The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/1759-5908.htm

A systems thinking approach to e-learning on climate change: capacity-building for junior high school teachers in the Philippines

John Trixstan Santos Ignacio
Department of Biology, School of Science and Engineering, Ateneo de Manila University, Quezon City, Philippines and Senior High School Department, Chiang Kai Shek College, Tondo, Philippines

Charlotte Kendra Gotangco Gonzales
Department of Environmental Science, School of Science and Engineering, Ateneo de Manila University, Quezon City, Philippines and Ateneo Institute of Sustainability, Ateneo de Manila University, Quezon City, Philippines, and

Queena Lee-Chua
Department of Mathematics, School of Science and Engineering, Ateneo de Manila University, Quezon City, Philippines

Received 15 February 2023
Revised 4 July 2023
Accepted 26 October 2023

Abstract

Purpose – A mixed-method study was performed to determine the impact of integrating systems thinking (ST) into an electronic learning module for junior high school teachers in the Philippines. The study aims to assess how an ST approach to pedagogy compared against a conventional approach in terms of contribution to the participants' global climate change content knowledge, holistic thinking and depth and accuracy of knowledge and reasoning.

Design/methodology/approach – The study implemented e-learning modules using an ST approach versus a conventional approach in teaching climate science to junior high school teachers. The paper presents quantitative data obtained from pre and posttests results of the 20 teacher-participants and qualitative data obtained during the focus-group discussion (FGD) after the implementation of the study.

Findings – The results from the statistical analysis indicated that the ST group obtained a significant increase in their assessment scores compared to the non-ST group, according to predetermined criteria. Content knowledge, depth and accuracy of knowledge and reasoning increased the most. The participants mentioned during the FGD that the module helped deepen their understanding of climate change.

Research limitations/implications – The study was limited to 20 teacher-participants, but it has relevance for public school teachers in the country given that participants had raised concerns regarding the lack of training in their schools for teaching climate science. They admitted that they lacked critical information to include in climate change topics in their classes.

The authors would like to acknowledge the Department of Science and Technology–Science Education Institute (DOST-SEI), for their support through the Capacity Building Program in Science and Mathematics Education (CBPSME) scholarship grants. The corresponding author wants to acknowledge his partner, Wendy S. Villamin, for her support during the study.

Mr John Trixstan Santos Ignacio is no longer associated with Senior High School Department, Chiang Kai Shek College, Tondo, Philippines and updated his affiliation as – Department of Biology, School of Science and Engineering, Ateneo de Manila University, Quezon City, Philippines and Department of Biology, College of Science, De La Salle University, Manila, Philippines.

International Journal of Disaster Resilience in the Built Environment
© Emerald Publishing Limited
1759-5908
DOI 10.1108/IJDRBE-02-2023-0022

Originality/value – This paper shows how the ST approach can be used to teach climate change to junior high students. The e-learning module can provide teachers with better understanding, knowledge and reasoning to teach climate change to high school students more effectively.

Keywords Capacity-building program, Systems thinking, E-learning module, Global climate change, Pedagogy

Paper type Research paper

1. Introduction

Climate change education (CCE) is a significant factor in addressing problems concerning climate-related issues (UNESCO, 2015). When implemented in formal settings such as schools and universities, it gives students the opportunity to participate in conversations about climate change (Chang and Pascua, 2017), which can lead to more informed decisions on consumption and lifestyle, and on appropriate mitigation and adaptation strategies. Knowledge co-production and collaborative research, which are crucial for driving innovative nature-based solutions in cities (Frantzeskaki *et al.*, 2019), would not be viable without solid foundations in climate literacy given that community stakeholders are expected to participate in the process of co-designing strategies fit for the community's context and needs.

However, there are many misconceptions about climate change, and given the complexity of the climate system, it can be difficult to accurately comprehend the interconnections among the different related environmental issues. In addition, educators (e.g. teachers, instructors) themselves are also suffering from misconceptions and lacking in capacity to teach climate change. Liu *et al.* (2015) revealed that most science teachers had misconceptions about the relationship between global warming and the holes in the ozone layer. Li and Liu (2022) diagnosed confusion about the differences between the concepts of weather and climate, between climate change and pollution unconnected to global warming and between the facts and misconceptions about the depletion of stratospheric ozone as a significant cause of global warming. In the Philippines, Garcia and Cobar-Garcia (2022) provided data showing teachers from Manila and Nueva Ecija have insufficient knowledge of climate change. In the Philippine basic education context, these challenges are compounded by the limited time/inclusion of climate change in the curriculum and a compartmentalized approach to education which leave little opportunity for teachers and students to integrate between topics. These challenges show the importance of holistically engaging the education sector in solving climate change and building climate-literate teachers, students and community (Chang and Pascua, 2017).

The pandemic aggravated the challenges in the education sector – schools were largely unprepared for the shift to the online mode. Teachers and learners were confronted with the difficulties in following instructions and assessing the quality of learning, in the midst of other disturbances such as power and internet interruptions, especially during typhoon (Agayon *et al.*, 2022). However, the pandemic also presented an opportunity to develop the remote learning mode to extend reach and access when face-to-face meetings are not feasible (e.g. during extreme weather events or public health crises). Even though schools are gradually opening up to in-person classes, different learning management systems are still being used as modes of instruction in which students can access the learning materials in their subjects (Vergonia and Mombas, 2022). Other steps taken to mitigate the impact on education included revising the curriculum, providing technological resources and infrastructure to both students and teachers and improving instructional deliveries and assessment (Barrot *et al.*, 2021). The Department of Education (DepEd) in the Philippines instituted new curricula for elementary and secondary levels that were supposedly adaptive to the pandemic context, but climate change topics were not prioritized in the prescribed Most Essential Learning Competencies (MELCs). Teachers were allocated a maximum of only 5 h to cover climate change topics in every grade level. Later on, at the higher education level, all undergraduate students are again exposed to CCE through a module in a Science, Technology and Society course as the only required exposure across all programs in universities/colleges.

Given the increasing need for and interest in CCE (Monroe *et al.*, 2019), as both a mitigation and adaptation strategy, it is important to innovate teaching and learning approaches amidst the challenges presented by our "new normal." Thus, the researchers explored incorporating a systems thinking (ST) approach in an online setting intended for instructors at the basic education level, specifically in junior high school. By prioritizing the climate literacy of instructors, a ripple effect might be achieved with the students they interact with.

ST focuses on the connection of different parts of a system and on how they interact with other systems to perform a function or achieve a goal. ST has been used in different fields such as the science education (Shekh-Abed *et al.*, 2021; Mahaffy *et al.*, 2019), health management (Sahin *et al.*, 2020), resource management (Dyball *et al.*, 2020) and business management (Rebs *et al.*, 2019). Using ST has been shown to engage learners in their courses, to help them comprehend and conceptualize content more deeply, to pose better questions and to create more conceptual connections (York *et al.*, 2019). ST promotes skills such as systems-as-cause thinking, dynamic thinking, scientific thinking, 10,000-meter thinking and closed-loop thinking to name a few (Richmond, 2018). Furthermore, ST can help in the development of ecological values and leading learners to pro-climate mindsets and behaviors that protect rather than destroy the physical world (Ballew *et al.*, 2019).

The challenges brought by climate change require a more comprehensive non-linear approach (Bierbaum *et al.*, 2018). ST in climate education addresses such issue especially for students to understand the importance of looking at the bigger picture in solving climate change. Utilization of ST in knowing the interconnection between the different Earth subsystems and its effect on the Earth's climate is essential in improving the understanding of students, as they look at it as a complex system and as they recognize different components and their dynamic relationships (Stave and Hopper, 2007). ST can be of use, for example, through concept mapping where users can link two or more concepts in forming propositions in understanding climate change (de Sousa *et al.*, 2019; Novak and Cañas, 2006). In addition, McAlister *et al.* (2022) elaborated that ST can be improved through the use of different models such as participatory modeling, complexity-aware modeling (mainly used for participants to learn and practice ST) and virtual simulation modeling (for greater understanding of complexity) which are all essential in understanding global environment health and climate change. For instance, Climate Interactive, a sample resource, includes educational materials and system dynamics simulations. Participants can also use the En-ROADs simulator to evaluate the impact of policy decisions on greenhouse gas emissions.

There are different ST tools such as causal loop diagram (CLD) and behavior over time graph (BOTG). A CLD illustrates the connections among different elements in the system and the feedback loops occurring in a system that are responsible for observed trends and behaviors. By taking a causal perspective on a problem, students can better understand the structural dynamics that underpin what might be initially perceived as surprising or confusing behavior. On the other hand, BOTG, a graph that depicts a pattern of change over time, is a critical tool for modeling various systems and verifying our understanding of them. By teaching how to comprehend and use BOTG, teachers can aid students to discern and articulate patterns thus develop a more thorough and robust understanding of the system.

This study, therefore, aimed to determine the effects of integrating ST into learning and reasoning about the climate system among teacher-participants using the Global Climate Change E-learning module (GCCELM) developed by Ignacio *et al.* (2023).

2. Methods

2.1 Research design

The study used a mixed-method research design, specifically, the embedded experimental model in which content analyses of participant responses support the results of pre and posttests to provide a backbone for the quantitative data (Creswell *et al.*, 2003). Using random sampling, 30 science teachers from Metro Manila, the National Capital Region and the nearby Region IV-A were recruited according to the following criteria: they must be licensed professional teachers and junior high school science teachers. All participants gave informed consent, were asked to clarify expected tasks prior to the start of the online training and answered a pretest (see Section 2.2).

Participants were then divided into two groups – an ST group and a non-ST (NST) group using randomizer software. Pretest scores and participant profiles were consulted to ensure both groups were equivalently matched. Participants of the ST group underwent online training using a version of the GCCELM that integrates ST approaches while the participants of the NST group used a version of the GCCELM that incorporated conventional approaches. The GCCELM (both the NST and ST versions) were validated by a pool of experts as being Highly Acceptable for teaching climate change (Ignacio *et al.*, 2023). These two versions have identical academic content but different methods. The NST version followed the conventional classroom teaching style which used lectures, videos and different interactive activities but without using the concept of systems. Whereas the ST version used an e-learning module that explicitly framed the climate as a system of the Earth's interconnected spheres (atmosphere, hydrosphere, cryosphere, lithosphere, biosphere). CLDs and BOTGs were included in the discussions and activities as well as other tasks that assisted users in comprehending ST and movies that demonstrate how to link system components.

The GCCELM was designed to be completed in 15 h or within 10 sessions and for asynchronous implementation. Participants proceeded at their own pace but were given two months to accomplish the entire learning module. After accomplishing the required activities, teacher-participants took the posttest to determine their conceptual understanding of climate change (see Section 2.2).

The test responses of the participants were anonymized and scored by a pool of evaluators (see Section 2.2) who did not know to which group each respondent belonged. A paired *t*-test assessed differences of mean scores between pre and posttests of the two groups. Mean scores were subjected to independent *t*-tests to compare the differences across the two groups in terms of content knowledge, depth, accuracy of learning and holistic approach.

After the online modules were completed, the participants were debriefed about their experiences. The researchers conducted and recorded online focus-group discussions (FGD) via Zoom which took an average of 1 h and 30 min per session. NST and ST groups were separated in the FGDs, with 6 FGDs conducted, attended by 16 participants (8 from each group). Participants were asked if and how the learning module improved their content knowledge, depth and accuracy of knowledge and reasoning and holistic approach on climate change. Participants were also asked about challenges encountered during the implementation of the research study. Participants' responses were transcribed using the recordings from the sessions. Data were processed using Quirkos, a qualitative data analysis software, to streamline participants' responses based on the research questions.

For qualitative data, thematic analysis was used to study FGD results. Themes emerged, defining relevant views and experiences, which in turn were used to examine the impact of ST on participants' climate change knowledge, depth and accuracy of knowledge and reasoning, holistic perspective and pedagogical method. Subthemes were also created to further break down the responses into smaller chunks through coding (Sutton and Austin, 2015) to be assembled into patterns (Braun and Clarke, 2006).

2.2 Assessment tools

The pre and posttests were researcher-made instruments used to assess the teachers' level of climate change literacy. The table of specifications on which the open-ended questions in the pre and posttests were based was composed of learning objectives identical to the e-learning module. This assessed the knowledge of the teacher-participants before and after the learning module following these objectives:

- identify how the components of the Earth affect the climate system;
- identify the processes that are currently driving climate change; and
- address the impacts of climate change across different sectors that can be potential feedback processes in other sectors.

The pretest was designed to be answered in a short response format containing the explanation to the open-ended questions with a maximum number of sentences. Questions were arranged from lower to higher-order thinking and were given an equal number of points. The posttest also consisted of three open-ended questions to identify how the two groups differed in their depth of learning, reasoning and understanding of the global climate system after taking the module. Posttest questions were parallel to the pretest questions but worded differently to ensure that the result of pre and posttests were comparable in terms of the objectives that the assessment questions wanted to address and its level of difficulty. This was to prevent any discrepancies between the result of both tests. For both pre and posttests, Question 1 assessed participants on their understanding of the parts of the Earth system and interactions that affect the climate system. Question 2 evaluated how participants discuss the impacts of society on climate change. Question 3 asked the participants to reflect on their own actions and their ripple effects across the larger community.

A pre and posttest validation tool was adopted from Lamoste *et al.* (2018) based on the table of specifications and the following criteria: cognitive complexity, content quality, meaningfulness, language appropriateness and fairness of the test questionnaire. Five experts from the fields of language, information technology, ST, science education and Earth and environmental science validated the pre and posttest instruments. These experts have at least a master's degree in their respective fields.

Participant responses to the assessment questions were evaluated by a pool of ten evaluators who have Master of Science degree in Science Education [which included at least one course related to earth and environmental science/climate science and a course on ST approaches in science, technology, engineering, and mathematics (STEM)] and who had taught climate science topics for at least two years in their respective schools. Evaluators used a rubric adapted from Clewner (2023), Arter and McTighe (2001) and Luft *et al.* (2020). The rubric was composed of three criteria:

(1) content knowledge which referred to the facts, concepts, theories and principles that are taught and learned about climate science;

(2) depth and accuracy of knowledge and reasoning which referred to the degree or complexity of knowledge that the content curriculum standards and expectations required; and

(3) holistic approach which referred to the interconnections among the topics and how key variables and systems might change over time and in their respective contexts.

These were graded on a scale of 4–0, in this manner: 4 (exemplary), 3 (accomplished), 2 (developing), 1 (beginning) or 0 (underdeveloped).

3. Results

3.1 Participant profiles

A total of 20 science teachers accomplished the entire learning module: 8 from City of Manila, seven from Rizal Province (which is still part of the greater Metro Manila area), and 5 from Quezon City. The ST group was composed of three from Rizal Province, two from City of Manila and five from Quezon City. There were six teachers who specialized in biology, two teachers who specialized in physics, one teacher who specialized in chemistry and one teacher who specialized in general chemistry. Most of these teachers have five to seven years of experience. The NST group was composed of four participants from City of Manila, four from Rizal Province and two from Quezon city. There were seven teachers who specialized in general science, one teacher who specialized in biology and two teachers who specialized in physics. Most of these teachers have one to three years of teaching experience. Among the 20 participants, 18 are female and 2 are male. Each group (ST and NST) was composed of nine females and one male. The participants are licensed professional teachers and had at least one year of teaching experience.

Equivalence between the NST and ST groups was established through an independent *t*-test of the pretest scores, which showed no significant difference in their mean score at the 95% level.

3.2 Assessment scores

Table 1 shows the independent and paired *t*-test results of the two groups based on their total scores, content knowledge, depth and accuracy of knowledge and reasoning and holistic approach. The researchers used the gain in the mean score which is shown in the table. The ST group obtained a larger gain in their mean score than the NST group in all components, rejecting the null hypothesis at the 95% significance level. Therefore, there was a significant difference in the climate change literacy of teachers before and after using the e-learning module with the integration of ST. It can also be seen that the NST group showed minimal improvement with their scores in all the components while the ST group significantly improved at a 95% level of significance.

Thematic analyses were conducted after all the participants accomplished the posttest. Five themes arose during the FGD (Figure 1):

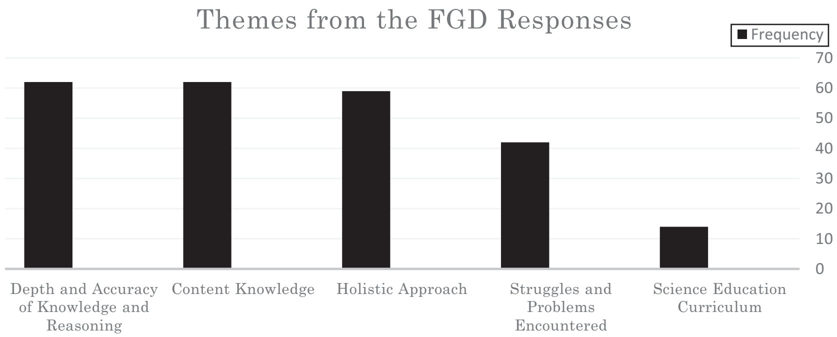
(1) depth and accuracy of knowledge and reasoning talks about the awareness of climate change problems and familiarization of the content;

(2) content knowledge refers to how GCCELM deepens the understanding and content of participants and on how they see the bigger picture;

Criteria	ST	NST	Difference	Significant?
Total score				
Pretest	7.11	7.26	−0.15	*No*
Posttest	9.68	7.77	1.91	*Yes*
Gain	2.57	0.51	2.06	*Yes*
Significant?	*Yes*	*No*		
Content knowledge				
Pretest	2.47	2.52	−0.05	*No*
Posttest	3.33	2.75	0.58	*Yes*
Gain	0.86	0.23	0.63	*Yes*
Significant?	*Yes*	*No*		
Depth and accuracy of knowledge and reasoning				
Pretest	2.34	2.40	−0.06	*No*
Posttest	3.23	2.58	0.65	*Yes*
Gain	0.89	0.18	0.71	*Yes*
Significant?	*Yes*	*No*		
Holistic approach				
Pretest	2.29	2.36	−0.07	*No*
Posttest	3.11	2.45	0.66	*Yes*
Gain	0.82	0.09	0.73	*Yes*
Significant?	*Yes*	*No*		

Source: Authors' own creation

Table 1. Independent and paired *t*-test results of ST and NST groups



Source: Authors' own creation

Figure 1. Frequency of themes from the FGD responses of ST and NST groups

(3) holistic approach focuses on how participants connect different sectors to climate change and how such interconnections affect the entire climate system;

(4) struggles and problems encountered focus on the challenges experienced by the participants while doing the learning module; and

(5) science education curriculum refers to the inclusion of climate change topics to the junior high school science curriculum.

The themes in the FGD showed that depth and accuracy of knowledge and reasoning, content knowledge and holistic approach all have the same level of concerns raised while there were also some participants who shared their struggles and problems encountered.

They also voiced out how GCCELM can be used as a supplementary materials in teaching climate change for junior high school students.

The depth and accuracy of knowledge and reasoning theme was composed of subthemes, namely:

- awareness of problems wrought by climate change;
- familiarization with the content;
- contextualization of the content which refers to the application of the climate science content on farming and industries;
- involvement which refers to the role of teachers in encouraging students to take action in mitigating and adapting to climate change; and
- thinking skills.

The content knowledge theme was composed of subthemes, namely:

- deepening of content knowledge which refers to the ability of the learning module to further deepen the climate science content knowledge;
- ground knowledge which refers to their prior knowledge about the topic;
- level of content knowledge of the participants after the implementation of the learning module; and
- misconceptions which refer to the prior knowledge of teachers which were corrected by the learning module.

The holistic approach theme was composed of subthemes, namely:

- interconnections shown in the learning module;
- feedbacks in the CLDs and the possible effect that they may cause in the system;
- behavior of the climate system which refers to how the system reacts to the changes;
- bigger picture of the climate system; and
- thinking skills.

The problems encountered per theme were composed of subthemes, namely:

- time management which refers to how participants managed their time in answering the learning module;
- workload which refers to the other academic or extracurricular responsibilities that the participants had during the time of the study implementation;
- acquisition of information which refers to how teacher-participants acquired information while they were doing the learning module (e.g. some participants experienced some difficulties in terms of the content);
- navigation; and
- layout which both refers to the interface of the module.

The science education curriculum theme was composed of subthemes, namely:

- inclusion of climate change topics in the K12 science education curriculum;
- old curriculum or how climate change topics were discussed in the basic education curriculum of the science teachers when they were in high school; and
- the learning module which refers to the quality of the utilized module materials in public schools.

4. Discussion

The paired t-test results indicated that both groups increased their scores in the posttest compared to their pretest, but the gain of the ST group represented a significant difference while that of the NST group was not. The independent t-test results also indicated that the mean scores of the ST group across all criteria – content knowledge, depth and accuracy of knowledge and reasoning and holistic approach – were significantly different from the NST group. The themes arose during the FGD supported the result of the paired t-test. The increase in mean scores of both ST group and NST group in all criteria showed that all participants acquired a certain level of awareness about the climate change issue, deepened their content in climate science and saw bigger picture rather than parts of it.

However, there may have been mitigating factors. Time management was identified as a major challenge as mentioned in one of the themes: "struggles and problems encountered" – NST participants reported having heavier workload coinciding with the time of the GCCELM post-assessment. Participants also reported some difficulty with the navigation of the learning module. Two participants admitted to having skipped some parts of the module and proceeding directly to the activities. On the other hand, participants in the ST group reported that they were able to allot enough time to complete the posttest despite their work and academic requirements.

Though some experienced problems, it should be taken in consideration how all teacher-participants recommended to deepen the science content taught in the high school level and to use ST as a tool in understanding the interconnection in our planet in fighting against climate change. Despite the difficulties with time management, both NST and ST groups gave positive feedback on the content of the GCCELM and felt that they learned something new, and their understanding of climate change was improved. According to the participants, some content of the GCCELM was not commonly tackled in high school and even in college. For example:

NST006: "When talking about land use, maybe it wasn't discussed like that in high school or college. It seems that such a concept was not introduced. That's what I liked about the module."

NST013: "This can deepen the understanding on climate change, activities are good, real-life situation activities [. . .]"

NST003: "This topic [climate change] is connected to the people. That is what struck me most in the learning module."

A participant from the ST group compared the GCCELM to the material prescribed by DepEd and felt that the former was "better" because it had more information. The GCCELM helped the teacher-participants realize that the students lack important content concerning climate change. NST005 candidly said:

> The information that I am giving to the students is lacking, because even us, we are not aware because we are not given any chance to attend seminars, this was not the focus, so we are just focusing on what is in the curriculum and the competency.

Teacher-participants felt that the current curriculum contains limited information about climate change. This can be seen in the result of their pretest result wherein both groups obtained a total score that can be interpreted as "Beginner" though this changed after the implementation of the module. The score of ST group increased from "Beginner" to "Developing" which meant that there was an improvement in terms of their content knowledge, depth and accuracy of knowledge and reasoning and holistic approach while the NST group was still in the "Beginner" bracket.

ST011 felt that because this is not adequately included in the curriculum, they failed to realize the extent of the problem. This is compounded by the lack of proper training on improving climate change's knowledge and skills for teachers:

> This affects our lives [. . .]. We don't realize it because this is not included in our curriculum. And we don't have proper training on this.

ST012 also shared the same sentiment with ST011 that in the MELCs of the updated curriculum since the pandemic began, there was insufficient information on climate change. This was emphasized by ST004 through stating that given only one week to teach this complicated topic, they were only able to cover the basics of global warming and its effect on the environment.

Participants across both groups appreciated the localization of the content and the application to actual experiences – this further deepened their understanding of the climate change problem and provided insights on how to relate the lessons to their students' contexts. ST007 shared:

> So for me [. . .] the concepts in the Philippine context helped me answer and understand the concepts available.

Participants also appreciated the use of multimedia – they cited the importance of videos and graphic organizers, such as the CLDs for the ST Group and pictures and infographics for the NST Group, as guides in deepening the discussion about climate change. NST015 shared that:

> There are graphics, which are important in the module so that it is not boring to answer; there are videos and pictures; there are in-depth discussions of the topic, and the content has an application.

However, NST005 also shared the sentiment that this learning modality might not be feasible in public schools where students are often given print materials, rather than interactive modules.

Responses from the teacher-participants supported findings (Monroe *et al.*, 2019) that some educators lack essential knowledge on climate change. These feedbacks from both the NST and ST groups suggested that there may be potential gains in climate literacy by improving on the materials used even without an explicit ST framing. Specifically, we should consider reviewing the currently prescribed content and updating it with research findings beyond the basic discussions of greenhouse gases; localizing or contextualizing the content; and incorporating multimedia resources when feasible. In addition, new curricula must be coupled with training opportunities for teachers. These training opportunities should be factored in as part of the teachers' load to ensure that teachers are able to focus and participate in the learning process. Allotting time for training might entail a systems view of the administrative aspect of education including the job descriptions of teachers and how work is assigned and distributed. Previous studies had investigated issues with teacher workload and wellbeing in the Philippines (Ancho and Bongco, 2019; David *et al.*, 2019; Magalong and Torreon, 2021; Robosa *et al.*, 2021; Orlanda-Ventayen and Ventayen, 2022) as a necessary step in conducting teacher training to analyze the factors that might help or hinder maximizing the capacity-building opportunity.

Within the participants of the ST group, the concept of "interconnections" was raised in varying ways. According to them, the module raised their awareness about climate change and how it can affect the agriculture, fisheries, livestock and other industries. They added that the GCCELM allowed them to see the bigger picture by emphasizing the interconnections among the factors that affect our climate system. Participants highlighted the new learning they acquired and the misconceptions debunked about climate change. According to ST004 and ST014:

ST004: "Before, my thinking was like it's because of pollution and bigger industries, but right now, I see the bigger picture, that every household, the consumption of food, and also the [trash] [. . .] "I thought that [with] climate change [. . .] the oceans are not affected, but [they are] still affected [. . .] "

ST014: "Right now I see the connection between the other industries and the economy as well as the things that will happen to the fishes [. . .]"

These responses indicated that the GCCELM helped participants in both 10,000-meter thinking (or the ability to see the bigger picture of the climate system) and system-as-cause thinking (as seen in the ability to recognize what factors are driving the problems in the climate system). The CLD was an important tool toward this end. Because of the CLDs presented in the learning module, the participants in the ST group easily identified the connection between each variable and its possible feedback through the circular cause-and-effect approach. ST012 mentioned:

> This is not the usual diagram (CLD) showing cause and effect. You need to explore each side of that cause and what will be the effect until you reach the point that you could see the bigger picture [. . .].

The ST version of the GCCELM also showed some challenges. Some participants got confused about how to read the CLD and needed to go back to the introduction page for them to review the connections. They recommended that the learning module give more examples for the students to deepen their understanding of ST and CLDs. ST014 also mentioned that:

> It kind of pressured me to think outside the box [. . .].

However, these were seen as challenges that could help enhance students' 21st-century skills such as holistic and critical thinking over time. ST007 opined:

> The capacity to connect factors [needs] time for students to understand connections [. . .]. This will fit the [students in the] higher levels, especially this can develop critical thinking of the students [. . .].

After finishing the module, the participants expressed their thoughts on how critical climate change is, not just for their students but also for their family and friends. ST011 mentioned:

> This learning module gives me a new perspective that I need to know more regarding climate change, and the need to raise awareness [. . .].

The module became an eye-opener for the teachers regarding their awareness of this global problem, including their involvement in activities to mitigate climate change. This was where ST014 realized how significant her involvement with climate change activities is:

> I have to do an action plan maybe, because I lack involvement with other climate change activities [. . .].

Some participants suggested teaching climate change through ST, for the learning module showed teachers how to teach these subjects. In fact, ST007 linked her climate change teaching technique to ST:

> Usually, we are teaching in a linear way of presenting information to our students like defining what is deforestation or carbon sequestration, what are the causes of deforestation and its possible effect in our environment [. . .] integrating systems thinking will help the students realize

that climate is a system with interacting components, and we need to study how this system behaves and its feedback mechanism.

These feedbacks, taken together with the improved performance in the posttest versus pretest scores, showed that ST has the potential to assist educators in improving their skills and material knowledge and to create innovative climate change teaching methodologies with an emphasis on outcome-based learning since the module includes a student action plan. A concrete potential impact of the ST approach to CCE is in restructuring linear thinking (i.e. A leads to B leads to C) to circular or feedback thinking (i.e. A leads to B leads to C which affects A). The latter is crucial in understanding the tipping points of the climate system, which are often products of reinforcing feedback; as well as what makes effective interventions, which often involves balancing feedback to mitigate adverse impacts.

However, fully encouraging ST cannot be accomplished by reframing existing climate change lessons alone. If only five hours is allotted to climate change topics in the student curriculum, it would be infeasible to learn the basics of systems tools and cover material on the climate system within that time – noting that the GCCELM for the teacher-participants was designed to be covered in 15 h. Research on ST pedagogy and integration in STEM and other disciplines needs to be combined with a full curriculum review (Roychoudhury *et al.*, 2017). For example, we can identify other points in the curriculum where climate-related concepts may be introduced (e.g. introducing the molecular structure of GHGs that precisely leads to the greenhouse effects as part of the modules on Properties and Structures of Matter [*which can be taught in Grade 9 Science*]; or discussing the Earth's energy balance as part of the Energy module [*which can be taught in Grade 10 Science*]).

In the Philippine context, there are other questions that might also need to be addressed: for one, does the science curriculum need to be decongested, so more time can be allotted to focus on over-arching topics such as climate change that require an integration and synthesis of different disciplines? The K-12 curriculum where a spiral approach was introduced in teaching different subjects was instituted in year 2012, but the question is: Has this shown to be beneficial thus far? Or should we emphasize discipline-based mastery instead? There is a wide range of topics that instructors need to teach to their students. This becomes problematic particularly when teachers fail to finish a topic in their respective grade level. The teachers of the next grade level will need to discuss the essential topics in the previous year for them to provide a foundation of concepts for the students, and this will have a domino effect on the succeeding grade levels given the limited time allocated for each topic. The review of Pacala (2023) asserted that the spiral curriculum can promote mastery in science education but the curriculum must be decongested. Batidor and Casinillo (2021) founded that the spiral progression approach improved performance, but that performance was overall still unsatisfactory. They noted that more extensive teacher training in their respective fields would be a key factor, but as this research reflects, building capacities of teachers to integrate disciplines may also be important, especially when approaching complex topics such as climate change. Tackling these larger and more systemic questions can help develop curricula that better addresses 21st century issues and the skills needed to solve them.

5. Conclusions and recommendations

This study aimed to identify how ST affects teachers' understanding of climate change, as they transfer information to their students. The content of the learning module provided new information for teachers that they can implement in their climate science lessons. ST integration in the module development also added a new pedagogical approach in teaching climate change topics to junior high school students. Using the learning module, teachers can help students enhance their ST skills, such as 10,000-meter thinking and systems-as-cause thinking, in dealing with climate change problems. The results from the statistical analyses indicated that the ST group obtained a significant increase in their pretest and posttest scores as compared to the NST group. After taking the learning module, the ST group received a significant increase in content knowledge, depth and accuracy of knowledge and reasoning and holistic approach.

Both groups claimed that they acquired new knowledge after taking the learning modules which includes biophysical factors and their effect on climate change, the connection of climate change to farming and fishing industries and the utilization of an action plan as an output. However, the ST group was better able to articulate feedback relationships while the NST group mainly explained climate drivers and impacts in a linear way. The learning module activities in the ST group helped them see the connection between each variable; thus, developed their understanding and awareness of climate change.

Teachers raised concerns regarding the lack of training for teaching climate science. They admitted that they lacked critical information to include in climate change topics in their classes. They also raised that in the DepEd's MELCs, the topic was not given sufficient emphasis. Thus, updating the prescribed materials and providing teacher training can substantially improve the climate literacy of teachers and students, even without the ST framing. Integrating a ST approach will potentially have the added benefits of facilitating 21st-century skills. Implementation of ST in teaching STEM should be considered as an important component of teacher training.

This research is a pioneering study in the Philippines in terms of the application of ST in an online learning modality for basic education teachers and students. The outcomes introduced a new perspective on teaching climate science in high school. The study was limited to a pool of volunteer participants who were challenged with balancing their workload and participation in the study. Moving forward, the GCCELM, particularly the ST version, should be implemented with more teacher-participants to obtain a wider perspective on its effectivity. As the participants of this study were in urban and peri-urban areas, it would be valuable to assess viability of the online ST approach in rural contexts.

On a broader scale, this study brings to fore issues within the larger educational system, both in terms of curriculum design and the workload of teachers. A curriculum review may be conducted to assess how to introduce climate topics in different subjects in the K-12 curriculum (e.g. connecting climate change to topics in the other sciences and even social science subjects) so as not to be limited by the prescribed number of hours in the current MELCs. Taking this a step further, might reevaluate the number of hours prescribed for each topic in what is already a congested curriculum and how the spiral approach may be helping or hindering holistic understanding. In this way, a holistic systems approach can be integrated into the design of the curricula as well as within the content. In the short-term, future rollouts of the GCCELM should also explore partnerships with schools to incorporate this in planned teacher development programs rather than as additional to teachers' existing commitments. However, in the long-term, teacher workload may need to be re-assessed to allow regular and comprehensive retooling and professional development. Applying a systems perspective of STEM education, future research will need to articulate the supporting structures needed, whether in terms of administration or pedagogical resources to reinforce innovations in CCE that can promote holistic understanding of and action on climate change.

References

Agayon, A.J.D., Agayon, A.K.R. and Pentang, J. (2022), "Teachers in the new normal: challenges and coping mechanisms in secondary schools", *Journal of Humanities and Education Development (JHED)*, Vol. 4, available at: https://ssrn.com/abstract=4026389

Ancho, I. and Bongco, R. (2019), "Exploring Filipino teachers' professional workload", *Journal of Research, Policy and Practice of Teachers and Teacher Education*, Vol. 9 No. 2, pp. 19-29.

Arter, J. and McTighe, J. (2001), *Scoring Rubrics in the Classroom: Using Performance Criteria for Assessing and Improving Student Performance*, Corwin Press.

Ballew, M.T., Goldberg, M.H., Rosenthal, S.A., Gustafson, A. and Leiserowitz, A. (2019), "Systems thinking as a pathway to global warming beliefs and attitudes through an ecological worldview", *Proceedings of the National Academy of Sciences*, Vol. 116 No. 17, pp. 8214-8219.

Barrot, J.S., Llenares, I.I. and Del Rosario, L.S. (2021), "Students' online learning challenges during the pandemic and how they cope with them: the case of the Philippines", *Education and Information Technologies*, Vol. 26 No. 6, pp. 7321-7338.

Batidor, P.G. and Casinillo, L.F. (2021), "Evaluating spiral progression approach (SPA) in teaching science and mathematics for junior high curriculum", *Philippine Social Science Journal*, Vol. 4 No. 3, pp. 39-47.

Bierbaum, R., Cowie, A., Barra, R., Ratner, B., Sims, R., Stocking, M., Durón, G., Leonard, S. and Whaley, C. (2018), "Integration: to solve complex environmental problems", *Scientific and Technical Advisory Panel to the Global Environment Facility, Washington, DC*, p. 10.

Braun, V. and Clarke, V. (2006), "Using thematic analysis in psychology", *Qualitative Research in Psychology*, Vol. 3 No. 2, pp. 77-101, doi: 10.1191/1478088706qp063oa.

Chang, C.H. and Pascua, L. (2017), "The curriculum of climate change education: a case for Singapore", *The Journal of Environmental Education*, Vol. 48 No. 3, pp. 172-181, doi: 10.1080/00958964.2017.1289883.

Clewner, A. (2023), "One short answer response rubric to rule all short answer response rubrics", available at: www.greeleyschools.org/cms/lib/CO01001723/Centricity/Domain/4216/NHS%20MCJROTC%20Short%20Answer%20Grading%20Rubric.pdf

Creswell, J.W., Plano Clark, V.L., Gutmann, M.L. and Hanson, W.E. (2003), "Advanced mixed methods research designs", *Handbook of Mixed Methods in Social and Behavioral Research*, Vol. 209 No. 240, pp. 209-240.

David, C.C., Albert, J.R.G. and Vizmanos, J.F.V. (2019), "Pressures on public school teachers and implications on quality", available at: http://hdl.handle.net/11540/9702

de Sousa, L.O., Hay, E.A. and Liebenberg, D. (2019), "Teachers' understanding of the interconnectedness of soil and climate change when developing a systems thinking concept map for teaching and learning", *International Research in Geographical and Environmental Education*, Vol. 28 No. 4, pp. 324-342.

Dyball, R., Davila, F. and Wilkes, B. (2020), "A human ecological approach to policy in the context of food and nutrition security", *Handbook of Systems Sciences*, Springer, Singapore, pp. 1-26.

Frantzeskaki, N., McPhearson, T., Collier, M.J., Kendal, D., Bulkeley, H., Dumitru, A., Walsh, C., Noble, K., Van Wyk, E., Ordóñez, C. and Oke, C. (2019), "Nature-based solutions for urban climate change adaptation: linking science, policy, and practice communities for evidence-based decision-making", *BioScience*, Vol. 69 No. 6, pp. 455-466.

Garcia, M.N.Z. and Cobar-Garcia, M.R.V. (2022), "The environmental literacy of elementary and high school teachers based in Manila and Nueva Ecija province: a mixed methods study", *Environment, Development and Sustainability*, Vol. 24 No. 5, pp. 1-25.

Ignacio, J.T., Gonzales, C.K.G. and Chua, Q.L. (2023), "Development of an e-Learning module integrating systems thinking for climate change", *Ubiquitous Learning: An International Journal*, Vol. 16 No. 2, p. 1.

Lamoste, L., Distor, J., Ong, M. and Lagunzad, C. (2018), "Weavering urban agriculture and science education toward sustainability, food security, and livelihood", Thesis.

Li, Y.Y. and Liu, S.C. (2022), "Examining Taiwanese students' views on climate change and the teaching of climate change in the context of higher education", *Research in Science and Technological Education*, Vol. 40 No. 4, pp. 515-528.

Liu, S., Roehrig, G., Bhattacharya, D. and Varma, K. (2015), "In-service teachers' attitudes, knowledge and classroom teaching of global climate change", Papers in Natural Resources 1000.

Luft, J.A., Hanuscin, D., Hobbs, L. and Törner, G. (2020), "Out-of-field teaching in science: an overlooked problem", *Journal of Science Teacher Education*, Vol. 31 No. 7, pp. 719-724.

McAlister, M.M., Zhang, Q., Annis, J., Schweitzer, R.W., Guidotti, J. and Mihelcic, J.R. (2022), "Systems thinking for effective interventions in global environmental health", *Environmental Science and Technology*, Vol. 56 No. 2, pp. 732-738.

Magalong, A.A. and Torreon, L.C. (2021), "Teaching workload management: its impact on teachers' well-being and effectiveness", *American Journal of Multidisciplinary Research and Development (AJMRD)*, Vol. 3 No. 2, pp. 31-36.

Mahaffy, P.G., Matlin, S.A., Holme, T.A. and MacKellar, J. (2019), "Systems thinking for education about the molecular basis of sustainability", *Nature Sustainability*, Vol. 2 No. 5, pp. 362-370.

Monroe, M.C., Plate, R.R., Oxarart, A., Bowers, A. and Chaves, W.A. (2019), "Identifying effective climate change education strategies: a systematic review of the research", *Environmental Education Research*, Vol. 25 No. 6, pp. 791-812.

Novak, J.D. and Cañas, A.J. (2006), "The theory underlying concept maps and how to construct them", *Florida Institute for Human and Machine Cognition*, Vol. 1 No. 1, pp. 1-31.

Orlanda-Ventayen, C. and Ventayen, R.J. (2022), "Stress and depression in the workplace of educators in the Philippines", *International Journal of Occupational Safety and Health*, Vol. 12 No. 4, pp. 325-335.

Pacala, F.A.A. (2023), "Discipline-based vs. spiral learning approach to science education: a critical analysis in the Philippine setting", *IJIET (International Journal of Indonesian Education and Teaching)*, Vol. 7 No. 1, pp. 41-47.

Rebs, T., Brandenburg, M. and Seuring, S. (2019), "System dynamics modeling for sustainable supply chain management: a literature review and systems thinking approach", *Journal of Cleaner Production*, Vol. 208, pp. 1265-1280.

Richmond, B. (2018), "The 'thinking' in systems thinking: how can we make it easier to master?", *The Systems Thinker*, Leverage Networks, 16 August, available at: https://thesystemsthinker.com/the-thinking-in-systems-thinking-how-can-we-make-it-easier-to-master

Robosa, J., Paras, N., Perante, L., Alvez, T. and Tus, J. (2021), "The experiences and challenges faced of the public school teachers amidst the COVID-19 pandemic: a phenomenological study in the Philippines", *International Journal of Advance Research and Innovative Ideas in Education*, Vol. 7 No. 1, pp. 10-6084.

Roychoudhury, A., Shepardson, D.P., Hirsch, A., Niyogi, D., Mehta, J. and Top, S. (2017), "The need to introduce system thinking in teaching climate change", *Science Educator*, Vol. 25 No. 2, pp. 73-81.

Sahin, O., Salim, H., Suprun, E., Richards, R., MacAskill, S., Heilgeist, S., Rutherford, S., Stewart, R.A. and Beal, C.D. (2020), "Developing a preliminary causal loop diagram for understanding the wicked complexity of the COVID-19 pandemic", *Systems*, Vol. 8 No. 2, p. 20.

Shekh-Abed, A., Hazzan, O.R.I.T. and Gero, A. (2021), "Promoting systems thinking and abstract thinking in high-school electronics students: integration of dedicated tasks into project-based learning", *International Journal of Engineering Education*, Vol. 37 No. 4, pp. 1080-1089.

Stave, K. and Hopper, M. (2007), "What constitutes systems thinking? A proposed taxonomy", In *25th International Conference of the System Dynamics Society*, July, Vol. 29.

Sutton, J. and Austin, Z. (2015), "Qualitative research: data collection, analysis, and management", *The Canadian Journal of Hospital Pharmacy*, Vol. 68 No. 3, p. 226.

UNESCO (2015), "Climate change education", *UNESCO.org*, UNESCO, 1 January, available at: www.unesco.org/en/education/sustainable-development/climate-change

Vergonia, B. and Mombas, S.E. (2022), "Ready to go? Profiling Philippines high school teachers' readiness for blended learning in post-COVID-19 era", *Journal of Educational Management and Instruction (JEMIN)*, Vol. 2 No. 1, pp. 12-23.

York, S., Lavi, R., Dori, Y.J. and Orgill, M. (2019), "Applications of systems thinking in STEM education", *Journal of Chemical Education*, Vol. 96 No. 12, pp. 2742-2751.

Further reading

Korkmaz, M. (2018), "Public awareness and perceptions of climate change: differences in concern about climate change in the west Mediterranean region of Turkey", *Applied Ecology and Environmental Research*, Vol. 16 No. 4, pp. 4039-4050.

Lee, K., Gjersoe, N., O'Neill, S. and Barnett, J. (2020), "Youth perceptions of climate change: a narrative synthesis", *Wiley Interdisciplinary Reviews: Climate Change*, Vol. 11 No. 3, p. e641.

Corresponding author

John Trixstan Santos Ignacio can be contacted at: trixstan.ignacio@obf.ateneo.edu

For instructions on how to order reprints of this article, please visit our website:
www.emeraldgrouppublishing.com/licensing/reprints.htm
Or contact us for further details: **permissions@emeraldinsight.com**

View publication stats