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# Predicting Learning Interest among Taiwanese Students in the Context of Big Science Issues

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**Abstract:** Research shows that learning enjoyment in specific socio-scientific issues (SSI) plays an important role in predicting grade 10 students' learning interest and learning enjoyment (i.e., genuine interest) in SSI subjects generally. However, it remains unexplored whether learning enjoyment also mediates a predictive effect of learning interest in a Big Science SSI of pressing contemporary global concern—COVID-19—on grade 12 high school students' learning interest in SSI generally. The purpose of this study is to investigate how learning enjoyment may mediate the predictive effect of learning interest in the specific Big Science SSI of COVID-19 specifically on students' learning interest in SSI subjects generally. Latent variable modeling using data collected from grade 12 students (N = 691) showed personal perceptions of learning enjoyment in SSI partially mediated the predictive effect of learning interest in the SSI of COVID-19 on learning interest in other Big Science SSI subjects. Implications for promoting among science educators and policy specialists the active development of students' individual interests and involvement in other 21st century Big Science SSI challenges are forwarded.

**Keywords:** *Big science, COVID-19, learning enjoyment, learning interest, socio-scientific issues.*

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## Introduction

The COVID-19 pandemic, due to its wide-ranging impacts on nearly all aspects of human life, can be considered a defining global moment in many respects. Specifically, the pandemic has been characterized by Sardar (2021, p. 6) as the first (although not necessarily the last) "global, clearly recognizable, postnormal event." Sardar (2010) defines "postnormal times" as a period "[of] uncertainty, rapid change, realignment of power, upheaval and chaotic behavior [...] where old orthodoxies are dying, new ones have yet to be born, and very few things seem to make sense" (p. 435). Sardar (2021) further argues that this transitory postnormal period eventually will lead to the era of the "transnormal," whereby, the dynamic changes of postnormality reposition humanity into a "trans"—or stable—state. The postnormal period also might be characterized by what Weinberg's (1972) terms "trans-science," a systemic situation where professionals within the scientific community have difficulty attaching consistent degrees of certainty or confidence to their answers sufficient to alleviate the concerns of the larger non-scientific community or mitigate their lack of trust in science or scientists as a source of assurance (Jack et al., 2017, p. 967).

Such circumstances require input into decision-making processes from all affected members of society and the incorporation of a wider range of perspectives for achieving acceptably workable solutions. Elsner et al. (2022) suggest that the COVID-19 pandemic presents an opportunity for science educators to increase students' engagement and interest in science by relating their understanding of viruses to their personal experiences with the outbreak. They state:

> While much of current research in education during the pandemic has focused on students' attitudes, mental health concerns, and the impact of school closures (Mirahmadizadeh et al., 2020; Rao & Rao, 2021; Thakur, 2020), little is understood about high school students' interest in learning about COVID-19 (p. 1).

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Although Elsner et al. (2022) point out a need for such research, empirical investigations into students' learning about COVID-19 are sparse, as are empirical research studies into how interest in learning interest in the COVID-19 pandemic might also predict' learning enjoyment and learning interest in socio-scientific issues (SSIs) more generally. The purpose of the current study, therefore, is to examine predictive relationships among these constructs in Taiwanese high school students in the wake of the COVID-19 pandemic. Specifically, we asked to what extent learning interest in COVID-19 both directly and indirectly predicts learning interest in more broadly considered SSI (where the indirect effect is mediated by learning enjoyment) and to what extent these direct and indirect effects differ by student major.

## Literature Review

The following section presents existing literature pertaining to learning enjoyment and learning interest, as well as literature that has examined COVID-19 as an SSI.

### *Learning Enjoyment and Learning Interest*

Hartley (2006) posits that learning enjoyment is an emotional state related to how people feel about or intuitively respond to some object, activity or field of knowledge rather than what or how they think about it. Learning interest can be understood as always directed towards some object, activity, or field of knowledge (Krapp, 2002), and includes emotional and cognitive components as independent but interacting variables (Hidi & Renninger, 2006).

The interconnection and interplay of interest (i.e., cognition) with emotion (i.e., feeling) within students has been found to be important in their learning of science (Dávila-Acedo et al., 2021). Several studies have argued that interest in / enjoyment of science each are positively related to students' science learning (Ainley & Ainley, 2011; Jack & Lin, 2018). Ainley and Ainley suggest that students' enjoyment of science is developed from previous experiences, is central to the inter-relationship between science interest, value, and knowledge, and correlates to personal expectations about future science learning, participation in science activities, and improved science learning performance. Zhu and Mok (2018) also identify interest as one of the strongest factors predicting students' self-regulated learning. F. Chen and Cui (2020, pp. 6, 15) further confirm both interest and enjoyment as "powerful predictors" of student achievement in science learning.

Recent studies (Jack et al., 2021, 2024) investigating high school students' learning enjoyment and learning interest in socio-scientific issues posit that these two aspects of active learning make up what Dewey (1903) defines as genuine interest in learning. Jack et al. (2024) also posit that genuine learning interest reflects a conceptualization of individual interest as more ambiguously composed of feeling-related interest and value-related interest (Hidi & Renninger, 2006; Jack & Lin, 2014; Schiefele, 1992; Schraw & Lehman, 2001).

### *COVID-19 as an SSI*

The COVID-19 pandemic has been considered by some to be the largest, most pressing, and challenging SSI of the 21st century (see, for example, Berkley, 2020; Coccia, 2021; Koff et al., 2021; Zoumpourlis et al., 2020). The pandemic shares characteristics of both Big Science and socio-scientific issues (Berkley, 2020; Brown & Susskind, 2020). The development of effective vaccinations against the virus has motivated the mobilization of vast national public resources and the coordination of professional expertise from diverse disciplines of practice (Li et al., 2021; Slaoui & Hepburn, 2020; Verdecia et al., 2021). As an issue of global and seemingly universal impact, COVID-19 illustrates the immediacy and vital necessity of promoting scientific literacy and informed decision-making among students (Anderson et al., 2020; Ke et al., 2020).

A majority of previous studies highlighting the association between COVID-19 and SSI have focused on public health policy (e.g., Vuolanto et al., 2024) or medicine (e.g., Wu & Kong, 2023). The current study differs from previous studies pertaining to COVID-19 as an SSI in that it additionally examines the mediating role of learning enjoyment in the relationship between learning interest in COVID-19 and more general learning interest.

Elsner et al. (2022), in surveying 224 high school students with six open-ended questions, found that students were most interested in topics pertaining to COVID-19, but only 6.7% of the students indicated that they rely on their teachers as a source of COVID-19-related information. The authors suggest an opportunity for science educators to leverage students' interest in COVID-19 into increased situational interest and potentially improved academic performance and engagement. Presenting and discussing current "big science" issues additionally can allow students to learn about and experience these topics with less anxiety compared to obtaining the information from internet sources (Ho et al., 2020).

Research carried out prior to the COVID-19 pandemic (Jack et al., 2021, 2024) found that engaging students' learning about controversial socio-scientific issues in science was significantly related to students' learning interest and learning enjoyment about science. When dealing with controversial socio-scientific issues, people generally tend to evaluate evidence, generate counter-evidence, and test hypotheses through the biased lenses of previous attitudes and experiences (Stanovich et al., 2013). This means that students' attitudes and experiences likewise tend to have significant impact (both positive and negative) on their own considerations of socio-scientific issues, such as their learning interest and learning enjoyment (Jack & Lin, 2018; Lin et al., 2013).

Hartley (2006) posits that learning enjoyment is an emotion state related to how people feel about or intuitively respond to some object, activity or field of knowledge rather than what or how they think about it. Learning interest can be understood as always directed towards some object, activity, or field of knowledge (Krapp, 2002), and includes emotional and cognitive components as independent but interacting variables (Hidi & Renninger, 2006).

The interconnection and interplay of interest (i.e., cognition) with emotion (i.e., feeling) within students has been found to be important in their learning about science (Dávila-Acedo et al., 2021). Several studies have argued that interest and enjoyment of science are both positively related to students' science learning (Ainley & Ainley, 2011; Jack & Lin, 2018). Ainley and Ainley (2011) suggest that students' enjoyment of science is developed from previous experiences, is central to the inter-relationships among science interest, value, and knowledge, and correlates to personal expectations about future science learning, participation in science activities, and improved science learning performance. As well, Zhu and Mok (2018) identify interest as one of the strongest factors predicting students' self-regulated learning. F. Chen and Cui (2020, pp. 6, 15) further confirm both interest and enjoyment as "powerful predictors" of student achievement in science learning.

Recent studies (Jack et al., 2021, 2024) investigating high school students' learning enjoyment and learning interest in socio-scientific issues posit that these two aspects of active learning make up what Dewey (1903) defines as genuine interest in learning. Jack et al. (2024) also posit that active and positive aspects of learning motivation can be reflected within the classroom learning environment, and this learning motivation is composed of "feeling-related interest" and "value-related interest" (Hidi & Renninger, 2006; Jack & Lin, 2014; Schiefele, 1992; Schraw & Lehman, 2001).

Instruments for measuring students' learning interest and learning enjoyment specific to socio-scientific issues have been developed (López-Fernández et al., 2021), and previous studies (e.g., Stenseth et al., 2016) have examined how learning interest predicts learning enjoyment. However, studies have yet to investigate how students' learning interest in a single, critical, post-normal event of substantial impact—the COVID-19 pandemic—might predict students' learning enjoyment and learning interest in contemporary socio-scientific issues more generally considered.

Moreover, many practicing professionals in science education continue to advocate for a science citizenship approach to promoting science-related content learning interest among students (Jack et al., 2017; National Academies of Sciences, Engineering, Medicine, 2018). The goal of this approach is to cultivate and instill within students a "useful scientific literacy" (Anelli, 2011, p. 239) able to provide personal perspective from their acquired knowledge of science and reasoning skills and the means to address with others not only the Big Science questions such as COVID-19 but also in solving problems related to their daily personal issues and life situations relevant to environment and health safety (Wan & Bi, 2020). Feinstein (2011) posits that science education needs to promote among students the usefulness of science, stating:

> I am referring to the very specific notion that science education can help people solve personally meaningful problems in their lives, directly affect their material and social circumstances, shape their behavior, and inform their most significant practical and political decisions. (p. 169)

Thus, this notion of "personally meaningful problems" could be a critical factor in endeavors to stimulate and leverage a more general interest in SSIs among learners that can nurture their growing sense of science citizenship. Consequently, it is important to empirically assess whether this more general interest in SSIs can be predicted by interest in specific, contemporary SSIs that permeate and affect the everyday lives and concerns of these learners, and examine what role their learning enjoyment might play in mediating this interest.

Information understood as meaningfully relevant to a student's own life experience can ignite and sustain personal attention and focus of interest. In the context of formal classroom science education, such a state of absorption is both transformative and energizing, and can transform students' negative interest or disinterest in science-related subjects into a positive and personally validating genuine interest for learning classroom presented science-related information content (Jack & Lin, 2014; Tran et al., 2021). Previous research has shown that learning interest in SSI (LI-SSI) and learning enjoyment in SSI (LE-SSI) play an important role in predicting broadly-considered genuine interest in learning SSI among first year high school students (Jack et al., 2021). However, it remains unclear whether interest in a specific, contemporary SSI topic of immediate and overriding concern—COVID 19—significantly contributes to predicting students' learning enjoyment and learning interest in more general big socio-scientific issues.

The aim of this investigation is to examine how learning interest in a very specific SSI topic of contemporary concern—COVID-19—might be related to learning interest in other Big Sciences SSIs more broadly considered, and how learning enjoyment might mediate this relationship. We posit that learning interest in COVID-19, whether this interest is concerned interest (i.e., when emotion is negative and cognitive attention is highly attentive [Jack & Lin, 2018]) or genuine interest (i.e., when emotion is positive and cognitive attention is highly attentive [Jack et al., 2021]), elicits individual motivation to actively seek out and engage related information that may in turn influence personal decision-making and behavior choices. Because many of the specific health aspects and social consequences related to the

COVID-19 pandemic are presently speculative and uncertain at the time of this study, we limited the measurement domain of learning interest in COVID-19 to (1) public concerns regarding COVID-19, (2) the origin of COVID-19, (3) the health effects of COVID-19 (e.g. emotional ups and downs and psychological stress) and (4) the impact of COVID-19 on global carbon dioxide emissions. In addition to this measure of interest in COVID-19, we also measured students' enjoyment and interest in learning more general SSI topics including alternative energy development, global warming, and nuclear waste. The purpose of this study was to investigate how high school students' learning interest in COVID-19 might predict their learning interest and learning enjoyment in contemporary SSIs generally. Due to the ongoing and potentially overwhelming personal and social nature of the COVID-19 pandemic on the student participants, we focused on learning interest in COVID-19, but did not attempt to measure students' enjoyment from learning about COVID-19, because the effects of COVID-19 represent a type of lived reality that is uncomfortable and potentially disturbing for educators and students alike, as well as for their families (Hughes et al., 2022). General descriptive aspects of the COVID-19 pandemic and socio-scientific issues as developed for the survey applied during this study were predicated on discussions among practicing civics and science education teachers and their students, online national and international news reports, a review of SSI literature, and consideration of prior existing instruments. Further details on the instrument development are provided in the Instrumentation section.

### *Research Questions*

Three research questions were posed in this study.

RQ1: Does learning interest in COVID-19 predict learning interest in more broadly considered SSIs?

RQ2: Does learning interest in COVID-19 indirectly predict learning interest in SSIs, which are more broadly considered, as mediated by learning enjoyment of SSI?

RQ3: Do the direct and indirect effects of learning interest in COVID-19 on learning interest in SSIs, when broadly considered, differ by student major?

## Methodology

### *Research Design*

The current study utilized a cross-sectional, correlational design to examine survey data collected from a convenience sample of high school students in Taiwan. Latent variable structural equation modeling was used to analyze the resulting data. Measurement invariance analysis was used to establish measurement equivalence between science majors and non-majors, and multi-group analysis was used to examine substantive differences in the posited relationship. Additional details pertaining to the research design are presented below.

### *Participants*

A total of 691 responses were collected from high school students in southern Taiwan. Three hundred fifteen students (45.59%) identified themselves as men; 376 (54.41%) students identified themselves as women, and no other self-identified sex- or gender-related types were reported. Among all students surveyed, 359 (51.95%) were enrolled in a science-related subject track (engineering or engineering and biology), and 332 (48.05%) were enrolled in a non-science subject track.

### *Instrument*

Data were collected from student participants using: 1) a 6-item scale assessing enjoyment of socio-scientific issues, 2) a 5-item scale assessing interest in socio-scientific issues, and 3) a 5-item scale assessing interest in the topic of COVID-19. For items on each scale, response options ranged from 1 = strongly disagree to 6 = strongly agree. Items in the learning interest in SSI instrument and the learning enjoyment of SSI instrument were generated from a panel discussion among two high school civics teachers and five high school English teachers and, additionally, a scoping review of 10th grade high school civics and biology textbooks was conducted (Jack & Lin, 2018). These two instruments were used in a separate study (Jack et al., 2024) involving a distinct sample of high school students in which psychometric evidence for the construct, convergent, and discriminant validity was examined, and gender differences in the constructs assessed. The complete set of items pertaining to each construct is shown in Table 1.

*Table 1. Constructs and Item Descriptions*

| Construct | Item |
|---|---|
| Learning Enjoyment (SSI) | 1. I usually feel happy when learning about the topic of how technology is applied to society. |
| | 2. I like to read information about the problems arising from the application of emerging technologies to this society. |
| | 3. I really like to discuss with others how to solve the problems related to the application of new technologies in society. |
| | 4. I really like to discuss with others how to solve related problems arising from the application of new technologies to society. |
| | 5. When I am learning how to apply new technologies to social issues related to this aspect, I often feel that time flies very quickly. |
| | 6. When I learn about the problems arising from the application of new technologies to society, I am often surprised and excited. |
| Learning Interest (SSI) | 1. I am interested in slowing down global warming. |
| | 2. I am interested in reducing carbon dioxide emissions. |
| | 3. I am interested in solving problems related to nuclear waste disposal (e.g., Taiwan Orchid Island). |
| | 4. I am interested in using food (such as corn and soybeans) to develop alternative energy sources. |
| | 5. I am interested in reducing the use of plastic products (e.g., soft bead facial cleanser, plastic products use) |
| Learning Interest (COVID-19) | 1. I am interested in public concerns about COVID-19. |
| | 2. I am interested in the origin of COVID-19. |
| | 3. I am interested in the health effects of COVID-19 (e.g., emotional ups and downs and psychological stress). |
| | 4. I am interested in the impact of COVID-19 on carbon dioxide emissions. |
| | 5. I am interested in the impact of COVID-19 on travel. |

*Note.* Response options for each item were 1 = *strongly disagree*, 2 = *disagree*, 3 = *mildly disagree*, 4 = *mildly agree*, 5 = *agree*, and 6 = *strongly agree*.

*Data Analysis*

We first computed descriptive statistics to describe the data. Second, structural equation modeling (SEM) was used to assess research questions 1 and 2. SEM was chosen to best account for measurement error in the constructs of interest and to facilitate the examination of indirect effects. Prior to fitting the structural model, a confirmatory factor analysis was used to assess the construct validity of the measurement model. For the fitted models, the chi-square statistic was examined to assess model fit. However, the chi-square statistic is known to be sensitive to sample size (Hu & Bentler, 1999). Thus, to assess the goodness of fit of the conceptual model, we focused on other indices including 1) root mean square error of approximation (RMSEA ≤ .06; Steiger & Lind, 1980), 2) non-normed fit index (NNFI ≥ .90; Tucker & Lewis, 1973), 3) comparative fit index (CFI ≥ .90; Bentler, 1990), and 4) standardized root mean square residual (SRMR ≤ .08; Hu & Bentler, 1999).

To address research question 3, measurement invariance (MI) analysis was first used to determine measurement equivalence between student majors (science majors vs. non-science majors). In MI analysis, a set of increasingly constrained, nested measurement models are fitted to the data, where these models represented configural invariance, metric invariance, scalar invariance, and residual error invariance (Dimitrov, 2010). In addition to the conventional difference in the chi-square statistic ($\Delta\chi2$), we calculated the observed change in the CFI (ΔCFI) and RMSEA (ΔRMSEA). The critical value was set to .01 for ΔCFI (Cheung & Rensvold, 2002), and .015 for ΔRMSEA (F. F. Chen, 2007). Following MI analysis, multigroup SEM was carried out to assess differences in the model relationships by major. Multigroup analysis provides a more efficient means of examining group differences in the positive relationships than techniques involving interaction terms, and allow for increased conceptual and visual clarity of group differences. All analyses were carried out using maximum likelihood estimation and employing the Lavaan package (Rosseel, 2012) in R.

## Findings/Results

Descriptive statistics (Table 2) did not reveal evidence of excessive nonnormality. Skewness ranged from -0.94 to -0.06, and kurtosis ranged from -0.47 to 1.04. Across items, mean scores ranged from 3.91 to 4.82, while standard deviations ranged from 0.96 to 1.22. There were no missing values in the data. Due to the relative lack of skewness/kurtosis, non-robust ML was used to estimate model parameters.

*Table 2. Descriptive Statistics for Items Pertaining to Learning Interest in COVID-19, Interest in Socio-scientific Issues, and Enjoyment of Socio-scientific Issues*

| Construct | Item | N | Mean | Std. Dev. | Min | Max | Skew | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| Learning Enjoyment (SSI) | 1 | 691 | 4.38 | 0.96 | 1 | 6 | -0.37 | 0.29 |
| | 2 | 691 | 4.26 | 1.06 | 1 | 6 | -0.33 | 0.07 |
| | 3 | 691 | 4.32 | 1.00 | 1 | 6 | -0.40 | 0.38 |
| | 4 | 691 | 4.07 | 1.08 | 1 | 6 | -0.11 | -0.13 |
| | 5 | 691 | 3.95 | 1.16 | 1 | 6 | -0.06 | -0.42 |
| | 6 | 691 | 4.30 | 1.07 | 1 | 6 | -0.31 | -0.25 |
| Learning Interest (SSI) | 1 | 691 | 4.36 | 1.05 | 1 | 6 | -0.42 | 0.04 |
| | 2 | 691 | 4.25 | 1.05 | 1 | 6 | -0.27 | -0.16 |
| | 3 | 691 | 4.07 | 1.13 | 1 | 6 | -0.17 | -0.47 |
| | 4 | 691 | 4.48 | 1.11 | 1 | 6 | -0.42 | -0.36 |
| | 5 | 691 | 4.37 | 1.15 | 1 | 6 | -0.47 | -0.19 |
| Learning Interest (COVID-19) | 1 | 691 | 4.51 | 1.07 | 1 | 6 | -0.63 | 0.46 |
| | 2 | 691 | 4.79 | 1.12 | 1 | 6 | -0.73 | 0.03 |
| | 3 | 691 | 4.82 | 1.06 | 1 | 6 | -0.94 | 1.04 |
| | 4 | 691 | 3.91 | 1.21 | 1 | 6 | -0.21 | -0.19 |
| | 5 | 691 | 4.68 | 1.22 | 1 | 6 | -0.89 | 0.38 |

To answer research questions 1 and 2, a structural equation model (SEM, Figure 1) was fitted to the data. Both the measurement model and structural model were assessed.

*Measurement Model*

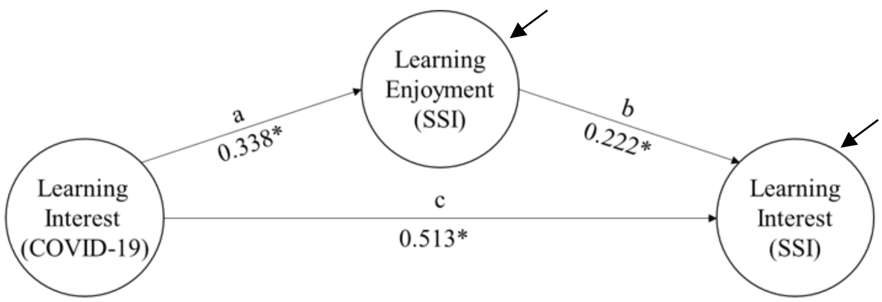
The measurement model (i.e., confirmatory factor analysis) showed a good fit to the data [$\chi 2$ (101) = 497.23, $p < .001$; CFI = .92; NNFI = .91; RMSEA = .075; SRMR = .070] providing construct validity evidence for the latent variables. Standardized factor loadings, component reliability (CR), and average variance extracted (AVE) obtained from the fitted measurement model are shown in Table 3. All loadings were statistically significant and larger than .50. These results indicated that each latent trait was adequately measured by corresponding items. The CRs and AVEs ranged in value from 0.73 - 0.90 and 0.36 - 0.59, respectively. The smallest AVE (0.36) in three latent variables was larger than the largest squared correlation (0.35) between latent variables, providing evidence of discriminant validity based on the guidelines provided by Fornell and Larcker (1981). The high CRs provide evidence of component reliability. Additionally, McDonald's (1999) omega internal consistency coefficient—which makes fewer and more realistic assumptions than Cronbach's alpha (Dunn et al., 2014)—was computed for each construct. Observed values of omega were .82 (Learning Interest in SSI), .90 (Learning Enjoyment of SSI), and .74 (Learning Interest in COVID-19), providing further evidence of construct reliability.

*Structural Model*

The structural model (Figure 1) showed a good fit to the data, [$\chi 2$ (101) = 497.23, $p < .001$; CFI = .92; NNFI = .91; RMSEA = .075; SRMR = .070]. The structural coefficients are shown in Figure 1. All coefficients were statistically significant at the .001 level. Learning interest in COVID-19 positively predicted both learning enjoyment and learning interest in SSIs more generally ($\beta = 0.39$, $p < .001$ and $\beta = 0.51$, $p < .001$, respectively). Learning enjoyment of SSI also positively predicted learning enjoyment of general SSI ($\beta = 0.22$, p < .001). Additionally, the indirect effect of learning interest in COVID-19 on learning interest in SSI was statistically significant ($\beta = 0.08$, $p < .001$). Moreover, the effect of learning interest in COVID-19 on learning interest in SSI was partially mediated by learning enjoyment of SSI.

*Table 3. Standardized Factor Loadings, Component Reliability (CR), and Average Variance Extracted (AVE) for Learning Enjoyment of Socio-scientific Issues, Learning Interest in Socio-scientific Issues, and Learning Interest in COVID-19*

| | | Unstandardized | | Standardized | | | |
|---|---|---|---|---|---|---|---|
| **Construct** | **Item** | **Factor Loading** | **Residual Variance** | **Factor Loading** | **Residual Variance** | **CR** | **AVE** |
| Learning Enjoyment (SSI) | 1 | 1.00 | 0.32 | 0.81 | 0.35 | 0.90 | 0.59 |
| | 2 | 1.11 | 0.38 | 0.81 | 0.34 | | |
| | 3 | 1.09 | 0.28 | 0.85 | 0.28 | | |
| | 4 | 1.05 | 0.50 | 0.75 | 0.43 | | |
| | 5 | 1.03 | 0.70 | 0.69 | 0.52 | | |
| | 6 | 1.01 | 0.53 | 0.73 | 0.47 | | |
| Learning Interest (SSI) | 1 | 1.00 | 0.20 | 0.90 | 0.18 | 0.83 | 0.51 |
| | 2 | 1.03 | 0.15 | 0.93 | 0.13 | | |
| | 3 | 0.66 | 0.95 | 0.51 | 0.75 | | |
| | 4 | 0.61 | 0.89 | 0.52 | 0.72 | | |
| | 5 | 0.79 | 0.77 | 0.65 | 0.58 | | |
| Learning Interest (COVID-19) | 1 | 1.00 | 0.59 | 0.70 | 0.51 | 0.73 | 0.36 |
| | 2 | 0.76 | 0.92 | 0.51 | 0.74 | | |
| | 3 | 1.01 | 0.57 | 0.71 | 0.50 | | |
| | 4 | 0.92 | 0.99 | 0.57 | 0.68 | | |
| | 5 | 0.90 | 1.04 | 0.55 | 0.70 | | |




*Note.* $^{*}p < .001$.

*Figure 1. Structural Model for Learning Enjoyment of Socio-scientific Issues, Learning Interest in Socio-Scientific Issues, and Learning Interest in COVID-19*

*Multi-group SEM*

To assess research question 3, multi-group SEM was conducted to discern whether differences in the observed relationships among the latent variables were evident by student major. Prior to assessing this, measurement invariance analysis was conducted to determine the measurement equivalence of the latent constructs across student majors. Configural invariance, metric invariance, scalar invariance, and residual invariance were assessed in a stepwise manner by fitting a set of increasingly constrained models. Because the change in the chi-square statistic ($\Delta\chi2$) could be influenced by the large sample size, we focused on the change in CFI values (ΔCFI). Results (Tables 4 and 5) showed evidence of metric invariance (i.e., equivalent configuration and equivalent loadings) by major, with the change in CFI exceeding Cheung and Rensvold's (2002) criterion value of 0.01 only for the scalar invariance model and the residual invariance model and the change in RMSEA not exceeding F. F. Chen's (2007) criterion value of 0.015 for any model. Evidence of metric invariance allows for subsequent examination of multigroup structural differences in relationships among constructs (Dimitrov, 2010).

*Table 4. Goodness-of-Fit for Models Used to Assess Measurement Invariance by Major*

| Model | $\chi^2$ | df | RMSEA | SRMR | NNFI | CFI | AIC | BIC |
|---|---|---|---|---|---|---|---|---|
| Model 1 | 632.35*** | 205 | 0.078 | 0.071 | 0.904 | 0.918 | 28495 | 28944 |
| Model 2 | 651.30*** | 218 | 0.076 | 0.075 | 0.908 | 0.917 | 28488 | 28878 |
| Model 3 | 719.15*** | 231 | 0.078 | 0.079 | 0.903 | 0.906 | 28530 | 28861 |
| Model 4 | 753.89*** | 247 | 0.077 | 0.082 | 0.905 | 0.903 | 28533 | 28791 |

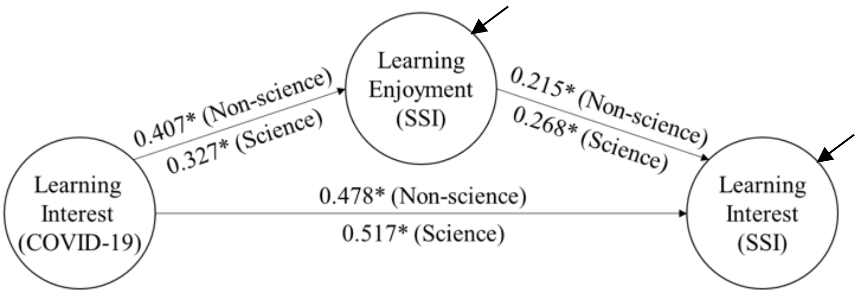
*Notes.* Model 1 = configural model, Model 2 = metric invariance model (equal factor loadings), Model 3 = scalar invariance model (equal factor loadings and intercepts), Model 4 = residual invariance model (equal factor loadings, intercepts, and residuals). RMSEA = root mean square error of approximation; NNFI = non-normed fit index; and CFI = comparative fit index. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

*Table 5. Change in Goodness-of-Fit Statistics for Assessing Measurement Invariance across Major*

| | Δχ² | Δdf | p-value | ΔRMSEA | ΔSRMR | ΔNNFI | ΔCFI |
|---|---|---|---|---|---|---|---|
| Model 1 versus Model 2 | 18.96 | 13 | .124 | -0.002 | 0.004 | 0.004 | -0.001 |
| Model 2 versus Model 3 | 67.85 | 13 | <.001 | 0.002 | 0.004 | -0.005 | -0.011 |
| Model 3 versus Model 4 | 34.74 | 16 | <.001 | -0.001 | 0.003 | 0.002 | -0.004 |

*Notes.* Model 1 = configural model, Model 2 = metric invariance model (equal factor loadings), Model 3 = scalar invariance model (equal factor loadings and intercepts), Model 4 = residual invariance model (equal factor loadings, intercepts, and residuals). ΔRMSEA = change in root mean square error of approximation; ΔNNFI = change in non-normed fit index; and ΔCFI = change in comparative fit index.

Given the demonstrated measurement invariance by major, we next assessed differences in the structural model by major. A multi-group model was fitted to assess differences by student major, the model showed good fit to the data [χ2 (215) = 649.04, $p < .001$; CFI = .92; NNFI = .91; RMSEA = .076; SRMR = .074]. Examination of the fitted model (Figure 2) shows that learning interest in COVID-19 had statistically significant positive direct effects ($p < .001$) on general learning interest in SSI for both science majors and non-science majors. Similarly, learning interest in COVID-19 directly predicted learning enjoyment in SSI ($p < .001$) for both groups of students. Examination of indirect effects showed that learning interest in COVID-19 indirectly predicted general interest in SSI for both non-science majors ($\beta$ = 0.09, $p$ = .001) and science majors ($\beta$ = 0.09, $p < .001$). Similarly, the effect of learning enjoyment of SSI on learning interest in SSI was statistically significant for both non-science majors ($\beta$ = 0.21, $p$ = .001), and science majors ($\beta$ = 0.27, $p < .001$). Based on these observations, there was evidence of an indirect effect of interest in COVID-19 on learning interest more broadly considered, as partially mediated by learning enjoyment of SSI, for both non-science majors and science majors.




*Note.* $^{*}p < .001$.

*Figure 2. Multi-Group Structural Model for Learning Enjoyment of Socio-Scientific Issues, Learning Interest in Socio-Scientific Issues, and Learning Interest in COVID-19 by Student Major*

## Discussion

The purpose of this study was to investigate the tenability of a generalized three-dimensional theoretical construct model using survey data collected from 12th grade Taiwan students, where the three latent factors consisted of: 1) learning interest in SSI, 2) learning enjoyment of SSI, and 3) learning interest in COVID-19. Results showed that (1) learning interest in COVID-19 positively predicted learning interest in SSI broadly-considered; (2) learning enjoyment in SSI positively predicted learning interest in SSI; and (3) the effect of learning interest in COVID-19 on learning interest in SSI was partially mediated by learning enjoyment. These findings are consistent with previous research results showing learning enjoyment of science as central to science interest with correlates to personal expectations about future science learning (Ainley & Ainley, 2011). Interest in a specific SSI (i.e., learning interest in COVID-19) was related to students' emotional response to learning (i.e., learning enjoyment in SSI) and, in turn, learning emotion was correlated to interest in learning about more general SSI topics.

Through multi-group analysis (Figure 2), we found that learning interest in COVID-19 positively predicted learning enjoyment in SSI and learning interest in more general SSIs for both science and non-science majors. We infer from the multigroup analysis that the movement or "flow" from enjoyment to interest is consistent for both science and non-science majors. Similarly, an indirect effect of learning interest in COVID-19 as mediated by learning enjoyment of SSI on learning interest in SSI was observed for both science and non-science majors. Although existing research (Topcu, 2010) has shown that science majors differ from non-science majors in their attitudes towards SSI, with science majors holding more positive attitudes, this finding doesn't necessarily imply that relationships among attitudinal constructs will differ among these two groups. In fact, Yerdelen et al. (2018) found that the impact of an SSI course on preservice teachers' interest in / usefulnesss of SSIs (as well as liking of SSIs and anxiety towards SSIs) was independent of whether students were a science or non-science majors. We agree with the rationale provided by Yerdelen et al., which is that adult undergraduates, regardless of major, can be expected to have fundamental skills in searching for and discussing the social aspects of scientific phenomena, and that an advanced level of scientific knowledge is not necessarily required to discuss SSIs. Existing literature also suggests that regardless of background (science or non-science) peoples' interest, attention, and emotional perspectives are similarly impacted by disasters involving the use of science within the greater society; e.g., nuclear power disasters (Kao, 2014). In fact, perhaps the similarity between these science and non-science majors observed in our study might in part be explained by the common experience these students shared throughout the COVID-19 pandemic where, for both types of students, conversations about COVID-19 almost certainly occurred outside the classroom. Further, Taiwan found itself in a unique situation at this time, being spared the worst effects of the pandemic but, at the same time, acutely and simultaneously aware of the global disruption outside its borders and potential for viral spread within its borders. These shared experiences may work to enhance the connection between learning interest in COVID-19 and learning enjoyment. Finally, the results of the current study also suggest that, although students who associate negative emotional experiences with a specific SSI topic may not be willing to voluntarily pursue such topics independently (Jack & Lin, 2018), they might be motivated to pursue investigation of a SSIs when emotional activation (enjoyment) is engaged.

## Conclusion

In conclusion, the implications of these findings are that they suggest that educators may leverage student interest in very specific SSIs that have prominence in contemporary society to facilitate student interest in SSIs more generally and that this interest may be more effectively promoted by activating students' emotional sense of enjoyment. Interest in specific SSIs and the corresponding leverage that could occur certainly could extend to other Big Science SSIs currently emerging and those yet to emerge. For example, Hsu et al. (2023) found that designing a decision-making AI chatbot could leverage high school students' learning interest by reducing negative learning anxiety and maintaining learning enjoyment during their use of this technology while investigating geographical climate issues. With the use of adaptive AI chatbot technologies in education (e.g., Nguyen et al., 2019; Ureta & Rivera, 2018), a possible exemplar way to extend studies such as Hsu et al. could be to apply the constructs of interest and enjoyment used in this study to investigate the indirect effect of learning interest in geographical climate issues on learning interest in climate change, as mediated by learning enjoyment of decision-making AI chatbot technologies. Another example is Liao's (2023) study investigating the impact of immersive VR technology on various aspects of online learning, which highlights how immersive VR technology can stimulate and improve students' interest and enjoyment in learning through the use of creative and immersive online learning environments. Immersive VR technology (e.g., Facebook Metaverse) is an emergent Big Science SSI (Fernandez, 2022; Gadekallu et al., 2022). Other specific SSIs that might leverage genuine interest, particularly among young learners, might include neural implants, humanoids, and avatars in society. Studies that investigate the role of specific SSIs in generating genuine interest could help to affirm or disaffirm the generalizability of the results observed in the current study and, if findings provide robust support, provide increased motivation for increased application of specific SSI topics of immediate relevance to students in their learning environments.

The findings of the study also are relevant to the goals of developing a sense of science citizenship among students. This notion of science citizenship moves beyond the development of scientific competencies solely for personal or professional reasons and emphasizes the individual's social and community responsibilities. Science citizenship is reflected in the forthcoming 2025 Programme for International Student Assessment (PISA, Organization for Economic Cooperation and Development [OECD], 2023) framework, which emphasizes the notion of scientific agency as a key competency among students—that is, their capacity to engage and act on SSI issues at personal, local, and global levels. The development of scientific agency by necessity entails an active, genuine interest among students as potentially activated by their learning enjoyment. With science citizenship, the distal outcome transitions beyond individual interest to active interest and involvement in the social good.

## Recommendations

We recommend that the evidence collected through investigations such as this can provide a way for other researchers to validate the generalizability of similar potentially mediated relationships characterizing enjoyment and interest in SSIs, as well as a model for how to examine the potential variance/invariance of this relationship among selected groups (e.g., defined by student major, gender, grade level, etc.). On a practical level, the results of the current study provide a degree of confidence for science educators considering making increased use of immediately-relevant SSI issues in their students' learning environments. Moreover, the results can further inform the practice of other science educators and policy specialists, particularly when they have the capacity and opportunity to work with other citizens as part of a broader articulated community whose associated interest is the use and monitoring of emerging sciences and technologies (e.g., issues involving pandemics, AI, climate, biotechnology, etc.) that have the potential to pose potential Big Science SSI challenges to the greater society within the 21st century.

## Limitations

There are several limitations to this study. First, Taiwanese grade 12 students participated when the severity of the national experience of COVID-19 in Taiwan was relatively low, with all schools open for face-to-face learning. As such, future studies may seek to clarify in greater detail the perceptual impacts of learning interest and learning enjoyment among COVID-affected student cohorts from other regions that have experienced dissimilar pandemic severity and mitigation disruptions. Second, the study was based on cross-sectional data, and although the data supported the validity of a model positing directional relationships, inferences about causality with cross-sectional data cannot be established definitively. Finally, the current study was limited to examining how the constructs of interest were related when considered by high school-aged children, and these results may not necessarily generalize to younger or older groups of individuals. Nonetheless, the implications for science educators and policy specialists regarding how best to educate learners regarding Big Science SSI challenges of the 21st century have never been more urgent nor critical.

### Ethics Statement

Subjects involved in this study signed an agreement providing their informed consent to participate in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by Taiwan National Cheng Kung University Human Research Ethics Committee - HREC case number: 109-537.

### Conflict of Interest

The authors declare that they have no competing interests.

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### Authorship Contribution Statement

Jack: Concept and design, drafting the manuscript, initial drafting of the manuscript, and securing of funding. Chen: Statistical analysis and writing up analysis results. Wang: Interpretation of results. Smith: Editing/reviewing and critical revision of the manuscript.

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