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Integrating Environmental Knowledge into a Short Interdisciplinary Course on Sustainability

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ABSTRACT

This study examines the efficacy of a novel college sustainability course in promoting relevant environmental knowledge and interest in careers related to environmental aspects within the Taiwanese educational context. The core content of the course covers the essential concepts of sustainability and introduces students to environmental issues and their interrelation with the nexus of food, energy, and water, as well as related economic and social issues. This action competence-focused course was designed to allow students to develop their understanding of sustainability through a combination of engaging lectures, novel group activities, case studies, exercises, and team projects. The sample consisted of 44 Taiwanese undergraduate and graduate students majoring in the science, technology, engineering, and mathematics (STEM) disciplines. Participants' interest in STEM careers and perceived knowledge were measured by a pre-test and post-test administered before and after the program, respectively. Analyses of variance, correlation analyses, and cross-lagged panel regression analyses were conducted to test four hypotheses. Results of repeated-measure analysis of covariance indicated that knowledge increased significantly from pre-test to post-test, but not career interest. Results of a cross-lagged panel regression analysis also indicated that pre-test knowledge was a significant positive predictor of post-test career interest. By creating an engaging class atmosphere and promoting experiential self-learning activities, this course was highly effective in enhancing students' knowledge of key sustainability aspects. Implications for interest development theory and sustainability pedagogy are also discussed.

Keywords: environmental knowledge, sustainability, sustainable development goals, interdisciplinary course, STEM, career planning, Taiwan

Introduction

Sustainable development refers to meeting the needs of the present without compromising the ability of future generations to satisfy their own needs (Brundtland, 1987; Borowy, 2021). Eight millennium development goals were adopted for a 15-year period (United Nations Report, 2015), and these goals have been broadened into 17 sustainable development goals (United Nations Report, 2016). The United Nations declared 2004-2015 the Decade for Sustainable Development and introduced the Principles for Responsible Management Education to enhance and extend

Sustainability into mainstream education. Education for sustainability allows for the development of knowledge, skills, values, and broader perspectives necessary for people to act in ways that contribute to sustainable living by better understanding of environmental, social, cultural and economic systems and their interdependence. Evans et al. (2017) emphasized the need for a more systematic and cross-disciplinary approach to sustainability education with interactive teaching and learning methods. Aikens et al. (2016) noted that not all sustainability programs focus on topics such as climate change policy and intersectionality. Numerous sustainability courses lack interdisciplinary coverage on key topics. The learning processes include collaboration and dialogue; engaging the "whole system"; innovating curriculum as well as teaching and learning experiences; and processes of active and participatory learning, with assessment of learning processes and outcomes relationship.

Programs that focus on sustainable development are structured to achieve the following goal for students: encourage students to enhance their environmental knowledge to gain a broad understanding of sustainable development goals. Environmental educators have four responsibilities while avoiding indoctrination: (1) help learners understand why sustainable development ought to be of interest to them; (2) help students gain multiple perspectives on issues; (3) help students understand what they are learning and its significance; and finally (4) encourage students to continue to think about what to do, individually and socially, to keep their own and others' options open (Qablan et al., 2011; Scott, 2002). Kasimov et al. (2002) explained that guiding principles related to sustainability, environmentalism, economics, and social well-being need to be emphasized in education for sustainability. Owusu et al. (2017) stated that business students' interest in environmental issues is positively related to their environmental literacy levels; moreover, once they have a deeper understanding of environmental issues, they are more likely to be involved in environmental activities.

Charatsari and Lioutas (2018) found that participation in a short environmental education course provides students with higher levels of environmental knowledge and a more holistic understanding of the environment, while it also increases the impacts of environmental education in higher education and recommends the introduction of environmental education in curricula to facilitate the development of environmental thinking. A novel concept has been implemented by creating the University Regional Research Consortium for environmental monitoring and protection to improve education applicability (Şterbuleac & Toma, 2019). By forming relations with community members and decision-makers, a university offers ways of managing current environmental challenges (Şterbuleac & Toma, 2020). Choudhary et al. (2019) report that students with a science background are more likely to have higher levels of interest, knowledge, participation, and contribution toward the environment compared to students with non-science backgrounds.

Jensen and Schnack (1997) recommended the concept of *action competence* in environmental education, making the argument that environmental issues are deeply rooted in societies. Action competence was defined as relevant *knowledge*, *self-efficacy*, and *willingness* in three constructs: (1) knowledge of action possibilities; (2) confidence in one's own influence; and (3) the willingness to act (Breiting & Mogensen,1999; Jensen & Schnack, 1997; Olsson et al., 2020). Olsson et al. (2020) further defined action competence:

> In the action competence concept, which we here define as a latent capacity among individuals, the need for meaningful actions is described as the willingness to act for sustainability (p. 745).

Sass et al. (2021) emphasized the importance in action competence in sustainable development (ACiSD) and considered it as the desired outcome of education for sustainable development (ESD). Environmental education enables students to act on both societal and personal levels. Furthermore, Miller et al. (2021) found that, after an internship sustainability program, university students' environmental knowledge increases.

Taiwan, in particular, faces significant sustainability challenges. Due to its comparative disadvantage in agricultural production, the self-sufficiency rate in calorie-based calculations of staple food was 26.31% in 2021 (Taiwan Ministry of Agriculture, 2023). Another major challenge is related to the environment. As one of the most densely populated places in the world, Taiwan has to deal with the growing problem of microplastics, and food and electronic waste. In addition, its renewable energy sufficiency is also a concern as the country's electricity generation still mainly relies on thermal energy, while only less than 10% is from renewable sources (Bureau of Energy, Ministry of Economic Affairs, 2022). By 2025, the planned target is to have 20% renewable energy. In light of the nuclear disaster that occurred in March 2011 in Fukushima, Japan, Taiwan initiated the decommission of its nuclear power plants, which contributes to less than 10% of the nation's electricity. Plans are underway to replace these old nuclear power plants with thermal, hydropower, and wind energy.

Moreover, research has demonstrated that while students in Taiwan frequently show interest in sustainability and environmental issues, they rarely connect it to the nexus of food, water, and energy or to government policy, focusing instead on individual actions, such as recycling (Hsu & Pivec, 2021). They also appear to lack sufficient knowledge of climate change (Li & Liu, 2021). However, individual actions and behavior alone would be insufficient to solve the issues relating to sustainability and the linkages between energy, water, and food. The gravity of the environmental situation in Taiwan requires the development of a workforce with comprehensive sustainability knowledge and the occupational skills needed to address these crucial challenges. To do this, educators are encouraged to stimulate students' interest in pursuing careers in the fields of science, technology, engineering, and mathematics (STEM), in which environmental innovations will primarily be developed (Vennix et al., 2018). Furthermore, sustainable development courses should emphasize the linkages between food, water, and energy, and their relationship to government policy to ensure that sustainability knowledge and interests are broad enough to enable Taiwanese students to comprehensively understand the environmental issues that face Taiwan and the world beyond it.

The purpose of this study was to examine the efficacy of a novel college sustainability course in promoting relevant knowledge and STEM career interests related to environmental aspects of sustainability within a Taiwanese educational context. In Taiwan, short integrated and interdisciplinary courses focusing on sustainability is a fairly new concept in local education. Moreover, our course was taught in English and it delivers the cutting-edge knowledge in sustainability to students with its original formality in content. Hence, our course was considered as a novel college sustainability course since its concept and teaching method were new to college students in Taiwan. The four-day course was titled *Sustainable Development: Environmental, Economical, Managerial, and Health Perspectives: Inspiring Future Leaders in Sustainable Development,* and course schedules are described in Appendix I. The primary objectives of the course were to improve students' knowledge of the following:

(1) The major challenges of energy, food, and water consumption
(2) The management of natural resources and sustainability
(3) The impact of technology on sustainability and climate change
(4) Economic, business, and managerial perspectives on sustainable development.

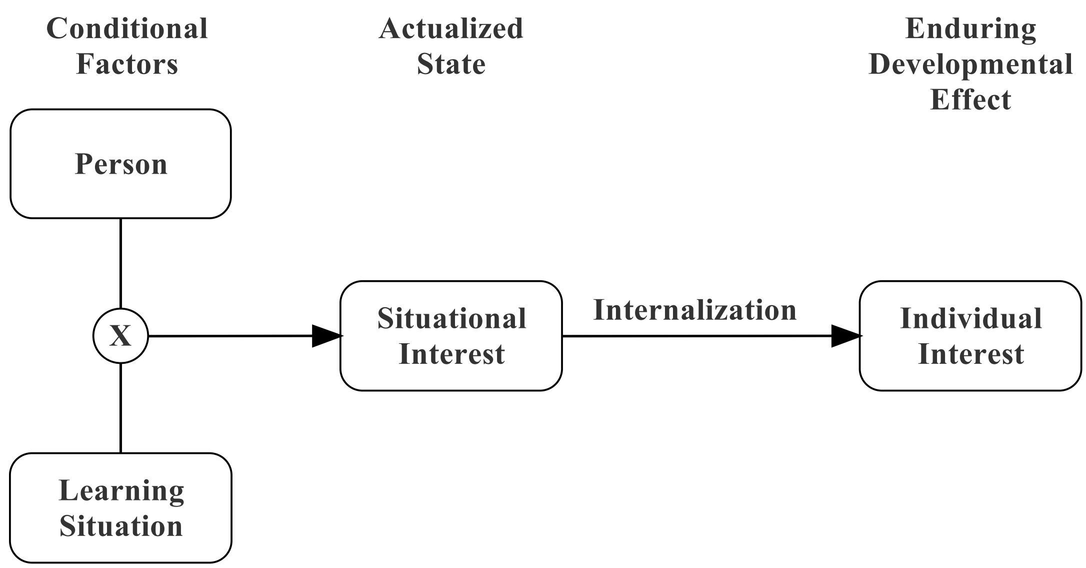
STEM education has a fundamental role in advancing technology, medicine, sustainability, agriculture, national security, economy, and society. STEM courses encourage finding the most viable global problems without necessarily considering the most sustainable option. To prepare STEM students to become potential change agents, they must learn to apply their knowledge to the three pillars of sustainability: economic, environmental, and social. An integration of sustainability into STEM courses is much needed (Zizka et al., 2021). We note that students may enter STEM careers not only to become practitioners but also to educate others about sustainability. However, in this study, we limited our focus to students who were primarily interested in careers in STEM practice rather than STEM pedagogy. This article has been organized into the following sections: theoretical framework, teaching sustainability, hypothesis development, teaching methodology, results, discussion, limitations, future research, and conclusions.

Theoretical Framework

We integrated two theoretical perspectives to examine the sustainability course: the Person–Object Theory of Interest (POI) (Krapp, 2002) and Alexander's Model of Domain Learning (MDL) (Alexander, 2004; Alexander et al., 1994). The POI posits that interest develops as a function of the relationship between a person and their life space. See Figure 1 for the person-object theory of interest model.

Figure 1

Model of the Person–object Theory of Interest Development



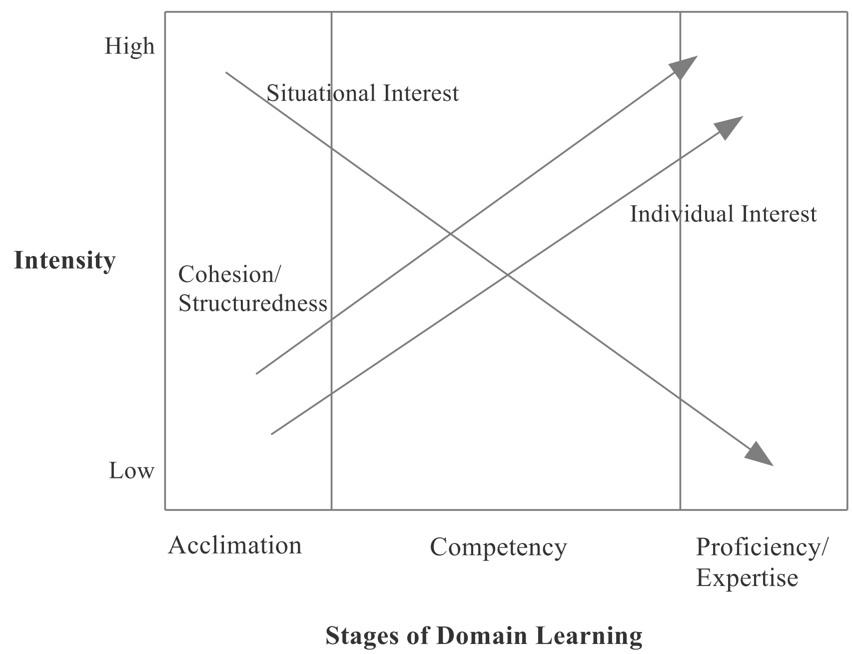
Note. Situational interests in this study are defined as the interest shown by students for the various problem-based learning emphasized in the course. Figure adapted from "Structural and dynamic aspects of interest development: Theoretical considerations from an ontogenetic perspective," by A. Krapp, 2002, p. 398. Copyright 2002 by Elsevier

From a personality theory perspective, this interest is assumed to develop through the connections made between an object of interest and the attitudes and feelings that define an individual, which are stable across situations and time. This type of interest is referred to as *individual interest.* However, interest can also be activated through transient interaction with an object or task. This structural component of interest, referred to as *situational interest*, is primarily determined by the features of the task and is characterized by heightened attention and affective engagement (Hidi, 2000; Hidi & Harackiewicz, 2001). The interaction of the person with the object—which can represent a concrete object, subject matter, or idea (Krapp & Prenzel, 2001)—is theorized to lead to the development of situational interest, which is then internalized over time as individual interest.

The MDL builds upon the POI by incorporating both situational and individual interests into a model that posits both as a function of domain and topic knowledge. See Figure 2 for information.

Figure 2

Model of Domain Learning (Alexander, 2004, pp. 273–298)



Note. From "A model of domain learning: Reinterpreting expertise as a multidimensional, multistage process." In D. Y. Dai and R. J. Sternberg (Eds.), Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development (pp. 273–298). Lawrence Erlbaum. Copyright by Lawrence Erlbaum.

According to this theory, domain learning occurs across three stages: acclimation, competency, and proficiency or expertise. Learners who are acclimating to the knowledge domain are theorized to possess high situational interest due to the novelty of the task. As learners develop competence in a domain, their situational interest declines. However, with declining situational interest, there is a concomitant increase in individual interest as the learner's competence increases and learning becomes more formalized and structured. We grounded the current study in this theoretical framework because other theories of interest development (e.g., Lent et al., 1994) focus exclusively on trait-like interest development rather than focusing equally on trait- and situation-based determinants of individual interest.

Empirical evidence supports both theoretical propositions. For instance, Tröbst et al. (2016) indicated that elementary students' perceptions of science instruction by their teachers were positively associated with the development of individual interest. Moreover, Tröbst et al. (2016) demonstrated that situational interest mediated this relationship, thus indicating that situational interest functions as a temporal antecedent of individual interest. Research has also shown that interaction with particular mathematical tasks (e.g., calculation) is positively associated with the development of interest in these tasks, as well as mathematics interest in general (Ufer et al., 2017). Studies employing pretest-posttest designs among college-aged students also suggest that effective teaching strategies can increase situational interest in STEM domains such as marine biology (e.g., Seidelin et al., 2021). Research focusing specifically on the MDL has also supported its theoretical propositions. In a sample of college students, Murphy and Alexander (2002) found that pretest interest in psychological subject matter was associated with increased interactive knowledge, which in turn predicted an increase in posttest subject-matter knowledge. Studies have also supported the theory's tenets among undergraduate students in the life and physical sciences. For instance, Alexander et al. (1995) found that participants with greater knowledge of immunology displayed higher interest in and recall of information on the topic than participants with less immunology knowledge. Similarly, Alexander et al. (1994) demonstrated that domain knowledge of physics was a positive predictor of both interest in physics and later recall of physics information. Despite these supportive findings, there remains a dearth of research on these interest development models among undergraduate students in STEM, which underscores the critical need for the present research. Moreover, there is not only a need to increase students' interest in conducting research in these STEM domains. There is also a need to raise students' awareness of the connections of STEM research topics to broader non-STEM issues (e.g., public policy, economics, politics) that are also implicated in discussions of environmental sustainability. The current research aims to unify these topics in this way.

Current Study

Numerous studies have supported the efficacy of interventions aimed at altering both environmental sustainability (e.g., Lehman & Geller, 2004) and science-related attitudes (e.g., Deemer & Sharma, 2019). Therefore, our first two hypotheses are as follows:

Hypothesis 1: Participants' perceptions of knowledge of environmental and sustainability issues will increase significantly from pre-test to post-test.

Hypothesis 2: Participants' individual interest in STEM careers will increase significantly from pre-test to post-test.

Given that prior knowledge provides a foundation for the development of individual interest (Alexander, 2004)—a finding that has been demonstrated consistently across STEM subject domains (e.g., Durik & Matarazzo, 2009; Tapola et al., 2013)—we expected that antecedent perceptions of knowledge would be associated with subsequent career interest. Hence,

Hypothesis 3: Participants' perceptions of knowledge of environmental sustainability at pre-test will be a significant positive predictor of STEM career interest at post-test.

Finally, MDL suggests that the relationship between knowledge and interest should strengthen with increasing exposure to an academic domain (Alexander, 2004). Lawless and Kulikowich (2006) obtained support for this assertion by finding that the correlation between these variables increases as students advance from undergraduate to graduate study. Therefore,

Hypothesis 4: The positive correlation between post-test knowledge and post-test interest will be significantly stronger than the positive correlation between pre-test knowledge and post-test interest.

Method

Course Contexts

The data presented here was collected during a four-day course that met during fall break in September 2018. Prior to the program, participants completed a pre-test which consisted of demographic, STEM career interests, and perceived knowledge questionnaires. In terms of the curriculum, the sustainability module was presented on the first day, the energy and technology modules were presented on the second day, the managerial, global health, and nexus modules were delivered on the third day, and students presented the results of their group projects on the fourth day. At the conclusion of all program activities, the participants were asked to complete a post-test survey that assessed their STEM career interests and perceived knowledge. We administered all surveys online.

We implemented revised course contents and teaching methodology from the pilot study conducted in 2016 through 2017. A more comprehensive questionnaire was used in administrating the survey since the course design covers a wide range of topics relevant to STEM careers, which may be of interest in career development for participants. The sustainability short course lasted for four days, which is not a typical duration for college-level courses in Taiwan. A typical university course is of three credits, with an approximately three-hour weekly class across 15-18 weeks. A short learning course is offered with less lecturing hours. Effectiveness of short learning courses are evaluated for the benefit of improving the students' self-efficacy (Judge et al., 2020); improving knowledge and skills (Argimon-Pallàs et al., 2011); and improving student communication skills (Hazelton et al., 2009). In this research, our course was considered short as it was offered for one credit hour, which is 18 hours in total. The short course provided enough data to test four hypotheses, all of which were grounded in the POI and MDL frameworks.

Our teaching methodology was developed in a short course for university students and implemented over the course of 3 years (i.e., 2016, 2017, and 2018) at two national universities in Taiwan. Revised course data was collected in 2016 and 2017 to modify and refine the course content and teaching methodology. Only data collected in 2018 are presented in this research. Despite a small sample size, we subjected the data collected in 2018 to empirical investigation to assess the preliminary efficacy of the pedagogical intervention.

Participants

The sample consisted of a total of 44 Taiwanese students majoring in STEM disciplines: 30 undergraduate students (five freshmen, six sophomores, nine juniors, and 10 seniors) and 14 graduate students. The majority of students (n = 37) were from National Chung Hsing University (NCHU) in Taiwan because few students were recommended to join the course by their advisors at other universities. As long as their majors were within the spectrum of STEM disciplines and they had language proficiency in English, they were qualified to participate in the program. Twenty-six participants identified as female and 18 identified as male. The participants' mean age was 20.49 years, with an average of 2.07 college courses (SD = 1.02), in which they had previously learned about some aspects of energy, water, food, environment, and health-related topics. Most of these courses were in economics (n = 25), followed by biology (n = 20), earth science (n = 13), chemistry (n = 12), technology (n = 9), physics (n = 3), and sociology (n = 1).

Measures

STEM Career Interest

Participants' interest in STEM careers was measured with a pre-test and post-test administered before and after the program using five items developed by the first author. These items asked participants to rate their interest in the following career domains: (a) science, (b) technology, (c) engineering, (d) environment, and (e) mathematics. Specifically, the item for each domain was as follows: "How would you rate your interest in (science, technology, engineering, environment, or mathematics)?" Items were rated on a Likert-type scale ranging from 1 to 4 (1 = never considered; 2 = very weak; 3 = moderate; 4 = very strong) (e.g., see Appendix II and III) and summed to create a composite score. Cronbach's alpha coefficients of .70 and .88 were obtained at pre-test and post-test, respectively.

Perceived Knowledge

Participants' perceptions of their knowledge of various issues related to environmental education were assessed using 10 items developed by the first author (see Appendix II). Items were rated on a Likert-type scale ranging from 1 to 5 (1 = not much; 2 = very little; 3 = a moderate amount; 4 = a considerable amount; 5 = a great deal). The scale exhibited excellent internal consistency reliability at pre-test ($\alpha = .86$) and post-test ($\alpha = .93$).

Course Curriculum

A pedagogical strategy is to focus on action competence in delivering courses. Education for sustainability is about engaging students with the world they live and developing the ability to act for a sustainable future. The teaching and learning approaches can include experiential learning, cooperative learning, problem-based learning, and inquiry-based learning. These approaches prepare students to be active participants, empower their capability of deliberating causes and effects, and constructs their visions for finding strategies toward solving sustainably problems. There has been a sharp increase in interdisciplinary teaching of sustainable development within environmental education (Chen & Liu, 2020; Jensen & Schnack, 1997). Examples of topics included in courses are sustainability or sustainable development, natural resources, environmental health, and global warming. Most of the courses were at the intervals of one week to one semester and reported positive outcomes (Chen & Lu, 2020). Pedagogical strategies and active learning included role-plays and simulations, group discussions, stimulus activities, debates, critical incidents, case studies, reflective accounts, critical reading and writing, problem-based learning, fieldwork and outdoor learning, modeling good practices, and seeing the big picture (Tilbury, 2011).

The lectures were chosen to provide a broader understanding of sustainability and sustainable development goals. A four-day framework was chosen to fit the course during fall break. We organized the lectures into two sessions per day, and each session focused on a different aspect of sustainability. At the start of the course, an "ice-breaker" session facilitated team-building. Appendix I shows details of the course curriculum and activities (introduction/icebreaker, lectures, open discussion, break, group projects, team buildings games, case studies, group presentations, and prize distribution). Interactive learning was incorporated as instructors encouraged students to ask questions and work in teams to respond to questions. Peer-to-peer student interactions were encouraged in providing broader perspectives and applying sustainability/sustainable development knowledge to increase their STEM career interests.

The course was divided into a series of lectures or sessions that discussed the various aspects of sustainability and its relationship with the environment, the energy, food and water nexus, global health, and related economic policy. Our lectures also included several pertinent case studies. The various topics of discussion or sessions were as follows.

Global Sustainability Challenges of the 21st Century. We defined sustainable development (Redclift, 2006) and discussed its impacts on policies relating to energy, climate and environment, water, and food security.

Energy Resources: Fossils and Renewables. In the first part of the lecture, students were introduced to three primary types of energy sources—fossil, renewable, and nuclear. The second part of the lecture included renewable forms of energy (i.e., solar, hydropower, wind, geothermal, and biomass).

Electricity Grid and Energy Storage. Two core concepts were covered in this lecture: energy storage (Luo et al., 2015) and electrical grids (Diamantoulakis et al., 2015).

Energy Utilization. We introduced students to the main energy-consuming sectors (U.S. Energy Information Administration, 2018): the industrial sector, the transportation sector, the residential sector, the commercial sector, and the electric power sector.

Food and Water. We introduced the concept of food security (Misra, 2014). We then outlined the four main dimensions of food security: availability, access, utilization, and stability. We also discussed the sources and usage of water, the water cycle, water availability, and the water footprint network (Gunders, 2012; Provide Access to Clean Water, 2018).

Environment and Climate. This session introduced students to the global environmental challenges brought about by human activity, the growth of the human population, and the increased stress that humans place on the biosphere (National Research Council, 2001; Rockström et al., 2009).

Economics and Business. In this session, students studied energy economics and commodities. In addition, we discussed policies, regulations, and the concept of a circular economy (McKinsey Center for Business and Environment, 2016; Castillo et al., 2018; Coyle & Simons, 2014).

Global Health. In this lecture, health as it refers to the global population, was discussed. Global health is defined as the "area of study, research, and practice that places priority on improving equity in health for all people worldwide" (Kaplan et al., 2009, para. 1).

NEXUS Perspective: Interdependencies and Interconnectedness. The water, energy, and food security nexus refers to the inextricable link between water security, energy security, and food security—actions in any one area usually have impacts in one or both of the others (D'Odorico et al., 2018). As the world population approaches nine billion and demands for basic services and the desire for higher living standards increase, the need for more conscious stewardship of the vital resources required to meet those demands and desires has become both more obvious and urgent. A nexus approach can enhance water, energy, and food security by increasing efficiency, reducing trade-offs, building synergies, and improving governance across sectors. A nexus approach is a requirement for effective policies to benefit society.

Case Studies on Environmental Impact. Several case studies were presented throughout the course. The selected case studies investigated the effects of industrial development activities or disasters on the environment, communities, and public health. These included the Fukushima disaster (American Nuclear Society, 2012), the BP Oil spill (National Academy of Engineering & National Research Council, 2012), and Nam Theun 2, a hydropower dam project in Laos (The World Bank, 2018).

Teaching Methodology

In the past few decades, interdisciplinary courses have greatly increased (e.g., neuroscience, molecular biology, and environmental sciences; Lattuca & Voigt, 2022). An interdisciplinary course is organized around a topic, broadly defined as an issue, theme, or problem. Interdisciplinary courses offer an alternative to traditional knowledge production processes in that they seek to be integrative and holistic understandings of the social and natural worlds. An interdisciplinary pedagogy emphasizes an innovative approach to student-centered learning processes in developing their skills: evaluation, synthesis, integration, higher-order critical thinking, and problem-solving. Interdisciplinary courses allow students to develop the ability to tolerate multiple perspectives, to broaden horizons, and to increase willingness and capacity to question assumptions about the world and themselves.

We provided opportunities in this course for both interdisciplinary learning and working in teams to more effectively consolidate the students' understanding of sustainability. Interdisciplinary learning links across different subjects to enhance learning. Team learning involves working in groups to discuss critical issues, role plays, case studies, and sharing and understanding each other's views of the big picture. This interdisciplinary teaching methodology allowed students to learn complex issues related to food, energy, water, policy, and related social and economic issues in a novel and interactive manner. Figure 3 shows interactive learning in the classroom, and Figure 4 shows the students leading discussions.

Figures 3 and 4

Students Leading Discussions

Students were teamed in small groups. Students were encouraged to lead the discussion and also discuss their topics among themselves (interactive and peer-to-peer learning). The role of the instructors was to facilitate discussion within team members as well as among teams. Students were encouraged to discuss their topics among themselves (interactive and peer-to-peer learning).

Team-Building Games

In order to encourage learning in an enjoyable and retainable manner, we played several sustainability-themed games throughout the course. These included "Paying for Predictions," "Nuclear Jeopardy," and "Sustainability Jeopardy." These covered aspects of sustainability that were discussed throughout the course.

Grading and Projects

We determined the students' grades on the basis of their performance on a mid-term exam, a final exam, their in-class participation, and a group project. For the final project, the class was split into groups of four or six students, and each group was assigned a different project topic. Project titles included "Food Waste in Taiwan," "Plastic Waste in Taiwan and Policy," "Case Study: Water Pollution in Taiwan," "Circular Economy and Paper Industry in Taiwan," "Recycling Disposable Chopsticks in Taiwan," "Energy Policy in Taiwan," and "Climate Change in Taiwan." The goal of these group projects was to help students think critically about a given problem related to Taiwan, identify possible solutions, and then analyze the pros and cons of these solutions. At the end of the course the students were required to submit a project report and deliver a short team presentation. Figure 5 and Figure 6 represent pictures of students making presentations on "Food Security in Taiwan" and "Plastic Pollution in Taiwan."

Figures 5 and 6

Student Presentations on "Food Security in Taiwan" and "Plastic Pollution in Taiwan


Students were teamed in groups of four to six people. Teams were given a range of topics to work on team projects. These topics were cutting edge and key issues related to sustainability and environment, food, energy, water, climate. Teams were assigned time every day during the course period to interact with the teaching assistant and instructors to research their topics. Finally, students delivered a 15 minute team presentation to the whole class on the last day of the course: introduce topic, what did you research, what is the gap, what are possible technology solutions and policy recommendations to implement, and finally answer any questions from their peer students. Team presentations were graded on contents, and delivery. Teams also worked outside the class room to discuss their topic.

Data Analytics

Several analytical methods were applied in this study to examine the relationships between pretest and posttest for participants in their career interest in STEM and perceived knowledge. Zero-order correlations, analysis of covariance (ANCOVA), Fisher's r–to–z transformations and z-tests, and path analysis were utilized in data analytics. ANCOVA is a suitable analytical method since the data represented participants' STEM career interest and perceived knowledge in pre- and post-tests. Path analysis is used to reveal whether perceived knowledge at pre-test can be a significant predictor of career interest at post-test.

Results

Zero-order correlations are presented in Table 1.

Table 1

Zero-Order Correlations Among the Study Variables

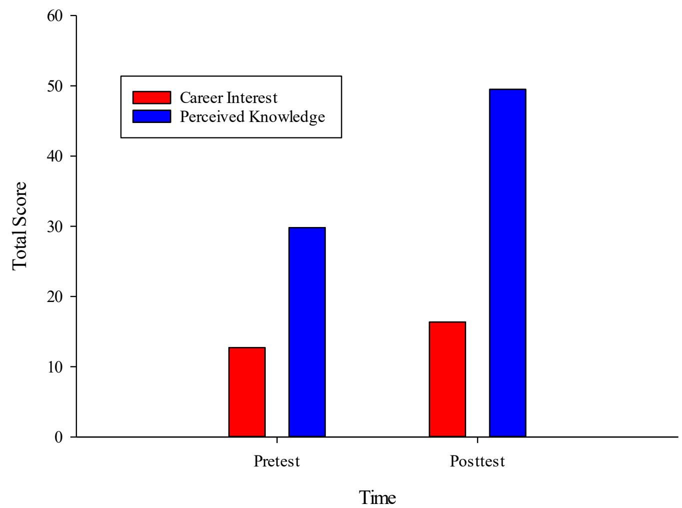
Variable	1	2	3	4
1. Pre-test career interest	—			
2. Post-test career interest	.50***	—		
3. Pre-test perceived knowledge	.19	.34*	—	
4. Post-test perceived knowledge	.09	.32*	.30*	—
5. *M*	12.72	16.36	29.82	49.50
6. *SD*	3.06	3.51	6.34	5.49

Note. * $p < .05$. *** $p < .001$

A bar graph of pre-test and post-test means for STEM career interest and perceived knowledge is also shown in Figure 7.

Figure 7

Pre-test and Post-test Means for STEM Career Interest and Perceived Knowledge



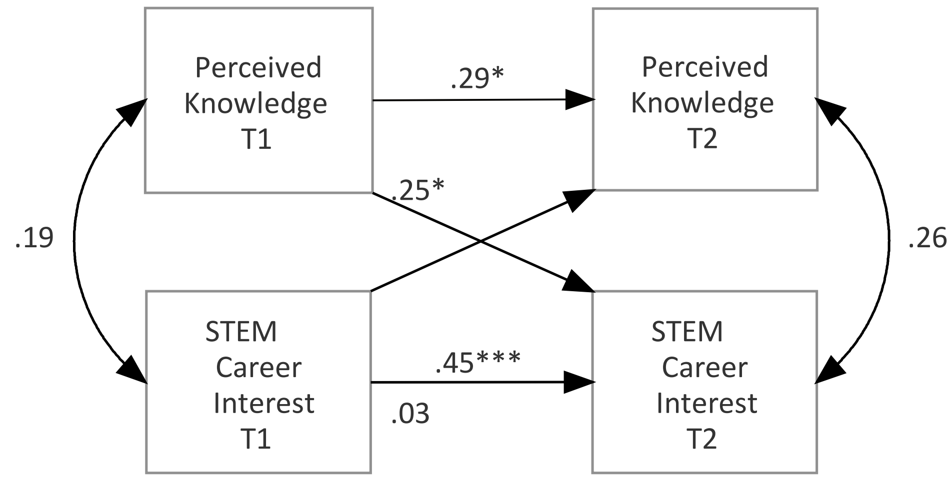
Pre-test career interest was positively and significantly correlated with post-test career interest ($r = .50$, $p < .001$), while pre-test perceived knowledge was also significantly associated with post-test perceived knowledge ($r = .30$, $p < .05$). Analysis of our four hypotheses is discussed below.

Our first hypothesis is that participants' perceptions of knowledge of environmental and sustainability increase significantly from pre-test to post-test. Our second hypothesis is that participants' individual interest in STEM careers will increase significantly from pre-test to post-test. To test the above two hypotheses, we conducted a repeated-measures analysis of covariance (ANCOVA) with time as the within-subject factor for both STEM career interest and perceived knowledge. We controlled for gender, program year, and the number of previous courses in which participants indicated they had learned about sustainability. Results revealed a significant multivariate effect of time (Pillai's $V = .50$, F (2, 39) = 19.48, $p < .001$, partial $\eta^2 = .50$). Despite this finding, follow-up univariate ANCOVAs indicated that only perceived knowledge increased significantly (F (1, 40) = 35.02, $p < .001$, partial $\eta^2 = .47$), from pre-test ($M = 29.82$, $SD = 6.34$) to post-test ($M = 49.50$, $SD = 6.34$). The effect of time for career interest approached significance, but it did not quite meet this threshold (F (1, 40) = 3.45, $p = .07$, partial $\eta^2 = .08$).

Our third hypothesis is that participants' knowledge of environmental sustainability at pre-test will be a significant positive predictor of STEM career interest at post-test. To test this hypothesis, we applied a cross-lagged panel regression model. To apply this model, we regressed the post-test interest and knowledge variables on their pre-test counterparts using path analysis. Results indicated that there were significant autoregressive effects, as pre-test interest was a significant positive predictor of post-test interest ($\beta = .45$, $p < .001$), and pre-test knowledge was a significant positive predictor of post-test knowledge ($\beta = .29$, $p = .04$). Importantly, perceived knowledge at pre-test was a significant positive predictor of career interest at post-test ($\beta = .25$, $p = .04$), thus supporting hypothesis three. See Figure 8 for information.

Figure 8

Cross-lagged Panel Model of STEM Career Interest Development



Our fourth hypothesis is that the positive correlation between post-test knowledge and post-test interest will be significantly stronger than the positive correlation between pre-test knowledge and post-test interest. To test this hypothesis, we converted the pre-test and post-test knowledge-interest correlations to *z*-scores using Fisher's *r*–to–*z* transformations and then performed a *z*-test on the difference between the two *z*-scores. Interestingly, the correlation between career interest and perceived knowledge was not significant at pre-test (r = .19, p = .21), but this relationship was significant at post-test (r = .32, p = .03). Nevertheless, results indicated that the difference between these correlations was not significant (z = -.33, p = .74); therefore, hypothesis four was not supported.

Discussion

The purpose of this study was to examine the efficacy of a novel college sustainability course in promoting relevant knowledge and interest in careers related to sustainability within a Taiwanese educational context for the purpose of raising awareness. Results from this study indicated that after participating in the course, students show improvement in their knowledge, interest, and self-efficacy over topics relating to sustainability.

The intervention was effective in increasing students' perceptions of knowledge, as their scores on the knowledge measure increased nearly 20 points from pre-test to post-test, supporting our first hypothesis regarding increased knowledge of environmental and sustainability issues. Our second hypothesis is not supported, as the increase in STEM career interest that was observed from pre-test to post-test—as predicted by the POI (person–object theory of interest) —was not statistically significant. The lack of a significant finding with respect to the second hypothesis regarding increased interest in STEM careers may be explained by the MDL (Alexander's model of domain learning). That is, the MDL states that individual interest should increase linearly as the learner's proficiency and knowledge structure becomes more coherent. Participants in our study may have developed subject matter proficiency over the course of the intervention, but one week affords little time to form a cohesive knowledge structure. However, information from multiple interdisciplinary fields relating to sustainability was introduced to the students during the course. Students were also required to participate in team discussions and at the end of the course, students delivered team presentations.

Hence, the amount of information students received and the coursework students had to do were considered intensive. If more time could be added to the course for other interactive activities such as field trips, the outcome of this short course would be even more effective, especially in terms of delivering a more cohesive knowledge to students.

The finding regarding hypothesis 3 is consistent with the MDL assertion that domain knowledge should provide a foundation for the development of interest over time. Exposure to a novel area of learning is a necessary precondition for students to develop the curiosity, attention, and enjoyment that is so critical to capturing interest in a task. Although we did not measure situational interest explicitly, it appears that greater understanding of the tasks that the participants were exposed to contributed to the formation of broader and more stable interest in STEM careers in general. This is consistent with previous findings which suggest that domain knowledge is positively associated with individual interest in STEM disciplines such as physics (Alexander et al., 1994; Tapola et al., 2013) and biology (Alexander et al., 1995; Durik & Matarazzo, 2009). The post-test correlation between knowledge and interest was not significantly stronger than the pre-test correlation between these variables, thus our fourth hypothesis was not supported. While the difference between the correlations was not statistically significant, our results are not inconsistent with the POI since there was a significant positive correlation between post-test career interest and post-test perceived knowledge. In our view, this represents preliminary evidence that the interaction of students with their learning environment fosters the development of interest. The lack of a significant finding may be due to insufficient statistical power given the relatively small sample size. Future research would do well to conduct a more robust test of this hypothesis with larger samples.

Our findings build upon the literature by demonstrating that knowledge within a unique environmental STEM domain is an important precursor to the development of interest in STEM careers. Why the participants expressed interest in these careers may be explained by their view of these careers being instrumental in helping them solve global challenges, such as climate change, food insecurity, and global health, or they may be interested in them for intrinsic reasons. In other words, they may see these careers as opportunities to achieve important personal or societal objectives, or they may simply be interested in STEM careers. Interestingly, our results showed no association between initial interest in STEM careers and greater acquisition of knowledge at a later point in time. The fact that initial knowledge was predictive of later interest, while the converse relationship (initial interest and later knowledge) was not significant, lends support to the MDL notion that proficiency in an academic domain is a necessary precondition for interest to develop.

Limitations and Future Research

As with any study, this one has limitations worth considering. As discussed in the results section, the sample was from a university in Taiwan. We recommend that future research examining the efficacy of similar courses be conducted with a larger sample of students from other cultures. We also did not directly measure participants' perceptions of situational interest following particular tasks. Thus, explicit connections between situational interest and STEM career interest could not be assessed. Future research evaluating the value of situational interest as a predictor of interest in STEM careers or even the more specific domain of environmental sustainability would be fruitful. Second, due to the lack of a control group, we cannot assume a causal relationship between the course and the observed effects. Although we statistically controlled for gender, academic classification, and prior knowledge (i.e., the number of previous courses in which students learned about sustainability), we could not make strong inferences of causality. Future research could build upon these results by including a control group or a comparison group that is exposed to a similar course or intervention. Furthermore, the efficacy of the intervention may have been limited by its selected short duration during fall break. Future research would do well to lengthen this or similar interventions to ensure that students' STEM career interests are sufficiently exposed to attitude-changing information. Furthermore, future research should also follow (e.g., a longitudinal study) the progress of students' career intentions throughout their years at university and may even include a post-graduation period to determine if their career choices are related to their initial interests in STEM subjects.

Future course offerings will aim to integrate other improvements into the curriculum and course structure. Students may be taken on tours of multiple industrial facilities to observe real world problems or document how they operate and affect sustainability. They will also be given the opportunity to work on industry-related projects by collaborating with local industrial partners. This will allow them to develop marketable skills and become competitive candidates when they decide to join the workforce. Another goal we have is to develop and expand the current course into a certificate or degree program in sustainability. Finally, to generalize our findings, it is important that future researchers reproduce this pilot study in other global settings and educational systems.

Conclusions

The four-day short sustainability development course introduces students to the environmental aspect through its interdependence with the nexus of energy, food, water, health, and economic considerations. The core content of the course described in this study covers the essential concepts of sustainability and introduces students to the environmental aspect through its interdependence with the nexus of energy, food, and water, health, and economic considerations. By creating an engaging class atmosphere with open-ended discussions and promoting experiential self-learning activities among the students, our findings suggest that this course was highly effective in enhancing the students' knowledge of key sustainability topics. Furthermore, the activities in the course such as group discussions, projects, and case studies helped to validate their understanding, broaden their perspectives, and allow them to appreciate the importance of the environment and sustainability.

This study's major contribution lies in the fact that it demonstrated the efficacy of a course that integrates environmental awareness in an engaging manner into STEM learning. It provided an opportunity for students to connect what they learn in the classroom to prominent socio-environmental concerns and issues of the real world, which they may gain a better understanding of, or even inspired to help solve, through such courses. An approach like this is needed, as some research has shown that sustainability in higher education sometimes fails to integrate environmental actions on campus with social and economic principles emphasized in community engagement projects (Zizka et al., 2021). In particular, Taiwanese university students are frequently limited in their understanding of sustainability issues, which they often see as only being related to individual actions or behavior, such as avoiding the use of straws, recycling plastic products, turning the lights off, and so on (Hsu & Pivec, 2021; Li & Liu, 2021). In particular, focusing on the nexus between energy, food, water and related economic and environment policy would help students gain a broader and more comprehensive understanding of modern sustainability issues.

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Appendix I

Course Schedule: Sustainability for Future Generations - Environmental, Economical, Managerial, and Health Perspectives

September 3rd (Monday)	
12:00-1:00 PM	Luncheon with Faculty and Students
1:00-1:30 PM	Free Time
1:30-2:50 PM	Introduction
2:50-3:00 PM	Break
3:00-4:20 PM	Sustainability Perspective
4:20-5:00 PM	Project Discussion with Instructor
5:00-7:00 PM	TA's Session: Work on Group Project
September 4th (Tuesday)	
10:30 AM -12:00 PM	Energy Perspective: Fossil and Renewable Resources
12:00-1:00 PM	Lunch
1:00-1:30 PM	Free Time
1:30-2:50 PM	Sustainable Agriculture Perspective: Food and Water
2:50-3:00 PM	Break
3:00-4:20 PM	Technology Perspective: Environment and Climate Change
4:20-5:00 PM	Project Discussion with Instructor
5:00-7:00 PM	TA's Session: Work on Group Project
September 5th (Wednesday)	
10:30 AM -12:00 PM	Managerial Perspective: Policies, Politics, and Regulations
12:00-1:00 PM	Lunch
1:00-1:30 PM	Free Time
1:30-2:50 PM	Business and Economics Perspective: Technology Diffusion and Circular Economy
2:50-3:00 PM	Break
3:00-3:55 PM	Global Health Perspective: Life-Style Changes and Diseases
355-4:05 PM	Break
4:05-5:00 PM	NEXUS Perspective: Interdependencies and Interconnections
5:00-7:00 PM	TA's Session: Work on Group Project
September 6th (Thursday)	
Decide your own time	Work in Your Group for Presentations
3:30-5:00 PM	Group Presentations
5:00-5:30 PM	Prizes, Certificate Presentations, and Group Photo
5:30-7:00 PM	Dinner with Faculty, Dean, TA, and Others
7:00 PM	Good Bye

Appendix II

STUDENT PRE-PARTICIPATION SURVEY

1. Name ____
2. Nationality __________________________________
3. Gender _________________
4. In what year were you born? _________________
5. Year in School: __________________________________
6. Which of the following courses did you take in the past 2-3 years (Select all that apply)?

Biology	Chemistry	Mathematics
Earth Science	Economics	Physics
Engineering	Technology	Other (please specify) ___________

7. In which of the following courses have you learned about energy, water, food, environment and health related topics?

Biology	Chemistry	Mathematics
Earth Science	Economics	Physics
Engineering	Technology	Other (please specify) ___________

8. How would you rate your interest in the following careers?

Please <u>circle</u> the most appropriate answer for each statement	Never considered	Very weak	Moderate	Very strong
Math-related career (e.g., accountant, economist,)	1	2	3	4
Science-related career (e.g., biologist, chemist, geologist).	1	2	3	4
Engineering related career.	1	2	3	4
Technology or computer related career.	1	2	3	4
Environment related career.	1	2	3	4

9. What do you know about sustainability?

Not Much				A Great Deal
1	2	3	4	5

Comments:

10. What do you know about energy

Not Much				A Great Deal
1	2	3	4	5

Comments:

11. What do you know about Climate Change?

STUDENT PRE-PARTICIPATION SURVEY

Not Much				A Great Deal
1	2	3	4	5

Comments:

12. What do you know about food?

Not Much				A Great Deal
1	2	3	4	5

Comments:

13. What do you know about water?

Not Much				A Great Deal
1	2	3	4	5

Comments:

14. What do you know about environment?

Not Much				A Great Deal
1	2	3	4	5

Comments:

15. What do you know about the economics of energy?

Not Much				A Great Deal
1	2	3	4	5

Comments:

16. What do you know about policy, politics, regulation, and strategy?

Not Much				A Great Deal
1	2	3	4	5

Comments:

17. What do you know about the nexus of energy, food, water, climate, and environment?

Not Much				A Great Deal
1	2	3	4	5

Comments:

18. What do you know about the circular economy?

Not Much A Great Deal

STUDENT PRE-PARTICIPATION SURVEY

1	2	3	4	5

Comments:

19. What do you know about the global health?

Not Much				A Great Deal
1	2	3	4	5

Comments:

20. What do you hope to learn (or gain) from this course?

Appendix III

STUDENT POST-PARTICIPATION SURVEY

1. Name ______________________________

2. How would you rate your interest in the following careers?

Please circle the most appropriate answer for each statement	Never considered	Very weak	Moderate	Very strong
Math-related career (e.g., accountant, economist,)	1	2	3	4
Science-related career (e.g., biologist, chemist, geologist).	1	2	3	4
Engineering related career.	1	2	3	4
Technology or computer related career.	1	2	3	4
Environment related career.	1	2	3	4

3. What do you know about sustainability?

Not Much — A Great Deal

1 2 3 4 5

Comments:

4. What do you know about energy?

Not Much — A Great Deal

1 2 3 4 5

Comments:

5. What do you know about Climate Change?

Not Much — A Great Deal

1 2 3 4 5

Comments:

6. What do you know about food?

Not Much — A Great Deal

1 2 3 4 5

Comments:

7. What do you know about water?

Not Much — A Great Deal

1 2 3 4 5

Comments:

8. What do you know about Environment?

Not Much — A Great Deal

1 2 3 4 5

STUDENT POST-PARTICIPATION SURVEY

Comments:

9. What do you know about the economics of energy?

Not Much				A Great Deal
1	2	3	4	5

Comments:

10. What do you know about policy, politics, regulation, and strategy?

Not Much				A Great Deal
1	2	3	4	5

Comments:

11. What do you know about the nexus of energy, food, water, climate and environment?

Not Much				A Great Deal
1	2	3	4	5

Comments:

12. What do you know about the circular economy?

Not Much				A Great Deal
1	2	3	4	5

Comments:

13. What do you know about the global health?

Not Much				A Great Deal
1	2	3	4	5

14. What do you know about the natural and man-made disasters?

Not Much				A Great Deal
1	2	3	4	5

Comments:

15. What did you think of the course? What were your major take-aways?

16. What are some things you liked about the course?

STUDENT POST-PARTICIPATION SURVEY

17. What are some things you would suggest changing about the course?

18. Describe – how course was inspiring to think like a leader?