.328)	3.11 (0.409)	3.768	<.001	0.38
Objective knowledge (about different causes of global warming)	2.21 (1.808)	2.11 (1.891)	−0.675	.500	–
Social norms	2.46 (0.813)	2.44 (0.804)	−0.013	.853	–
Perceived outcomes of actions	5.46 (1.513)	5.35 (1.547)	−0.116	.436	–
Perceptions of teaching	2.85 (0.644)	3.00 (0.626)	2.599	.010	0.24

Note. $n = 146$.

(87%), the different causes (95%) and the consequences of global warming (95%), as well as the ways in which we can reduce global warming (78%). At the same time, a vast majority of them (95%) felt that they needed 'a lot more' or 'some more' information in order to make up their minds about global warming.

As shown in Table 2, we observed statistically significant increases in students' concern about climate change (t (145) = 2.493, p =.014, d = 0.21) and subjective knowledge (t (145) = 3.768, $p < .001$, d = 0.38), but a decrease in openness to new information (t (145) = −3.427, p = .001, d = 0.36) about the causes of global warming. Although students were already rather concerned about climate change, their level of concern became even higher after the semester. They also grew more confident of their knowledge, and understandably felt less in need of new information. The alarming result is that students' perceptions of what causes global warming and awareness of scientists' research-based certitude were rather poor throughout pre- and post-surveys.

To explore the relationships among these variables, we used Pearson correlation for the post survey and found that students' concerns over climate change are positively correlated with perceived impact (r = 0.297, $p < .001$), perceived reality and causes of global warming (r = 0.279, p = .001), and their subjective knowledge (r = 0.210, p = .011). Also, there is a negative association between subjective knowledge and openness to new information (r = 0.244, p = .003). This supports the aforementioned result that the students thought they were more knowledgeable after completing the environment-related course, and expressed more concern about climate change, but felt less need for new information.

Action-related views

Students' action-related views, including perceived social norms (whether their friends are taking action) and expected effects of action to reduce global warming, were measured respectively using a four-point Likert item and two multiple-choice items. The analysis showed that these perceptions among students were not very positive. A full 57% of our

students (in pre-survey), similar to the US sample (55%) in Wachholz, Artz, and Chene (2014), said that humans have the capacity to reduce global warming, but that it is not clear that we will do what is needed to address the problem. Although about half of our students (52%) 'strongly' or 'somewhat' agreed that their friends were acting in some way to reduce global warming, a considerable number of them (33%) believed that taking personal actions will decrease their quality of life. The twin beliefs, that taking action may decrease their quality of life, and that humans could not really manage to reduce global warming, were somewhat prevalent, and likely to act as a barrier to climate action. The *t*-test showed that participating in a semester-long environmental studies course has made little impact on these action-related perceptions; students did not perceive greater activity among their friends, nor did they feel more optimistic about the effect of climate action (see Table 2). A Pearson correlation test revealed that these two perceptions were significantly, positively associated with each other ($r = 0.339$, $p < .001$).

While several national surveys have reported low degrees of environmental action among Taiwanese respondents despite satisfactory levels of environmental attitudes (Liu et al. 2015; Fahey 2012), our results are helpful in providing some evidence of why they do not act: first, if humans are not really to blame for global warming (as discussed in the above subsection), action to reduce global warming becomes limited in its scope and effects. Second, taking action as perceived by the students does not seem to lead to a better future.

Several researchers have identified *hope* as an important factor in environmental engagement (Liu and Lin 2018; Author 2018; Ojala 2012). Connecting climate change with an uncertain or even pessimistic future is likely to lead to a feeling of anxiety and hopelessness, and in turn prevent people from taking action. Our results re-emphasise the need for making instructional efforts to transform students' worries into a constructive motivational force by helping students think more critically and creatively about the complexity of climate change challenges, and articulate more clearly the ingredients necessary for a desirable future (Marcinkowski 2009).

Teaching-related views

In general, the students in our study rated their university positively in regard to its teaching of climate change, and their satisfaction level has become even greater after participating in the semester-long course. For example, 74% of the students in the pre-survey 'strongly' or 'somewhat' agreed that the university was doing a good job on teaching climate change, and 82% said so in the post-survey. Environmental learning seemed to make a significant, positive impact on their perceptions of climate change teaching at university (Table 2). Also, based on correlation analysis, we found that the students' satisfaction level vis-à-vis climate change teaching is significantly associated with perceived social norms ($r = 0.352$, $p < .001$) and confidence in knowledge ($r = 0.335$, $p < .001$). The more positively they feel about the university's efforts to teach climate change, the more positively they perceive related action taken by friends and the higher the confidence they have of their own knowledge.

Although 95% of the students responded to the open-ended question about how the university could improve its teaching of climate change, most of them provided short answers, such as 'offer more climate-related courses' and 'more campaign activities.'

Students' responses can be grouped into three themes: *curricular and instructional change, taking action*, and *research*. The majority of the students focused on the first theme, highlighting climate change as a curricular agenda, including providing students more inside and outside classroom learning experiences and allocating compulsory climate courses to all disciplines. Under this theme, many students (n = 73) pointed out the importance of using diverse approaches, such as films, field trips, inquiry projects, and workshops to enhance climate teaching and learning.

With regard to the second theme, *taking action*, the students (n = 32) felt that the university should make real efforts to reduce its own carbon footprint by, for example, making buildings greener and facilitating the bus transit system. As one student commented, 'Besides teaching, the university should act as a role model for fighting climate change. They need to help students learn by doing.' A small number of students (n = 4) gave responses pertaining to the theme, *research*. They felt that linking research and teaching is important at the university level. To underline this point, one student wrote, 'I hope the university wouldn't just preach on climate change. There should be more research-based discourse and inquiries, specifically targeting at misinformation.'

Student comments and suggestions about how to improve university climate change education are helpful in gaining insight into their learning experience regarding climate change. While students were generally very positive about their university's efforts to develop more climate-related curricular activities, they wanted teaching and learning to incorporate more diverse approaches, to be more experiential and action-based, and to involve deeper, more critical discourse. Given that university students have already developed considerable expertise regarding their own learning (i.e. what works and what doesn't work), their feedback is especially valuable for shaping curricular and instructional innovation on the subject of climate change.

Conclusion

Our study of university students' knowledge of and views on climate change revealed some alarming results. Students were generally very certain about the occurrence of global warming, but not about the major, anthropogenic cause. Their knowledge of the causes of global warming were surprisingly poor given that they were more exposed to climate education than were previous generations. Although they were very worried about global warming, many did not believe that taking action would necessarily lead to a better future. Although climate-related instruction seemed to be helpful in raising students' confidence in their own climate change knowledge, and concern about the issue, there was little improvement in actual knowledge and perceptions of actions. While the climate-related instruction was centred around other environmental topics, the instructional goal was not to improve students' conceptual understanding of climate change. Students might have felt that they learned something about climate change, but they did not really achieve better understanding of the mechanisms driving global warming. Moreover, students continued to feel unmotivated to take action, equating climate change action to a reduction in life quality and largely futile results, even after environmental instruction. This may be a result of the primarily subject- and lecture-based instruction on climate change. Nevertheless, the study also yielded hopeful results. Students expressed great interest in learning more about climate change and encouraged

universities to take a more active role in mitigation and adaptation actions. Their ideas about teaching and learning climate change embraced a whole-school approach where curricular and extracurricular activities, infrastructure, teaching training, and so on were all involved. This study extends the previous research on students' views about climate change by investigating enrolled students in related courses in the context of a Taiwanese higher education institution. The results of this study provide education policy makers and curriculum developers with useful information on students' views of climate change in tertiary education context. Needless to say, given the fact that this study was conducted at only one institution in Taiwan, additional work to investigate comparisons among university students and within other population groups is still much needed.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Taiwan Ministry of Science and Technology [MOST 107-2511-H-110 –008 -MY3].

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References

Aksit, O., K. S. McNeal, A. U. Gold, J. C. Libarkin, and S. Harris. 2018. "The Influence of Instruction, Prior Knowledge, and Values on Climate Change Risk Perception among Undergraduates." *Journal of Research in Science Teaching* 55 (4): 550–572. doi:10.1002/tea.21430.

Andersson, B., and A. Wallin. 2000. "Students' Understanding of the Greenhouse Effect, the Societal Consequences of Reducing CO2 Emissions and the Problem of Ozone Layer Depletion." *Journal of Research in Science Teaching* 37 (10): 1096–1111. doi:10.1002/1098-2736(200012)37:10<1096::AID-TEA4>3.0.CO;2-8.

Author. 2018. "Blinded for Review."

Boyes, E., and M. Stanisstreet. 1993. "The 'Greenhouse Effect': Children's Perceptions of Causes, Consequences and Cures." *International Journal of Science Education* 15 (5): 531–552. doi:10.1080/0950069930150507.

Boyes, E., and M. Stanisstreet. 1997. "Children's Models of Understanding of Two Major Global Environmental Issues (Ozone Layer and Greenhouse Effect)." *Research in Science & Technological Education* 15 (1): 19–28. doi:10.1080/0263514970150102.

Bråten, I., H. I. Strømsø, and S. Ladislao. 2011. "Trust and Mistrust When Students Read Multiple Information Sources about Climate Change." *Learning and Instruction* 21 (2): 180–192. doi:10.1016/j.learninstruc.2010.02.002.

Cordero, E., A. M. Todd, and D. Abellerra. 2008. "Climate Change Education and the Ecological Footprint." *Bulletin of the American Meteorological Society* 89 (6): 865–872. doi:10.1175/2007BAMS2432.1.

Cortese, A. D. 2003. "The Critical Role of Higher Education in Creating a Sustainable Future." *Planning for Higher Education* 31 (3): 15–22.

Fahey, S. J. 2012. "Curriculum Change and Climate Change: Inside outside Pressures in Higher Education." *Journal of Curriculum Studies* 44 (5): 703–722. doi:10.1080/00220272.2012.679011.

Feldman, L., M. C. Nisbet, A. Leiserowitz, and E. Maibach. 2010. "The Climate Change Generation? Survey Analysis of the Perceptions and Beliefs of Young Americans." In. Yale University and George Mason University: Yale Project on Climate Change.

Filho, L., M. M. Walter, P. Molthan-Hill, G. J. Nagy, L. V. Ávila, and A. L. Salvia. 2019. "Climate Change Scepticism at Universities: A Global Study." *Sustainability* 11 (10): 2981. doi:10.3390/su11102981.

Iding, M. K., M. E. Crosby, B. Auernheimer, and E. Barbara Klemm. 2009. "Web Site Credibility: Why Do People Believe What They Believe?" *Instructional Science* 37 (1): 43–63. doi:10.1007/s11251-008-9080-7.

IPCC. 2014. "Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III (WG3) to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). [Ottmar Edenhofer, Ramon Pichs-Madruga, Youba Sokona, Susanne Kadner, and Jan Minx, Steffen Brunner (Ed.)]." In.: Cambridge University Press.

Jamelske, E., J. Barrett, and J. Boulter. 2013. "Comparing Climate Change Awareness, Perceptions, and Beliefs of College Students in the United States and China." *Journal of Environmental Studies and Sciences* 3 (3): 269–278. doi:10.1007/s13412-013-0144-x.

Jeffries, H., M. Stanisstreet, and E. Boyes. 2001. "Knowledge about the 'Greenhouse Effect': Have College Students Improved?" *Research in Science & Technological Education* 19 (2): 205–221. doi:10.1080/02635140120087731.

Kollmuss, A., and J. Agyeman. 2002. "Mind the Gap: Why Do People Act Environmentally and What are the Barriers to Pro-environmental Behavior?" *Environmental Education Research* 8 (3): 239–260. doi:10.1080/13504620220145401.

Leiserowitz, A. A. 2005. "American Risk Perceptions: Is Climate Change Dangerous?" *Risk Analysis* 25 (6): 1433–1442. doi:10.1111/j.1540-6261.2005.00690.x.

Liu, S.-Y., S.-C. Yeh, S.-W. Liang, W.-T. Fang, and H.-M. Tsai. 2015. "A National Investigation of Teachers' Environmental Literacy as A Reference for Promoting Environmental Education in Taiwan." *The Journal of Environmental Education* 46 (2): 114–132. doi:10.1080/00958964.2014.999742.

Liu, S.-C., and H.-S. Lin. 2018. "Envisioning Preferred Environmental Futures: Exploring Relationships between Future-related Views and Environmental Attitudes." *Environmental Education Research* 24 (1): 80–96. doi:10.1080/13504622.2016.1180504.

Lorenzoni, I., S. Nicholson-Cole, and L. Whitmarsh. 2007. "Barriers Perceived to Engaging with Climate Change among the UK Public and Their Policy Implications." *Global Environmental Change* 17 (3–4): 445–459. doi:10.1016/j.gloenvcha.2007.01.004.

Lorenzoni, I., and N. F. Pidgeon. 2006. "Public Views on Climate Change: European and USA Perspectives." *Climatic Change* 77 (1–2): 73–95. doi:10.1007/s10584-006-9072-z.

Marcinkowski, T. J. 2009. "Contemporary Challenges and Opportunities in Environmental Education: Where are We Headed and What Deserves Our Attention?" *The Journal of Environmental Education* 41 (1): 34–54. doi:10.1080/00958960903210015.

Monroe, M. C., R. R. Plate, A. Oxarart, A. Bowers, and W. A. Chaves. 2017. "Identifying Effective Climate Change Education Strategies: A Systematic Review of the Research." *Environmental Education Research* 1–22. doi:10.1080/13504622.2017.1360842.

O'Byrne, D., W. Dripps, and K. A. Nicholas. 2015. "Teaching and Learning Sustainability: An Assessment of the Curriculum Content and Structure of Sustainability Degree Programs in Higher Education." *Sustainability Science* 10 (1): 43–59. doi:10.1007/s11625-014-0251-y.

Ojala, M. 2012. "Hope and Climate Change: The Importance of Hope for Environmental Engagement among Young People." *Environmental Education Research* 18 (5): 625–642. doi:10.1080/13504622.2011.637157.

Ortega-Egea, J. M., N. García-de-Frutos, and A.-L. Raquel. 2014. "Why Do Some People Do "More" to Mitigate Climate Change than Others? Exploring Heterogeneity in Psycho-Social Associations." *PLoS ONE* 9 (9): e106645. doi:10.1371/journal.pone.0106645.

Österlind, K. 2005. "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* 27 (8): 891–908. doi:10.1080/09500690500038264.

Papadimitriou, V. 2004. "Prospective Primary Teachers' Understanding of Climate Change, Greenhouse Effect, and Ozone Layer Depletion." *Journal of Science Education and Technology* 13 (2): 299–307. doi:10.1023/B:JOST.0000031268.72848.6d.

Read, D., M. Ann Bostrom, G. Morgan, B. Fischhoff, and T. Smuts. 1994. "What Do People Know about Global Climate Change? 2. Survey Studies of Educated Laypeople." *Risk Analysis* 14 (6): 971–982. doi:10.1111/j.1539-6924.1994.tb00066.x.

Reser, J. P., G. L. Bradley, A. Ian Glendon, M. C. Ellul, and R. Callaghan. 2012. "Public Risk Perceptions, Understandings and Responses to Climate Change in Australia and Great Britain." In. Gold Coast, Australia: Griffith Climate Change Response Adaptation Facility.

Rieh, S. Y., and B. Hilligoss. 2008. "College Students' Credibility Judgments in the Information-seeking Process." Digital media, youth, and credibility, 49–72.

Rye, J. A., P. A. Rubba, and R. L. Wiesenmayer. 1997. "An Investigation of Middle School Students' Alternative Conceptions of Global Warming." *International Journal of Science Education* 19 (5): 527–551. doi:10.1080/0950069970190503.

Santos, P. T., P. Bacelar-Nicolau, U. M. Azeiteiro, M. A. Pardal, and L. Bacelar-Nicolau. 2016. "Chapter 12: Assessing Student Perceptions and Comprehension of Climate Change in Portuguese Higher Education Institutions." In *Implementing Climate Change Adaptation in Cities and Communities*, edited by W. Leal Filho, K. Adamson, R. M. Dunk, U. M. Azeiteiro, S. Illimworth, and F. Alves, 221–236. Basel, Switzerland: Springer International Publisher.

Sebastian, P., and G. Tonia. 2017. "Low Factual Understanding and High Anxiety about Climate Warming Impedes University Students to Become Sustainability Stewards: An Australian Case Study." *International Journal of Sustainability in Higher Education* 18 (7): 1157–1175. doi:10.1108/IJSHE-09-2016-0179.

Semenza, J. C., D. E. Hall, D. J. Wilson, B. D. Bontempo, D. J. Sailor, and L. A. George. 2008. "Public Perception of Climate Change: Voluntary Mitigation and Barriers to Behavior Change." *American Journal of Preventive Medicine* 35 (5): 479–487. doi:10.1016/j.amepre.2008.08.020.

Shepardson, D. P., D. Niyogi, S. Choi, and U. Charusombat. 2009. "Seventh Grade Students' Conceptions of Global Warming and Climate Change." *Environmental Education Research* 15 (5): 549–570. doi:10.1080/13504620903114592.

Stevenson, K. T., M. Nils Peterson, H. D. Bondell, S. E. Moore, and S. J. Carrier. 2014. "Overcoming Skepticism with Education: Interacting Influences of Worldview and Climate Change Knowledge on Perceived Climate Change Risk among Adolescents." *Climatic Change* 126 (3–4): 293–304. doi:10.1007/s10584-014-1228-7.

Suwartha, N., and R. F. Sari. 2013. "Evaluating UI GreenMetric as a Tool to Support Green Universities Development: Assessment of the Year 2011 Ranking." *Journal of Cleaner Production* 61: 46–53. doi:10.1016/j.jclepro.2013.02.034.

Taiwan Ministry of Education. 2016. "Education Statistics Newsletter (Issue 55)." Author. Accessed 15 August 2018. http://stats.moe.gov.tw/files/brief/大專校院校數及規模概況.pdf (in Chinese).

Taiwan Ministry of Education. 2018. "News on Climate Change Education." E-news of Ministry of Education. https://epaper.edu.tw/news.aspx?news_sn=61195 (in Chinese).

UNESCO. 2012. "Climate Change Education for Sustainability Development." In. Paris, France: Decade of Education for Sustainable Development, UNESCO.

Vicente-Molina, M. A., A. Fernández-Sáinz, and J. Izagirre-Olaizola. 2013. "Environmental Knowledge and Other Variables Affecting Pro-environmental Behaviour: Comparison of University Students from Emerging and Advanced Countries." *Journal of Cleaner Production* 61: 130–138. doi:10.1016/j.jclepro.2013.05.015.

Wachholz, S., N. Artz, and D. Chene. 2014. "Warming to the Idea: University Students' Knowledge and Attitudes about Climate Change." *International Journal of Sustainability in Higher Education* 15 (2): 128–141. doi:10.1108/IJSHE-03-2012-0025.

Walz, K. A., and S. C. Kerr. 2007. "'Holes' in Student Understanding: Addressing Prevalent Misconceptions regarding Atmospheric Environmental Chemistry." *Journal of Chemical Education* 84 (10): 1693. doi:10.1021/ed084p1693.

Whitmarsh, L., S. O'Neill, and I. Lorenzoni. 2011. *Engaging the Public with Climate Change: Behaviour Change and Communication*. London, UK: Earthscan.