Assessing, Comparing, and Predicting Pedagogical Self-Efficacy in Civic Scientific Literacy among Taiwanese Teachers

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Executive Summary

The current study developed and collected data for instruments measuring the levels of self-efficacy and value that K-12 Taiwanese educators have for student learning activities that incorporate scientific agency, as well as a measure of trust in science. Results from data collected from $N = 94$ participants provided psychometric support for two-factor structure of pedagogical self-efficacy and pedagogical value of teaching practices that support student scientific agency. These two dimensions reflect 1) student authorship in scientific agency teaching activities, and 2) student co-agency in scientific teaching activities. Regression using these variables as outcomes found that respondents who taught (or planned to teach) senior high school or vocational high school showed significantly lower self-efficacy in teaching practices to promote students' scientific co-agency than respondents who taught (or planned to teach) elementary school. Conversely, compared to those who taught (or planned to teach) elementary school these same respondents who taught (or planned to teach) senior high school or vocational high school showed significantly higher valuing of teaching practices that promote students' scientific authorship agency. Also, when compared to in-service teachers, pre-service teachers showed significantly higher levels of valuing teaching practices that promote students' scientific authorship agency. Male educators showed significantly higher levels of trust in science than female educators. Additional predictive effects of participants' professional role and grade level taught were observed on outcomes pertaining to self-efficacy in integrating sustainable development goals into teaching practices.

Keywords: Civic scientific literacy, scientific agency, teaching practices, trust in science, sustainable development goals.

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Introduction

During the novel Covid-19 coronavirus pandemic that began in 2020, Taiwan earned worldwide acclaim for their effective containment of viral spread during the time in which no vaccine was available, with a total of only 1000 documented cases and only 10 deaths by March 2021 (Institute for Health Metrics and Evaluation, 2021) and very limited community spread of the virus. A number of authors (e.g., Huang, 2020; Lo & Hsieh, 2020; Nabben, 2020; and others) maintain that an important element contributing to Taiwan's success in this limiting the spread of the virus involved its pre-pandemic efforts to foster civic trust and civic engagement among its citizenry—a concerted and thoughtfully-planned strategy executed in direct response to the misinformation, conspiracies, and distrust Taiwan observed among its citizens during the SARS virus outbreak in 2002-2004. This notion of civic engagement, particularly as it applies to socio-scientific issues such as Covid-19, climate change, genetic engineering, and artificial intelligence (AI) clearly is a vital component of a healthy, functional democracy. The Taiwanese educational system, too, recognizes the importance of fostering civic engagement and civic competency from an early age. The Twelve-year Curriculum (or "108 Curriculum"), developed by the Ministry of Education in 2012 and first implemented in schools in 2019, is based on a framework that involves civic competency. Specifically, the framework centers on the concept of of *sù yǎng* (素養), or the "particular knowledge, skills, and attitudes that one needs for responding to complex life situations in the 'new economy era' and 'information society'" (Chen & Huang, 2017). More generally, the integration of 素養 into the curriculum involves the development of character, dispositions, and morality that constitute good citizenship and the Twelve-year Curriculum thus aims to foster skills and attitudes of lifelong learning among students and promote the values of personal initiative, communication/interaction, and social participation for the common good.

Intertwined with the notion of civic literacy/competency is the increasing importance of science in the lives of ordinary people. As previously mentioned, rapid changes in science are occurring that have profound and immediate impacts on even ordinary individuals. Moreover, the consequence of these rapid changes is that engagement with science is no longer an activity that is limited solely to individuals pursuing science education or seeking scientific careers. Rather, competency in the sense of being able to actively and critically engage, discuss, and evaluate the profound socio-scientific issues facing the world becomes an essential civic responsibility of every person. This "civic scientific literacy"—sometimes referred to as "public science literacy" or "public understanding of science" (see Lin et al., 2012; Shen, 1975; Sjøberg, 2015) is distinct from other forms of science competency in that it enables citizens "to become sufficiently aware of science and science-related public issues in order for the average citizen to become involved in the decision-making process regarding (socio-scientific) issues" (Chen et al., 2019, p. 299). Through this competency, ordinary persons in democratic societies enhance their ability to exercise their rights as informed citizens. This civic scientific literacy, although it requires basic foundation of scientific knowledge, also requires non-cognitive attributes such as interest and motivation that can sustain engagement with socio-scientific issues throughout one's lifespan. It also requires a mindset that is oriented towards scientific inquiry, or habits of mind that allow individuals to "think like scientists" (Elhai, 2023).

Scientific Agency

One habit of mind that pertaining to civic science literacy that has gained traction recently concerns the development of students' scientific agency. The Organisation for Economic Co-operation and Development (OECD, 2019) defines student agency as "the belief that students have the will and the ability to positively influence their own lives and the world around them as well as the capacity to set a goal, reflect and act responsibly to effect change" (p. 16). As such, OECD further clarifies that student agency involves the student characteristics of proactivity (as opposed to passivity) together with the ability to make their own responsible choices rather than accepting the choices of others. Student agency entails an ability of students to navigate their way independently through novel situations and contexts, rather than being provided with teacher-delivered directions or instructions. Importantly, OECD emphasizes that student agency is distinct from student autonomy or student choice in that agency necessarily occurs in a social context and involves "co-agency," whereby students develop this agency in mutually supportive social relationships with their teachers, peers, parents, and communities, who help to guide the student towards well-being.

Given the key role of co-agency, the ability of teachers to create learning activities and environments that nurture students' scientific agency, particularly at elementary and secondary school levels, is paramount. The Programme for International Student Assessment (PISA, 2023) recognizes the emergent role of scientific agency, and plans to incorporate measurement of this construct (particularly, as it pertains to environmental sustainability) in future assessments of students. However, little existing research has focused on measuring teachers' self-efficacy, value, and frequency-of-use of learning activities that can be used to promote their students' scientific agency.

OECD's (2019) Conceptual Learning Framework for the OECD Learning Compass defines student agency as "the belief that students have the will and the ability to positively influence their own lives and the world around them as well as the capacity to set a goal, reflect and act responsibly to effect change" (p. 16). As such, OECD further clarifies that student agency involves the student characteristics of proactivity (as opposed to passivity) together with the ability to make their own responsible choices rather than accepting the choices of others. Student agency entails an ability of students to navigate their way independently through novel situations and contexts, rather than being provided with teacher-delivered directions or instructions. OECD emphasizes that student agency is distinct from student autonomy or student choice in that it occurs in social context and involves co-agency, whereby students develop this agency in social relationships with their peers, teachers, parents, and communities, who help to guide the student towards well-being. To actualize agency, students need sufficient knowledge, skills, attitudes, and values. Similarly, Martin (2016) defines agency as "relative positioning in an immediate conversation as responsible for action" (p. 40), Hazari et al. (2019) build upon this to argue that student agency in conventional classrooms involves students making connections from topics that they learn in their classroom to the realities of their lives, and thus initiating exploration of ways that they can contribute and make meaningful change to their world. In this way, learners act as transformative agents of future change rather than adaptive respondents to the present.

In the United States, the Next Generation Science Standards (NGSS) emphasize the importance for students to learn "science as practice," whereby students become active participants in understanding, evaluating, and representing the world that surrounds them. As such, science as practice emphasizes the holistic processes that generate knowledge (Martin et al., 2016). Stroupe (2014) argues that, to engage in science-as-practice, students must assume the role of epistemic agents—that is, "individuals or groups who take, or are granted, responsibility for shaping the knowledge and practice of a community" (p. 488). Stroupe further maintains that teachers, rather than authoritatively providing instruction, knowledge, and practice, can provide ambitious instruction that provides students with environments and opportunities that allow them become epistemic agents. Ambitious instruction, according to Stroupe, is more inclusive than conservative forms of instruction, and supports the learning of students across gender, racial/ethnic, and class categories. However, given that science instruction in elementary and secondary school classrooms typically parallels the practice of science outside of the classroom, where the non-scientists seldom are granted authority to "do science," engaging in ambitious instruction involves teacher disruption of science practice expectations. Additionally, according to Stroupe, methods for collecting data (as well as analytic tools) pertaining to ambitious instruction are limited.

Reeve et al. (2003) and Reeve and Tseng (2011) introduce another aspect of student agency termed "agentic engagement" that involves students' ability to influence the flow of instruction and learning activities or, as described by Patall et al. (2019, p. 79), "students' involvement in terms of their proactive and constructive attempts to influence instruction and educational activities so that the activities better support their own motivation and learning by making them more interesting, valuable, or personal." By asserting agentic engagement, students become co-creators of the learning environment and can thereby enhance their classroom environment and increase their motivation and achievement (Patall, 2019; Reeve, 2013; Reeve & Tseng, 2011). The effects of agentic engagement are especially relevant during adolescence (Eccles et al. 1993; Erickson, 1968; Hill & Holmbeck, 1986), and have been demonstrated to positively impact student motivation and learning in these populations (Patall et al., 2019).

In line with the notion of agentic engagement, Cavagnetto et al. (2020), argue that a central element in the notion of scientific agency is authorship. Drawing from the ideas of Engle at al. (2012), Cavagnetto et al. define authorship as "active participation in knowledge generation as a function of learning" (p. 128). Although the authors acknowledge the possibility that scientific agency and authorship could be synonymous, they view authorship a a specific form of scientific agency that results in knowledge generation in the domain of science. Further, they maintain that specific learning conditions are critical to the development of agency/authorship and, in these environments, learners are more likely to take ownership of their learning and become more deeply invested in the ideas they generate. Although, young K-12 learners will likely not generate new scientific knowledge in the sense of creating knowledge that is new to the scientific field, they can generate knowledge that is new to themselves and, moreover, the key issue is the extent to which a particular learning environment facilities opportunity for learners to participate in activities that involve them in the knowledge generation process. Environments that effectively facilitate agency/authorship contrast with more traditional learning environments in which learners serve as passive recipients of ideas imposed on them resulting in lower levels of agency/ownership (Jimenez-Aleixandre et al., 2000). The former learning environments aim to produce compliant learners, while the latter aim to produce agentic learners. Learning environments and learner activities that foster scientific agency/authorship are characterized by two primary characteristics: learner safety and an embracement of complexity (Cavagnetto et al., 2020). Safe learning environments are those environments where learners do not feel personally threatened for expressing ideas. However, Cavagnetto et al. emphasize that such environments do not necessarily acknowledge all ideas as good ideas, and critique of ideas still occurs. Rather, deliberative argumentation is facilitated, whereby this deliberative process is one in which collective consensus is sought and all learners gain something, rather than a competitive process that results in winners and losers. The embracement of complexity in learning environments entails a recognition of the primacy of argumentation and specialized knowledge and the consequent need for learner dialogue (Cavegnetto et al., 2020). For example, rather than providing an outline for a research design to investigate how the size of sphere affects its rolling velocity, learners might be asked to design an experiment to empirically test hypotheses that they generate. In such environments, it is important that solutions to the problems are not overly structured through the use of worksheets or overly-prescriptive teacher guidance.

Compared to other areas of the world, Taiwan has particular advantages for developing student scientific agency and, more generally, civic scientific literacy. Nearly every Taiwanese school, for example, has laboratory facilities and adequate books, and parental support for science education remains high (Lu & Lien, 2015). However, challenges still remain in implementing pedagogical practices in schools to facilitate civic scientific literacy and student agency in students. For example, teachers' perspectives on science education reform and on their classroom practices are strongly impacted by Confucian culture and traditions (Huang & Asghar, 2018) and teachers typically feel that their primary responsibility is to prepare students for annual entrance examinations (Berry, 2011). Teachers thus feel that curricular content should focus on knowledge transferal/acquisition, and that constructivist pedagogies are ineffective for these purposes (Lu et al., 2010; Tsai & Kuo, 2008). However, although existing research has examined teachers' attitudes towards student-centered approaches to learning more generally, it is less clear about Taiwanese teachers' attitudes and practices towards fostering civic scientific literacy (generally) and student agency (specifically), and about teachers' perceived self-efficacy in providing learning environments that foster these skills in students.

Sustainable Development Goals

Improving civic science literacy in school-aged children has considerable grounding in educators' ability to integrate science into contemporary and pressing socio-scientific issues. One framework that has been integrated widely into the curricula of school-aged children, particularly as it relates to integrating socio-scientific issues into student learning—involves the United Nations' Sustainable Development Goals (SDGs; United Nations, 2023). This set of 17 SDGs have overarching goals of ending poverty and other deprivations (e.g., hunger), as well as improving education and health, stimulating economic growth, reducing inequalities, and preserving the environment and addressing climate change. The perceptions and knowledge of teachers are crucial in terms of effectively implementing education for sustainability into schools (Aznar, P. et al., 2014). García-González et al. (2020) found that a training process on Education for Sustainability was impactful in changing per-service teachers' knowledge of the SDGs.

Trust in Science

Finally, a factor that may be impactful in how effectively educators can prepare school-aged students to be exercise scientific agency involves the educators' personal views about science—specifically, their level of trust in the process and aims of science. Certainly social, epidemiological, and political events could influence these views. Borgerding and Mulvey (2022) carried out a mixed-methods study involve ten in-service and pre-service elementary school teachers. The authors found that credibility perceptions were couched in participants' perceptions of the nature of science, especially their understanding of empirical evidence, the nature of scientific models, subjectivity, tentativeness, and the manner in which science was embedded within sociocultural phenomena. Schmidt et al. (2022), using a larger sample of $N = 414$ in-service teachers in Germany, found that teachers trusted the knowledge claims made by educational scientists over claims made by other teachers. This result contrasted with other studies (e.g., Landrum et al., 2002; Merk & Rosman, 2019; Hendricks et al, 2021), which the authors attributed to a difference in sample composition (in-service teachers vs. pre-service teachers) and a corresponding difference in attributes such as work or practical experience.

Purpose of Study

The purpose of this study was to construct, administer, and examine data collected from a set of three measurement instruments that assess teachers' self-efficacy, value, and frequency-of-use regarding learning activities that promote their students' scientific agency and to relate these constructs to each other and also relate them to select demographic characteristics (e.g., experience, gender, school level). Additionally, we sought to measure and evaluate two additional constructs pertaining to the promotion of students' civic science literacy in schools: 1) in-service teachers' and pre-service teachers' trust in science and 2) teachers' and pre-service teachers' self-efficacy in incorporating sustainability and social justice concepts into their students' science learning activities. This study collected data from Taiwanese teachers in elementary/primary schools, junior high schools, and senior high schools/vocational schools, as well as from Taiwanese pre-service teachers, principals, and school administrators. Demographic information including gender, experience, grade-level-taught, teaching role also were collected.

Method

Instrumentation

The self-efficacy, value, and frequency-of-use instruments pertaining to student scientific agency each included 13 items with statements describing learning activities that promote students' scientific agency (e.g., "Students provide their own suggestions or make modifications to science-related learning activities," "Students develop their own scientific topic or research question to investigate"), where each item was aligned with 5-point ordinal response options indicating either frequency of practice (for measuring frequency of use), or degree of agreement (when measuring self-efficacy), or degree of importance (when measuring value). These items were developed in consultation with current literature on scientific agency, and also based on qualitative data obtained from interviews and focus groups carried out with Taiwanese teachers, students, principals, administrators, and parents, where emergent themes of student scientific agency and social justice emerged (Smith et al., 2023). Items were presented to experts in the field of science education to ensure content validity.

The scale assessing teachers' trust in science consisted of 9 items, where each item included a statement about science (e.g., "Scientific theories are trustworthy," "I trust that scientific research can find solutions to most science-related problems") together with a 5-point response scale ranging from 1 = *strongly disagree* to 5 = *strongly agree*. Several items (e.g., "Scientific theories are weak explanations") were negatively-worded and thus the obtained response for these items was reverse-coded. These items were derived from the *Trust in Science and Scientists Inventory* developed by Nadelson et al. (2014). To focus more clearly on trust in science as a construct, we excluded items from Nadelson et al.'s inventory that assessed trust in scientists as persons. We revised some items for clarity and also created new items that we perceived as being core to the construct of interest (e.g., "I trust findings of scientific research that have been accepted by the scientific community").

The fifth scale in this study was intended to assess teachers' and pre-service teachers' attitude towards incorporating sustainability into their students' learning activities. It consisted of nine items, where each item drew from one or more of the United Nations' sustainable development goals (SDGs; United Nations, 2023).

For each of the five instruments created in this study, items initially were written in English, then translated to Chinese. Back-translation of the items written in Chinese was used to ensure validity of the items across the two languages. The survey was administered in an online, web-based format using the Qualtrics platform, and it was made available to participants in their choice of Chinese or English language.

Sample

To obtain participants for this study, principals and school administrators in two elementary schools, 10 junior high schools, 16 high schools across Taiwan (northern, central, and southern regions) were contacted and asked to provide email addresses for teachers who were willing to participate in the study. Additionally, faculty members at three universities in Taiwan were contacted and asked to provide email addresses for pre-service teachers who were willing to participate. We obtained email addresses for 142 individuals in Taiwan who were in-service teachers, pre-service teachers, principals, or other administrators. Each participant who completed the survey was provided with a $200 NT gift card.

Procedure

Potential participants (in-service teachers, pre-service teachers, principals, and other administrators) were sent an initial email invitation to participate in the study. This email included a brief description of the study and also a link to the online survey itself. Individuals who selected the email link to the survey first were asked to provide informed consent by viewing an informed consent page on the online survey that described the study purpose, the required tasks, the time requirement (10-20 minutes), and whom they could contact if they had questions or concerns, and then were asked to indicate their consent (or non-consent) by clicking on clearly-marked survey buttons on provided on this informed consent page. Those who did not consent to participate were automatically directed out of the survey. Three follow-up email reminders were provided in the week following the initial invitation.

Approval to carry out the study was provided by the Human Research Ethics Committee at National Cheng Kung University (NCKU HREC), which was authorized in this role by Taiwan's Ministry of Education (MOE).

Results

Demographic Characteristics of Sample

A total of 94 individuals completed the survey, constituting a 66.2% response rate. Most respondents (n = 61, 64.9%) were teachers, while n = 24 (25.6%) were administrators (including one principal), and $n = 9$ (9.6%) were pre-service teachers. Table 1 shows more specific demographic characteristics of the participants, both for the overall sample as well as by professional role. Male respondents were slightly more common (57.4%) than female respondents (42.6%) and, among the teachers and administrators, most respondents had moderate amounts of work experience. Among the teachers, most taught high school (39.3%) or junior high school (36.1%) while fewer taught elementary school (24.6%). Among the pre-service teachers, most (77.8%) planned to teach in elementary schools.

Analyses of Responses to Teaching Practices Scales

Relative Frequency Distributions

Table 2 shows the relative frequency of responses from the in-service and pre-service teachers ($N = 70$) to items assessing their perceived self-efficacy in promoting scientific agency in their teaching practices (SATP-SE). Table 3 shows the relative frequency of responses from the in-service teachers, pre-service teachers, and administrators ($N = 94$) indicating their perceived value of teaching practices to promote student scientific agency (SATP-VALUE). Table 4 shows the relative frequency of responses from the in-service teachers ($N = 61$) to items assessing their actual use of specific teaching practices to promote students' scientific agency (SATP-USE). Table 5 shows the relative frequency of responses from in-service teachers' and pre-service teachers ($N = 70$) to the nine items pertaining to their perceived self-efficacy in implementing sustainable development goals (SDGs). There were no missing values in the data.

Table 1

Demographic Characteristics of Sample Participants

Characteristic		Teachers (*n* = 61)		Pre-service teachers (*n* = 9)		Administrators (*n* = 24)		Total (*n* = 94)	
		n	%	*n*	%	*n*	%	*n*	%
Years employed in the educational field	Not yet employed (pre-service teacher)	--	--	9	100.0%	--	--	9	9.6%
	Less than 5 years	8	13.1%	--	--	1	4.2%	9	9.6%
	5-10 years	10	16.4%	--	--	0	0.0%	10	10.6%
	11-15 years	19	31.1%	--	--	8	33.3%	27	28.7%
	16-20 years	7	11.5%	--	--	7	29.2%	14	14.9%
	21-25 years	11	18.0%	--	--	2	8.3%	13	13.8%
	26 years or more	6	9.8%	--	--	6	25.0%	12	12.8%
	Total	61	100.0%	9	100.0%	24	100.0	94	100.0%
Gender	Female	25	41.0%	4	44.4%	11	45.8%	40	42.6%
	Male	36	59.0%	5	55.6%	13	54.2%	54	57.4%
	Other gender	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Total	61	100.0%	9	100.0%	24	100.0%	94	100.0%
Grade level primarily taught (or plan to teach*)	Elementary/primary school	15	24.6%	7	77.8%	--	--	22	31.4%
	Junior high school	22	36.1%	2	22.2%	--	--	24	34.3%
	Senior high school / senior vocational school	24	39.3%	0	0.0%	--	--	24	34.3%
	Total	61	100.0%	9	100.0%	--	--	70	100.0%
Teach (or plan to teach*) science-related topics in classes	Yes	54	88.5%	9	100.0%	--	--	63	90.0%
	No	7	11.5%	0	0.0%	--	--	7	10.0%
	Total	61	100.0%	9	100.0%	--	--	70	100.0%

Note. *Pre-service teachers were asked about their future teaching plans for the indicated items.

Table 2

Relative Frequency Distribution of Participant Responses to Self-Efficacy in Scientific Agency Teaching Practices (SATP-SE) Items

I believe that I am able to create science-related learning activities where students…	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. argue a position on a socio-scientific issue that they've chosen (e.g., climate change, genetically modified food, nuclear power, etc.).	2.9%	2.9%	11.4%	64.3%	18.6%
2. present a self-selected scientific topic to their peers	0.0%	1.4%	11.4%	57.1%	30.0%
3. integrate aspects of their community's culture into science related learning activities.	1.4%	5.7%	38.6%	47.1%	7.1%
4. participate in a scientific project that engages with people in their community.	4.3%	10.0%	48.6%	31.4%	5.7%
5. meet or work with scientists or professionals in science-related fields.	1.4%	7.1%	20.0%	55.7%	15.7%
6. provide their own suggestions or make modifications to science related learning activities	0.0%	0.0%	12.9%	60.0%	27.1%
7. write a reflection based on their scientific observations.	1.4%	8.6%	45.7%	44.3%	1.4%
8. generate their own experimental procedures.	1.4%	10.0%	45.7%	42.9%	1.4%
9. develop a scientific topic or research question to investigate.	0.0%	2.9%	10.0%	51.4%	35.7%
10. locate misleading scientific claims that they see online and explain to peers why they are misleading.	1.4%	10.0%	51.4%	37.1%	1.4%
11. demonstrate how the results from their science activities can address human rights inequalities, such as gender inequality and racial inequality.	4.3%	7.1%	30.0%	50.0%	8.6%
12. demonstrate how the results from their science activities can address unequal opportunities for people to fulfill their potential (e.g., to obtain education, health care, housing, etc.).	2.9%	11.4%	27.1%	51.4%	7.1%
13. demonstrate how the results from their science activities can address unequal living conditions (e.g., large differences between people in income, quality of life, etc.).	2.9%	10.0%	31.4%	47.1%	8.6%

Note. Responses to these items are from pre-service and in-service teachers ($N = 70$).

Table 3

Relative Frequency Distribution of Participant Responses to Perceived Value of Scientific Agency Teaching Practices (SATP-VALUE) Items

Indicate how *important* you feel that each of the following are for your students to do when learning about science.	Not at all important	Slightly important	Moderately important	Very important	Extremely important
1. Argue a position on a socio-scientific issue that they've chosen (e.g., climate change, genetically modified food, nuclear power, etc.).	1.1%	7.4%	21.3%	51.1%	19.1%
2. Present a self-selected scientific topic to their peers.	0.0%	10.6%	38.3%	37.2%	0.0%
3. Integrate aspects of their community's culture into science-related learning activities.	3.2%	20.2%	28.7%	41.5%	6.4%
4. Participate in a scientific project that engages with people in their community.	7.4%	38.3%	33.0%	16.0%	5.3%
5. Meet or work with scientists or professionals in science-related fields.	0.0%	21.3%	28.7%	37.2%	12.8%
6. Provide their own suggestions or make modifications to science-related learning activities.	1.1%	7.4%	19.1%	54.3%	18.1%
7. Write a reflection based on their scientific observations.	1.1%	4.3%	20.2%	41.5%	33.0%
8. Generate their own experimental procedures.	0.0%	4.3%	13.8%	47.9%	34.0%
9. Develop a scientific topic or research question to investigate.	0.0%	4.3%	17.0%	47.9%	30.9%
10. Locate misleading scientific claims that they see online and explain to peers why they are misleading.	0.0%	5.3%	17.0%	43.6%	34.0%
11. Demonstrate how the results from their science activities can address human rights inequalities, such as gender inequality and racial inequality.	5.3%	20.2%	23.4%	44.7%	6.4%
12. Demonstrate how the results from their science activities can address unequal opportunities for people to fulfill their potential (e.g., to obtain education, health care, housing, etc.).	4.3%	14.9%	35.1%	38.3%	7.4%
13. Demonstrate how the results from their science activities can address unequal living conditions (e.g., large differences between people in income, quality of life, etc.).	3.2%	22.3%	28.7%	38.3%	7.4%

Note. Responses to these items are from in-service teachers, pre-service teachers, and administrators (N = 94).

Table 4

Relative Frequency Distribution of Participant Responses to Use of Scientific Agency Teaching Practices (SATP-USE) Items

Think about learning activities that you arrange for your students in science class. How often do your students engage in the following activities?	Never	Once a semester	2-3 times a semester	4-5 times a semester	More than 5 times a semester
1. Students argue a position on a socio-scientific issue that they've chosen (e.g., climate change, genetically modified food, nuclear power, etc.).	23.0%	44.3%	19.7%	4.9%	8.2%
2. Students present a self-selected scientific topic to their peers.	21.3%	37.7%	32.8%	1.6%	6.6%
3. Students integrate aspects of their community's culture into science-related learning activities.	52.5%	27.9%	11.5%	1.6%	6.6%
4. Students participate in a scientific project that engages with people in their community.	80.3%	11.5%	8.2%	0.0%	0.0%
5. Students meet or work with scientists or professionals in science-related fields.	55.7%	31.1%	11.5%	1.6%	0.0%
6. Students provide their own suggestions or make modifications to science-related learning activities.	32.8%	27.9%	27.9%	1.6%	9.8%
7. Students write a reflection based on their scientific observations.	23.0%	32.8%	29.5%	0.0%	14.8%
8. Students generate their own experimental procedures.	26.2%	29.5%	31.1%	3.3%	9.8%
9. Students develop their own scientific topic or research question to investigate.	19.7%	50.8%	23.0%	3.3%	3.3%
10. Students locate misleading scientific claims that they see online and explain to peers why they are misleading.	45.9%	31.1%	18.0%	3.3%	1.6%
11. Students demonstrate how the results from their science activities can address human rights inequalities, such as gender inequality and racial inequality.	62.3%	21.3%	14.8%	1.6%	0.0%
12. Students demonstrate how the results from their science activities can address unequal opportunities for people to fulfill their potential (e.g., to obtain education, health care, housing, etc.).	60.7%	18.0%	21.3%	0.0%	0.0%
13. Students demonstrate how the results from their science activities can address unequal living conditions (e.g., large differences between people in income, quality of life, etc.).	57.4%	24.6%	18.0%	0.0%	0.0%

Note. Responses to these items are from in-service teachers only ($N = 61$).

Table 5

Relative Frequency Distribution of Teachers' Responses to Self-Efficacy in Incorporating Sustainable Development Goals (SDGs) in their Pedagogy

To what extent do you agree that you're capable of incorporating the following topics into your students' science learning activities?	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. Poverty and hunger	3.3%	13.1%	26.2%	49.2%	8.2%
2. Good health and well-being	4.9%	3.3%	18.0%	65.6%	8.2%
3. Gender, ethnic, economic, and social inequities	4.9%	11.5%	29.5%	49.2%	4.9%
4. Affordable and clean energy	0.0%	3.3%	14.8%	63.9%	18.0%
5. Responsible energy consumption	1.6%	4.9%	16.4%	59.0%	18.0%
6. Sustainable communities	0.0%	9.8%	23.0%	52.5%	14.8%
7. Biodiversity	0.0%	6.6%	14.8%	52.5%	26.2%
8. Climate action	1.6%	0.0%	4.9%	68.9%	24.6%
9. Social justice	4.9%	13.1%	27.9%	49.2%	4.9%

Note. Responses to these items are from in-service teachers and pre-service teachers ($N = 70$).

Psychometric Analyses

We next assessed the dimensionality of the four teaching practices constructs: 1) scientific agency teaching practices self-efficacy (SATP-SE), 2) teacher scientific agency teaching practices use (SATP-USE), and 3) teacher scientific agency teaching practices value (SATP-VALUE), and teacher self-efficacy in implementing sustainable development goals in their teaching (SDGTP-SE). We did this by carrying out confirmatory factor analysis (CFA) using diagonally-weighted least-squares (DWLS) estimation (due to the ordinal nature of the item response options). Fit was evaluated using criteria proposed by Hu and Bentler (1999), where values of CFI and TLI should exceed .95 and SRMR should be lower than .08, and MacCallum et al. (1996), where RMSEA should be less than .08.

Results from CFA showed evidence of poor unidimensional fit for the SATP-SE construct (CFI = .870, TLI = .844, RMSEA = .525, and SRMR = .282), the SATP-VALUE construct (CFI = .939, TLI = .927, RMSEA = .289, and SRMR = .201), and the SATP-USE construct (CFI = .439, TLI = .327, RMSEA = .301, and SRMR = .166). Follow-up models next were fitted to data from each of the three scales (SATP-EF, SATP-VALUE, and SATP-USE) that hypothesized two orthogonal dimensions of student scientific agency consistent with a theoretical framework of scientific agency consistent with the work of Cavagnetto et al. (2020) and OECD (2019). These two orthogonal dimension were 1) "Authorship" (i.e., creating new knowledge), and 2) "Co-Agency" (i.e., the development of scientific agency by engaging in social relationships with peers, teachers, parents, and communities). These models showed better fit for the SATP-EF scale (CFI = .974, TLI = .968, RMSEA = .236, and SRMR = .151), and for the SATP-VALUE scale (CFI = .975, TLI = .969, RMSEA = .188, and SRMR = .139), although the misfit indices (RMSEA and SRMR) were above specified fit criteria. Very poor fit, however, was observed for data obtained from the SATP-USE scale (CFI = .439, TLI = .327, RMSEA = .301, and SRMR = .166) Hence, for this latter scale, we limited our interpretations to the information provided by participant responses to the individual items described previously. We also fitted a unidimensional CFA model using DWLS estimation for in-service and pre-service teachers' perceived self-efficacy in implementing SDGs. Results showed inadequate fit (CFI = .940, TLI = .920, RMSEA = .313, and SRMR = .153) based on criteria for each fit index. Hence, for this latter scale (as with the SATP-USE scale) we limited our interpretations to participant responses to individual items.

Table 6 shows the standardized factor loadings obtained from the two-factor models fitted to the SATP-EF and SATP-VALUE scales and Table 7 provides obtained values for three reliability indices (Cronbach's alpha, McDonald's omega, and average variance extracted). Values of alpha and omega each exceeded .80, indicating "very good" evidence of internal consistency reliability of scores (Dunn et al., 2014; Tavakol & Dennick, 2011). Average variance extracted (AVE) values exceeded .50, indicating acceptable convergent validity evidence (Fornell & Larcker, 1981).

Table 6

Standardized Factor Loadings for Two-Factor Model Describing the Scientific Agency Teaching Practices Self-Efficacy (SATP-SE) Scale and the Scientific Teaching Practices Value (SATP-VALUE) Scale

		SATP-SE		SATP-VALUE	
Item number	Item	Factor 1 (Authorship)	Factor 2 (Co-Agency)	Factor 1 (Authorship)	Factor 2 (Co-Agency)
1	Argue a position on a socio-scientific issue that they've chosen (e.g., climate change, genetically modified food, nuclear power, etc.).	0.58*	--	.74*	--
2	Present a self-selected scientific topic to their peers.	0.74*	--	.63*	--
6	Provide their own suggestions or make modifications to science-related learning activities	0.92*	--	.85*	--
7	Write a reflection based on their scientific observations.	0.97*	--	.81*	--
8	Generate their own experimental procedures.	0.92*	--	.81*	--
9	Develop a scientific topic or research question to investigate.	0.91*	--	.89*	--
10	Locate misleading scientific claims that they see online and explain to peers why they are misleading.	0.83*	--	.79*	--
3	Integrate aspects of their community's culture into science-related learning activities.	--	0.70*	--	.77*
4	Participate in a scientific project that engages with people in their community.	--	0.65*	--	.65*
5	Meet or work with scientists or professionals in science-related fields.	--	0.69*	--	.60*
11	Demonstrate how the results from their science activities can address human rights inequalities, such as gender inequality and racial inequality.	--	0.90*	--	.95*
12	Demonstrate how the results from their science activities can address unequal opportunities for people to fulfill their potential (e.g., to obtain education, health care, housing, etc.).	--	0.93*	--	.91*
13	Demonstrate how the results from their science activities can address unequal living conditions (e.g., large differences between people in income, quality of life, etc.).	--	0.97*	--	.92*

Notes. *Factor loading differs significantly from zero ($p < .001$). Analysis for SATP-SE was based on pre-service teachers and in-service teachers ($N = 70$). Analysis for SATP-VALUE was based on pre-service teachers, in-service teachers, and administrators ($N = 94$).

Table 7

Reliability Evidence for Data Obtained from the Scientific Agency Teaching Practices Self-Efficacy (SATP-SE) Scale and the Scientific Teaching Practices Value (SATP-VALUE) Scale

	Scientific Agency Teaching Practices Self-Efficacy		Scientific Agency Teaching Practices Value	
Reliability index	Factor 1 (Authorship)	Factor 2 (Co-agency)	Factor 1 (Authorship)	Factor 2 (Co-Agency)
Cronbach's Alpha	.88	.87	.87	.87
McDonald's Omega	.90	.90	.90	.90
AVE	.71	.70	.63	.66

Note. AVE = Average variance extracted.

Table 8 shows the item discrimination parameters for a two-dimensional graded-response model (Samejima, 1969, 1997) fitted to the SATP-EF and SATP-VALUE responses, while Figures 1 and 2 show the item response surfaces along the two dimensions. Most items showed good discrimination on the measured traits. Particularly high discrimination was evident for items pertaining to how results from science activities can human rights, human potential, and human living conditions (Items 11, 12, and 13). Lower discrimination was observed for the self-efficacy and value items that pertained to having students meet or work with scientists or professionals in science-related fields (Item 5).

Descriptive Statistics for Composite Scores

Table 9 shows descriptive statistics for total (composite) scores for the two dimensions of the scientific agency teaching practices self-efficacy and value constructs: Authorship and Co-Agency. For each respondent, these composite scores were computed as the mean of the item scores across items. Figure 3 provides histograms for these scores. Each of the constructs showed slight negative skewness.

Table 8

Discrimination Indices for Items from the Teaching Practices Self-Efficacy and Value Scales

Item number	Item	Scientific Agency Teaching Practices Self-Efficacy		Scientific Agency Teaching Practices Value	
		Factor 1 (Authoring)	Factor 2 (Relating)	Factor 1 (Authoring)	Factor 2 (Relating)
1	Argue a position on a socio-scientific issue that they've chosen (e.g., climate change, genetically modified food, nuclear power, etc.).	1.31	--	1.02	--
2	Present a self-selected scientific topic to their peers.	1.43	--	1.65	--
6	Provide their own suggestions or make modifications to science-related learning activities	5.75	--	2.10	--
7	Write a reflection based on their scientific observations.	7.46	--	4.22	--
8	Generate their own experimental procedures.	7.90	--	3.95	--
9	Develop a scientific topic or research question to investigate.	6.04	--	4.08	--
10	Locate misleading scientific claims that they see online and explain to peers why they are misleading.	2.96	--	2.53	--
3	Integrate aspects of their community's culture into science-related learning activities.	--	1.47	--	1.88
4	Participate in a scientific project that engages with people in their community.	--	1.38	--	1.49
5	Meet or work with scientists or professionals in science-related fields.	--	0.70	--	0.77
11	Demonstrate how the results from their science activities can address human rights inequalities, such as gender inequality and racial inequality.	--	8.69	--	8.46
12	Demonstrate how the results from their science activities can address unequal opportunities for people to fulfill their potential (e.g., to obtain education, health care, housing, etc.).	--	31.81	--	6.45
13	Demonstrate how the results from their science activities can address unequal living conditions (e.g., large differences between people in income, quality of life, etc.).	-	12.61	--	29.01

Figure 1

Item Response Surfaces for Scientific Agency Teaching Practices Self-Efficacy Items

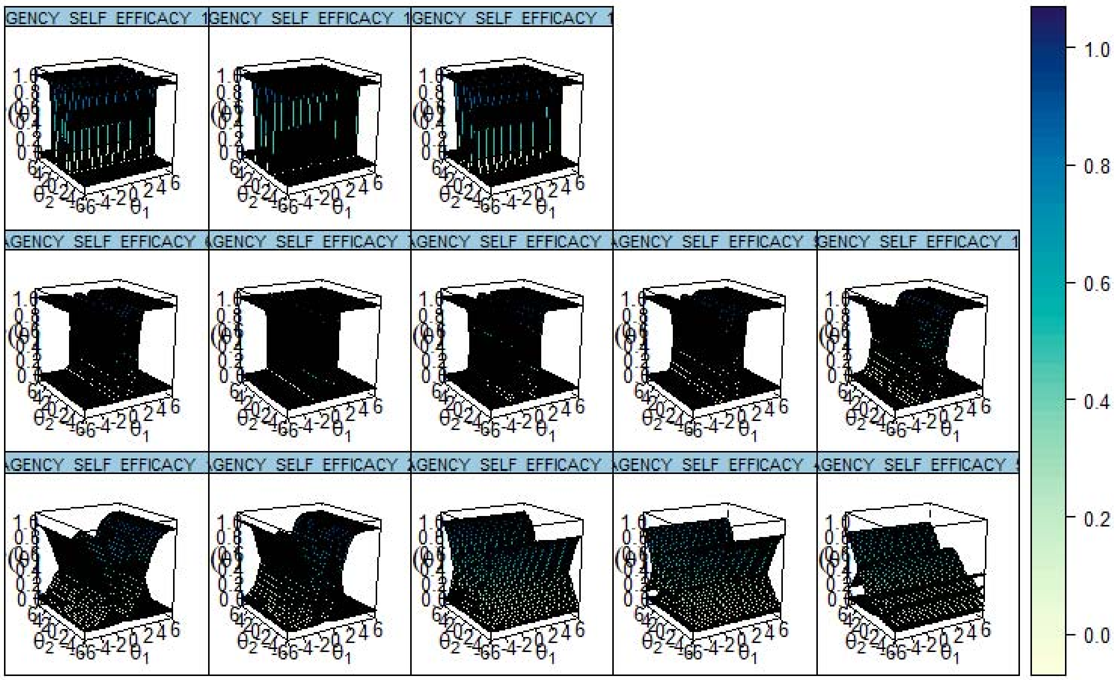


Figure 2

Item Response Surfaces for Scientific Agency Teaching Practices Value Items

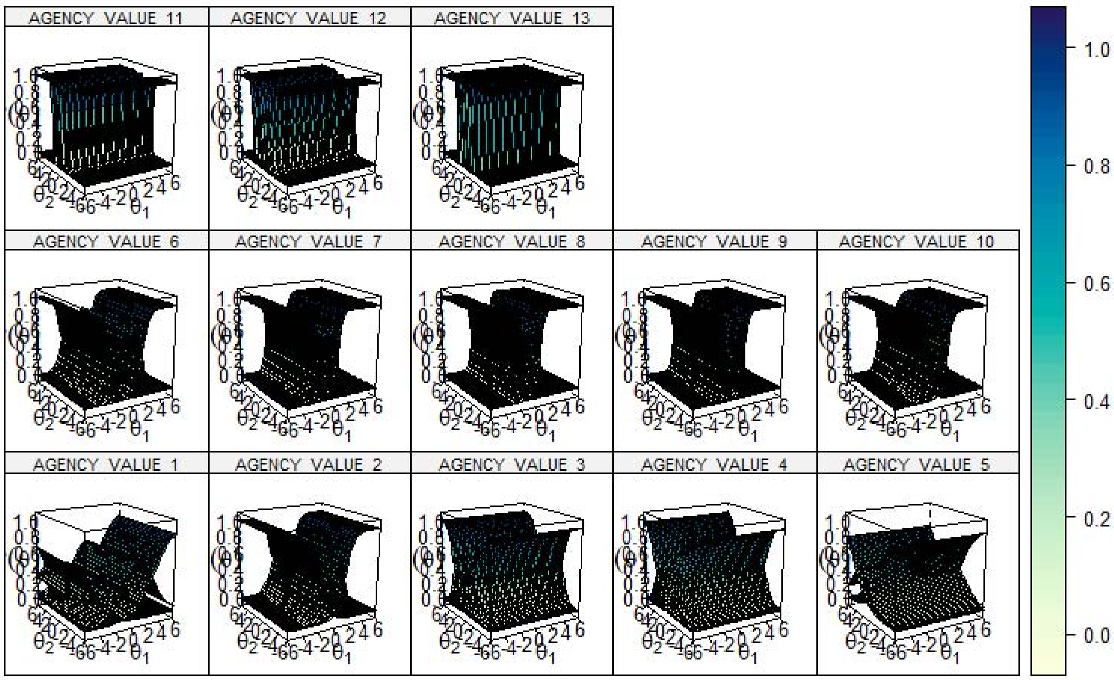


Table 9

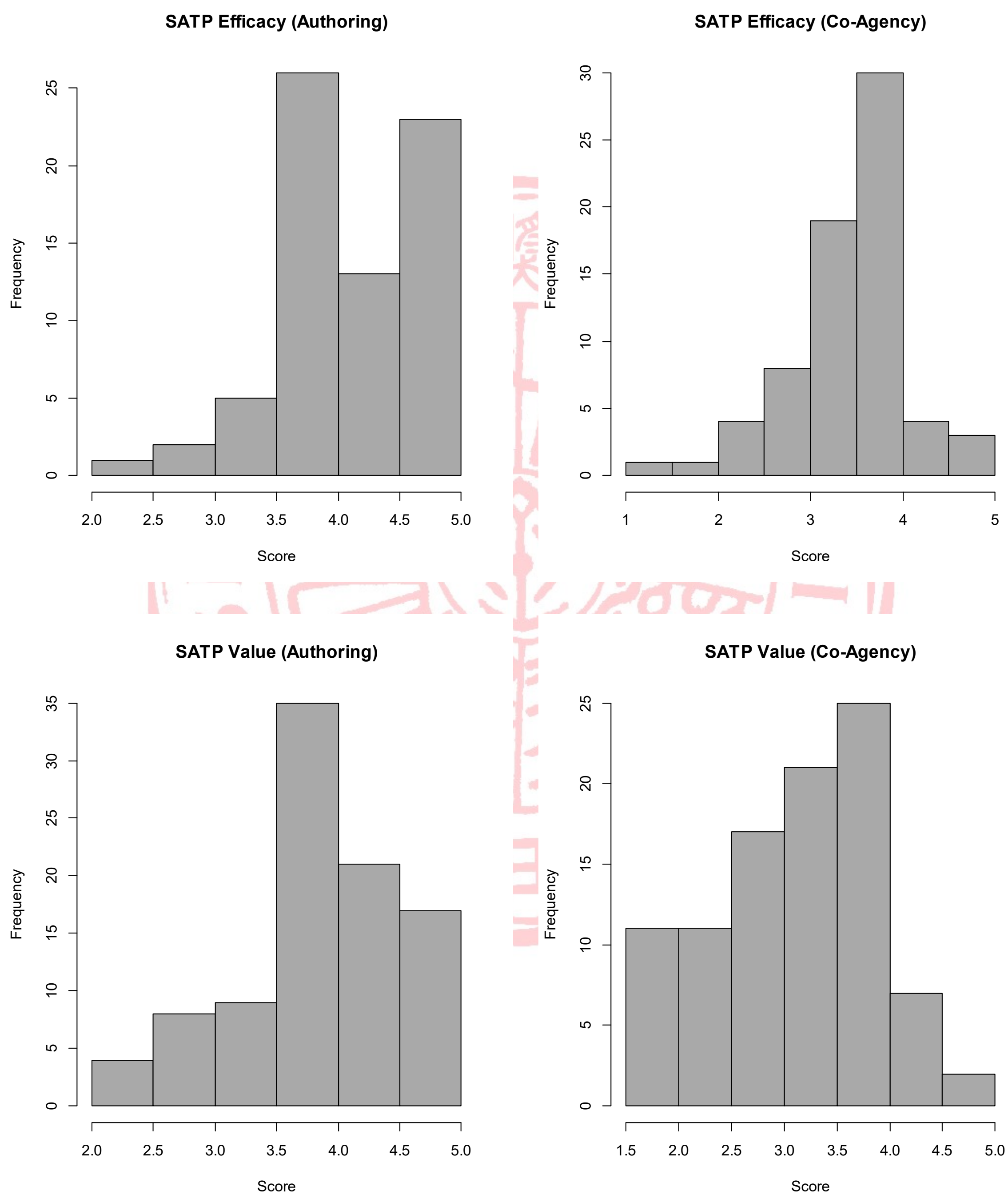
Descriptive Statistics for Scientific Agency Teaching Practices Composite Scores

Construct	Sub-construct	*N*	*M*	*SD*	Skewness	Kurtosis
Scientific Agency Teaching Practices Self-Efficacy	Authorship	70	4.18	0.56	-0.74	0.72
	Co-Agency	70	3.50	0.67	-0.69	2.03
Scientific Agency Teaching Practices Value	Authorship	94	3.91	0.64	-0.56	0.10
	Co-Agency	94	3.21	0.77	-0.11	-0.82

Note. Only in-service and pre-service teachers (N = 70) responded to scientific agency teaching practices self-efficacy items. All participants (N = 94), including in-service teachers, pre-service teachers, and administrators responded to scientific agency teaching practices value items.

Figure 3

Histograms of Scientific Agency Teaching Practices (SATP) Constructs



Predicting Teaching Practices

We next carried out a set of regression analyses to predict four distinct outcomes pertaining to teaching practices related to student scientific agency (i.e., the four composite scores described previously):

1. teachers' self-efficacy for teaching practices that promote scientific authorship agency in students
2. teachers' self-efficacy for teaching practices that promote scientific co-agency in students
3. teachers' value of teaching practices that promote scientific authorship agency in students, and
4. teachers' value of teaching practices that promote scientific co-agency in students.

For each of these four outcomes, we used respondents' professional role (in-service teacher vs. pre-service teacher) gender, grade level taught (or anticipated to teach, for pre-service teachers), and gender (female vs. male) as predictors.

Table 10 shows the results for these regressions. These results show that respondents who taught (or planned to teach) senior high school or vocational high school showed significantly lower self-efficacy in teaching practices to promote students' scientific co-agency than respondents who taught (or planned to teach) elementary school (β = -0.65, p = .048). Conversely, compared to those who taught (or planned to teach) elementary school these same respondents who taught (or planned to teach) senior high school or vocational high school showed significantly higher valuing of teaching practices that promote students' scientific authorship agency (β = 0.63, p = .040). Also, when compared to in-service teachers, pre-service teachers showed significantly higher levels of valuing teaching practices that promote students' scientific authorship agency (β = 1.01, p = .006). Respondents' gender was not a statistically significant predictor of any of the four outcomes (each $p > .05$).

Table 10

Results from Regression Model Predicting Self-Efficacy / Value of Scientific Agency Teaching Practices

Predictors	SATP-SE (Authorship)		SATP-SE (Co-Agency)		SATP-VALUE (Authorship)		SATP-VALUE (Co-Agency)	
	β	p	β	p	β	p	β	p
Intercept	-0.18	<.001	0.27	<.001	-0.19	<.001	0.15	<.001
Male gender (vs. female gender)	0.13	.607	-0.04	.859	-0.08	.721	-0.06	.824
Junior high school†	-0.12	.728	-0.15	.646	-0.30	.320	-0.18	.577
Senior high school / vocational high school†	0.22	.514	-0.65	**.048**	0.63	**.040**	-0.36	.281
Pre-service teacher (vs. in-service teacher)	0.49	.221	0.25	.512	1.01	**.006**	0.50	.199
R^2	.042		.103		.226		.072	

Notes.
†Reference category = elementary school. SATP-SE = scientific agency teaching practices self-efficacy, SATP-VALUE = scientific agency teaching practices value. Statistically significant effects are in bold type.

We additionally used the data from in-service teachers to examine how years of work experience predicted self-efficacy and value of teaching practices to promote students' scientific agency, controlling for gender and grade level taught. Among teachers, years of experience had no statistically significant effect on these outcomes (each $p > .05$).

As previously described in the confirmatory factor analysis results, the survey items that were used to assess teachers use of specific teaching practices to promote students' scientific agency (Table 4) did not show dimensional evidence of latent multi-item constructs. Therefore, we used each of these 13 teaching practices as distinct ordinal outcomes and carried out ordinal logistic regression to assess the extent to which grade level taught and gender predicted each outcome. (Note. Respondents' professional role was not used as predictor, because all respondents to this particular scale were in-service teachers). Results from these ordinal regression analyses showed that male gender was a positive, statistically significant predictor of the teachers use of "practices to promote students/ ability to generate their own experimental procedures" ($b = 1.38$, $p = .008$). Gender was marginally significant predictor of teacher use of "practices that involve students participating in scientific projects that engage with people in their community" ($b = 1.61$, $p = .067$), students "meeting or working with scientists or professionals in the field" ($b = 1.06$, $p = .062$), and students "developing their own scientific topic to investigate" ($b = 0.98$, $p = .065$). These ordinal regressions also showed that, compared to elementary school teachers, senior high school teachers / vocational high school teachers more frequently used teaching practices in which their students "demonstrate how the results from their science activities can address unequal opportunities for people to fulfill their potential" ($b = -1.55$, $p = .034$) and teaching practices in which students "demonstrate how the results from their science activities can address human rights inequalities" ($b = -1.70$, $p = .016$). A marginally significant difference between senior high school /vocational high school teachers and elementary school teachers was evident for teaching practices in which students "write reflections on their scientific observations," with senior high school teachers / vocational high school teachers engaging in this teaching practice more frequently than elementary school teachers ($b = 1.12$, $p = .066$).

In a similar manner, because confirmatory factor analysis did not show empirical evidence for a dimensional structure for teacher self-efficacy in implementing SDGs, we carried out s series of ordinal regression analyses to predict perceived self-efficacy for each individual SDG item. Gender, grade level taught (or anticipated to teach, for pre-service teachers) and professional role were used as predictors. These regression results showed statistically significant positive effects for pre-service teacher status on perceived self-efficacy to implement topics related to 1) affordable and clean energy ($b = 2.09$, $p = .011$), 2) sustainable communities ($b = 1.60$, $p = .042$), and 3) biodiversity ($b = 2.55$, $p = .024$). Marginally significant positive effects for pre-service teacher status were observed for self-efficacy to implement topics related to responsible energy consumption ($b = 1.46$, $p = .058$) and climate action ($b = 1.68$, $p = .062$). Regression results also showed that, compared to those teaching (or planning to teach) in elementary school, those teaching (or planning to teach) in senior high school /vocational high school showed significantly lower perceived self-efficacy to implement topics related to sustainable communities ($b = -1.35$, $p = .048$) and biodiversity ($b = -1.98$, $p = .012$).

Analysis of Responses to Trust in Science Scale Items

We next consider participant responses to the Trust in Science scale items. All respondents (in-service teachers, pre-service teachers, and administrators) responded to this set of items.

Relative Frequency Distributions

Table 11 shows the relative frequency distributions of participants' ($N = 94$) responses to the Trust in Science scale items.

Table 11

Relative Frequency Distribution of Participant Responses to Trust in Science Scale Items

Indicate your level of agreement/disagreement with each of the following statements.	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. Scientific theories are trustworthy.	1.6%	3.3%	11.5%	68.9%	14.8%
2. I trust that the findings of scientific research will make life better for people.	0.0%	1.6%	14.8%	60.7%	23.0%
3. I trust findings of scientific research that have been accepted by the scientific community.	0.0%	3.3%	18.0%	67.2%	11.5%
4. When scientists change their mind about a scientific idea it diminishes my trust in their work.	4.9%	37.7%	50.8%	4.9%	1.6%
5. People with stronger scientific literacy will have more trust in science.	3.3%	19.7%	36.1%	31.1%	9.8%
6. We can trust science to find the answers that explain the natural world.	0.0%	1.6%	16.4%	62.3%	19.7%
7. Scientific theories are weak explanations.	3.3%	57.4%	29.5%	8.2%	1.6%
8. I trust that scientific research can find solutions to most science-related problems.	0.0%	1.6%	13.1%	70.5%	14.8%
9. I trust science will provide us with a better future.	0.0%	1.6%	18.0%	57.4%	23.0%

Note. Responses to these items are from teachers, pre-service teachers, and administrators ($N = 94$).

Psychometric Analysis

Confirmatory factor analysis using DWLS estimation was used to assess the dimensional structure of the Trust in Science scale responses. Results from this analysis found marginal evidence for a unidimensional structure (CFI = .975, TLI = .966, RMSEA = .098, SRMR = .096). Examination of factor loadings (Table 12) showed that one of the negatively-worded items (Item 4: "When scientists change their mind about a scientific idea it diminishes my trust in their work") showed a very small (near-zero) and non-statistically significant factor loading ($\lambda = 0.02$, $p = .713$). The other negatively-worded item (Item 7) showed the expected negative factor loading, although it was relatively weak in magnitude ($\lambda = -0.30$, $p < .001$). Re-fitting the CFA without Item 4 resulted in good model fit (CFI = .990, TLI = .987, RMSEA = .070, SRMR = .080). Using this reduced set of eight items, computation of internal consistency estimates indicated good reliability based on Cronbach's alpha ($\alpha = .77$) and McDonald's omega ($\omega = .79$). The value of average variance extracted (AVE = .46) was below the suggested fit criterion (.50). However, Fornell and Larcker (1981) suggest that, if AVE is lower than .50, convergent validity may still be adequate if other reliability indices exceed .60, which occurred with these data.

Table 12

Standardized Factor Loadings for Single-Factor Trust in Science Model

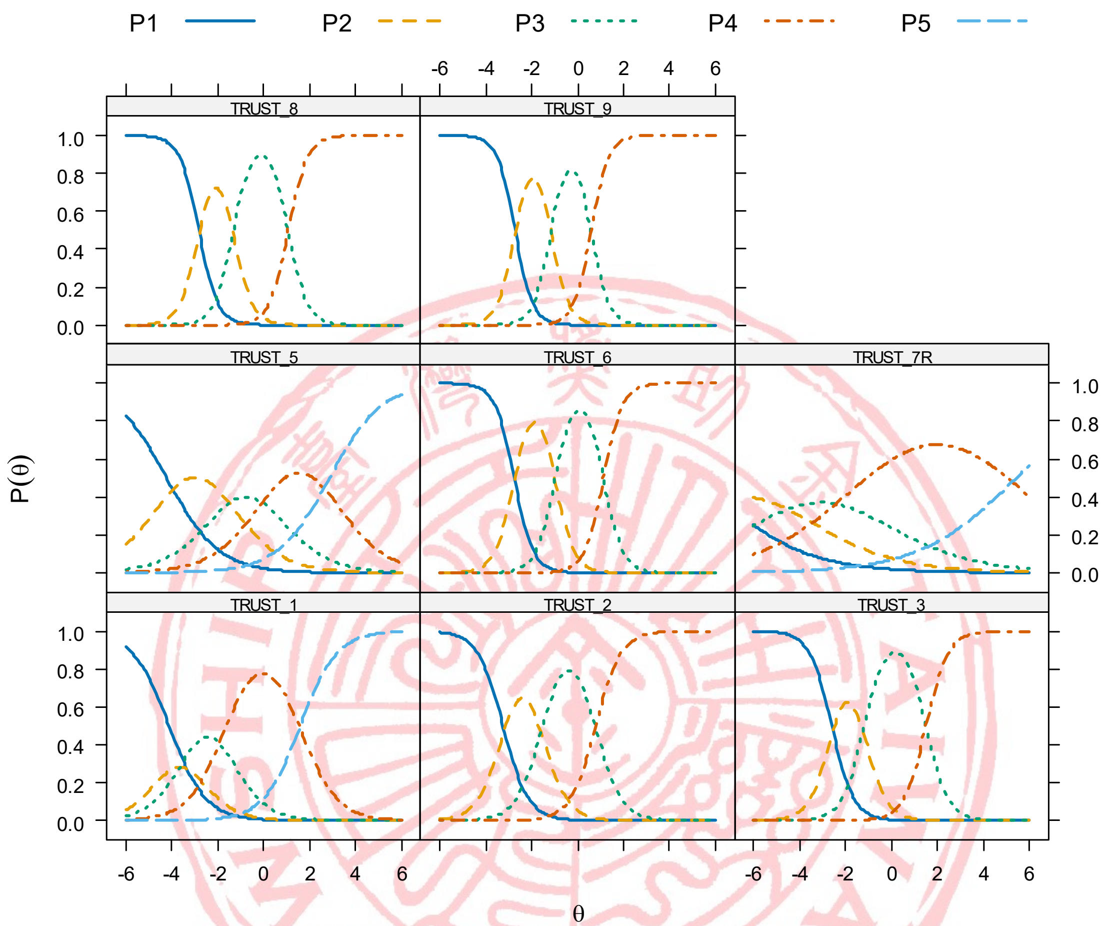
Item number	Item	Factor loadings (Model with all items)	Factor loadings (Model omitting item #4)
1	Scientific theories are trustworthy.	0.61*	0.61*
2	I trust that the findings of scientific research will make life better for people.	0.71*	0.71*
3	I trust findings of scientific research that have been accepted by the scientific community.	0.75*	0.75*
4	When scientists change their mind about a scientific idea it diminishes my trust in their work.	0.02	--
5	People with stronger scientific literacy will have more trust in science.	0.46*	0.46*
6	We can trust science to find the answers that explain the natural world.	0.79*	0.79*
7	Scientific theories are weak explanations.	-0.30*	-0.30*
8	I trust that scientific research can find solutions to most science-related problems.	0.81*	0.81*
9	I trust science will provide us with a better future.	0.81*	0.81*

Note. *Factor loading differs significantly from zero ($p < .001$).

Figure 4 provides the item characteristic curves for graded response models (Samejima 1969, 1997) for each of the Trust in Science items. Each of the items showed good discrimination across levels of the latent trust in science construct, with the exception of item 7 (a negatively-worded item).

Figure 4

Item Characteristic Curves (ICC) for Trust in Science Items



Note. P1, P2, P3, P4, and P5 refer to the probability curves for each of the five response options. Response for Item 7 have been reverse-coded.

Descriptive Statistics for Composite Scores

Table 12 shows descriptive statistics from the sample for composite Trust in Science scores computed for each respondent as the mean score across items, and Figure 5 provides a histogram of the scores. The distribution of scores was close to normal in shape, with very little skewness or kurtosis.

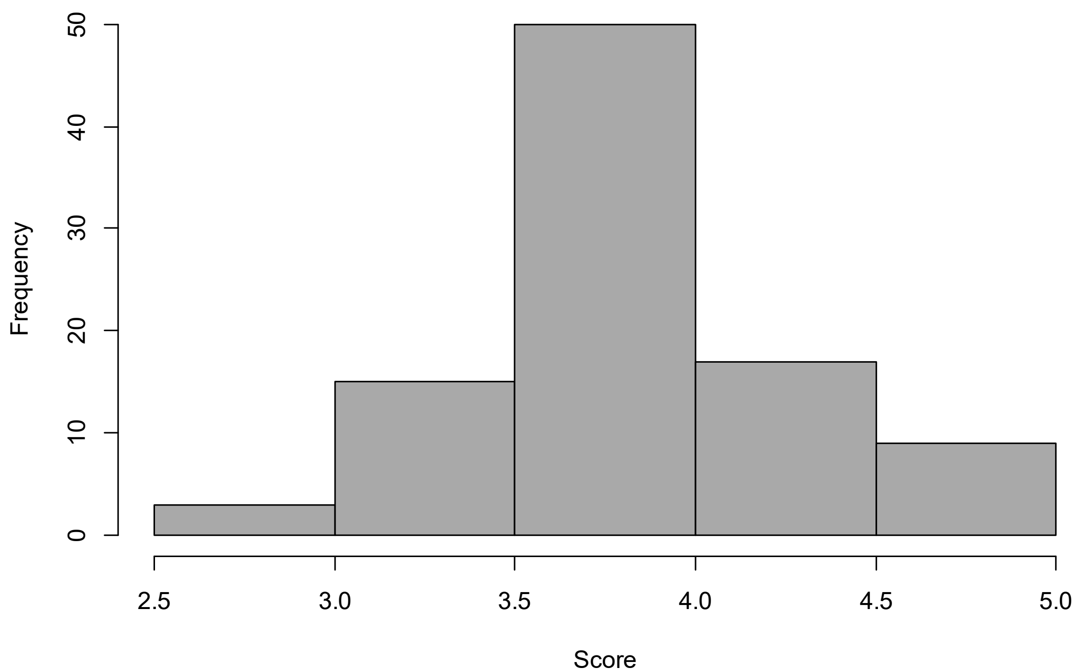
Table 12

Descriptive Statistics for Scientific Agency Teaching Practices Composite Scores

Construct	*N*	*M*	*SD*	Skewness	Kurtosis
Trust in Science	94	3.88	0.45	0.01	-0.03

Figure 5

Histogram of Trust in Science Scores



Predicting Trust in Science

We next fitted a multiple linear regression model predicting the composite Trust in Science scores from respondents' gender (female vs. male) and professional role (in-service teacher, pre-service teacher, or administrator). Results (Table 13) showed a significant positive effect of male gender on trust in science scores ($\beta = 0.45$, $p = .031$). That is, controlling for the respondent's professional role, males showed mean trust in science scores that were 0.20 points higher than females (Figure 6). No statistically significant effect for professional role (i.e., trust in science differences among in-service teachers, pre-service teachers, or administrators) was observed. The full regression model with all predictors explained 7.6% of the variability in the outcome variable.

Table 13

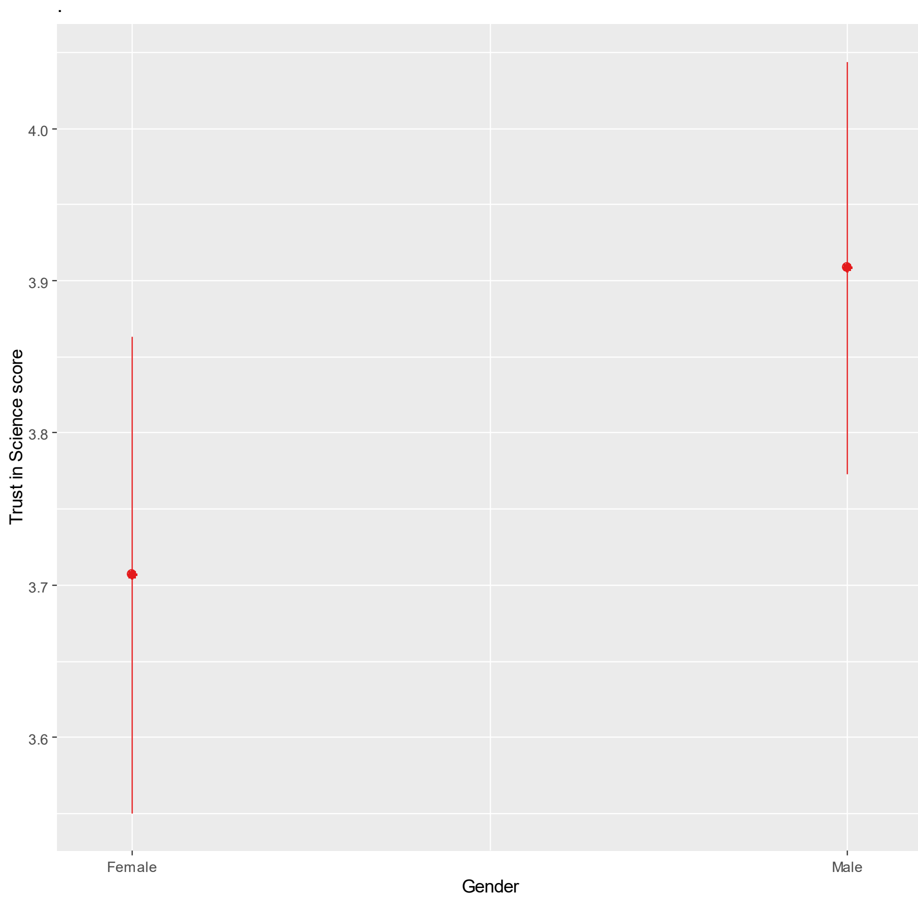
Results from Regression Model Predicting Trust in Science

	Trust in Science	
Predictors	*B*	*p*
Intercept	-0.38	<.001
Male gender (vs. female gender)	0.45	**.031**
Pre-service teacher (vs. in-service teacher)	0.39	.097
Administrator (vs. in-service teacher)	0.22	.537
R^2	.076	

Note. Responses were from teachers, pre-service teachers, and administrators ($N = 94$).

Figure 6

Adjusted Mean Trust in Science Scores by Gender



Summary and Insights

This study sought to develop and administer a set of scales measuring Taiwanese educators' self-efficacy, value, and extent of use pertaining to teaching practices that promote student civic science literacy. To this end we created three scales focused on teaching practices to promote students' scientific agency and a fourth scale to assess self-efficacy in incorporating sustainable development goals into pedagogical practices. Finally, we revised an existing measure of trust in science and assessed educators on this construct.

Results suggested two of the three scales pertaining to scientific agency (measuring educators' *self-efficacy* in teaching practices to promote student scientific agency, and educators' *value* of teaching practices to promote student scientific agency) provided evidence for reliability and validity. Results supported the presence of two dimensions for each of these two scales—"scientific co-agency" and "scientific authorship." These constructs represent 1) practices that facilitate students' development of scientific agency through their engagement in social relationships with peers, teachers, parents, and communities (i.e., co-agency) and 2) students' active participation in generating knowledge (i.e., authorship). The third scale pertaining to scientific agency—consisting of a set of items assessing the extent to which teachers *use* teaching practices that promote student scientific agency—did not show evidence of dimensional structure. However, this scale still could be used at the item response level to obtain information about very specific aspects of these teaching practices. A fourth scale was constructed to assess teachers' self-efficacy in incorporating sustainable development goals (SDGs) into teaching practice. Teacher responses to this scale did not show evidence of dimensional structure. However, this scale, too, might be used at the item level to explore teachers' self-efficacy in incorporating SDGs into their pedagogy.

Inferential analyses using scores obtained from the self-efficacy and value scales pertaining to teaching practices to promote scientific agency showed that, compared to elementary school teachers, high school / vocational school level teachers more strongly valued teaching practices that promote the first of the two dimensions of scientific agency—scientific authorship. Perhaps elementary school teachers do not feel that children at elementary grade levels do not yet have the capacity to create scientific knowledge. However, the notion of scientific authorship does not necessarily equate to novel scientific insights or findings. Children at the elementary school level, for example, might be prompted to creatively conjecture how observed results from a scientific inquiry activity might change if they alter some aspect of the activity in way that they choose. This idea of creativity aligns to a great extent with the third of the three categories of competencies in the Twelve-year Curriculum (Chen & Huang, 2017; Ministry of Education, 2014)—namely, "spontaneity." Certainly, young children are capable of spontaneity, and the challenge for educators becomes one of harnessing this natural spontaneity and energy and helping children direct it towards creative pursuits in science. A finding that was encouraging, however, was that Taiwanese pre-service teachers valued teaching practices to promote scientific authorship more strongly than in-service teachers. This suggests that teachers who are soon to enter the profession may have more positive perspectives about the role of authorship/creativity in students' science education.

A second finding from inferential analyses was that, compared to high school / vocational high school teachers, elementary school teachers showed higher self-efficacy in using practices to promote the second of the two dimensions of students' scientific agency—scientific co-agency. This difference may reflect a distinction in the curricula of these two educational settings. High school / vocational high school settings likely have more settings that focus more heavily on science content knowledge and laboratory procedures than elementary school settings, and there may be less time available for other learning activities. Nonetheless, given more recent emphases on the importance of scientific agency (see, for example, OECD, 2019)—and in particular the extent to which scientific agency is embedded in social context—suggest that teachers at the high school / vocational school level might benefit from increased professional development in how to integrate social and community contexts into their pedagogy. This aligns with two of the three main categories of competencies outlined in the Twelve-year Curriculum (Chen & Huang, 2017; Ministry of Education, 2014); namely, "communicative interaction" and "social participation." Clearly, the global village will demand that citizens possess these scientific agency skills, and the success of Taiwanese students in their future endeavors will be highly dependent on more than just technical competencies and knowledge.

Finally, scores obtained from Taiwanese educators (and pre-service teachers) on a scale assessing their trust in science showed reliability and validity evidence as unidimensional construct. Inferential analyses of data from Taiwanese educators (and pre-service teachers) using this scale showed that male respondents showed significantly higher trust in science than females. It is somewhat difficult to surmise reasons for this gender difference. Perhaps it is intertwined with individuals' views towards socio-scientific issues. For example, with regard to the issue of nuclear power, Ho et al. (2013) found that females were more strongly opposed than males to construction of a new power plant following the 2011 Fukushima power plant disaster, and Keller et al. (2012) observed that females perceived nuclear power plants as presenting higher levels of risk compared to males and demonstrated more negative feelings towards replacing nuclear power plants. Another example comes from Chen (2011), who found that female consumers in Taiwan showed more negative attitudes towards genetically modified foods than males. Different attitudes towards socio-scientific issues, of course, do not necessarily parallel differences in the extent to which individuals trust the basic tenants of science. Moreover, however, as science is a self-correcting endeavor carried out by humans, it is subject to the potential errors of humans and, additionally, the applications of science are dependent on human values and priorities. In a healthy and diverse society, these attitudes and priorities always will vary.

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