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ARTICLE

Ecological Stimuli Predicting High School Students' Genuine Interest in Socio-Scientific Issues

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Abstract

Existing literature attests to the importance of assessing the learning enjoyment and learning interest of students toward socio-scientific issues (SSI). However, there are few existing studies that examine how ecological stimuli, which are crucial to young learners' perceptual development and the shaping of ethical judgment, predict their learning enjoyment and learning interest in SSI. This investigation addresses this gap in the available literature by investigating and assessing the effects of self-perceived influences of three ecological stimuli constructs—textbooks, family/classmates, and news media—on a learning interest in SSI construct and a learning enjoyment from SSI construct among Taiwanese high school students. A structural equation model consisting of these five constructs was fitted to data collected from 966 students. Results show that influence on students' ethical judgments from textbooks and news media directly predict learning interest in SSI, with effects partially mediated by learning enjoyment from SSI. The influence of family/classmates on students' learning interest was fully mediated by learning enjoyment. The role of enjoyment and learning interest as predictors of these outcomes is discussed within the context of genuine interest in learning SSI content. The value and implications of these results for science education specialists and interest researchers are forwarded and suggested directions of future investigation submitted.

Keywords Enjoyment · Genuine interest · Individual interest · Moral/ethical judgment · Socio-scientific issues

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1 Introduction

A continuing international imperative among many policymakers is a universal curriculum that develops in students a global mindedness that engages respect for the perspectives of people from diverse ethno-cultural and socio-economic backgrounds. "Globally competent individuals can examine local, global and intercultural issues, understand and appreciate different perspectives and worldviews, interact successfully and respectfully with others, and take responsible action toward sustainability and collective well-being" (OECD, 2016, p. 4). Marope et al. (2017) propose that such mindfulness and associated competencies facilitate lasting human capital, community equality, and social cohesion.

In the OECD Learning Compass 2030, building moral and ethical foundations within students is recognized as principal to judicious decision-making, self-regulation, and interpersonal societal deportment. However, there is little agreement as to "what moral or ethical norms are or should be, as these are contingent upon culture, history, place and society" (OECD, 2019, p. 46). Though such situational diversity may limit attempts to consolidate a universal standard of ethical expectation, understanding how students' individual interest in ethics-/moral-related socio-scientific issues might be influenced by socio-environmental factors as experienced by students in their day-to-day living could prove instrumentally insightful, nonetheless.

Since the year 2000, the education system in Taiwan has undertaken the challenge to integrate and adapt how ethics and morals are taught at the K-12 level, unifying previously separate moral theory and ethics practicum content into a variety of courses by incorporating ethics/morals concepts and social learning examples familiar to students from their own daily life experiences along with the social issues of most concern to Taiwan society (Fang et al., 2015; Ho et al., 2013).

National science education standards in Taiwan and other countries (Chiu, 2016; Fitzgerald & Corrigan, 2020; Forsthuber et al., 2011; Goldfarb & Pritchard, 2000; National Research Council, 1996; Park et al., 2020) emphasize the building of moral and ethical foundations in students. This is a necessity recognized as the fundamental criterion to the successful development of judicious decision-making, self-regulation, and interpersonal student engagement in investigating the nature of socio-scientific issues (Herman et al., 2022; Van Der Leij et al., 2021).

While such an emphasis has been a regular component of science education practice and outcome expectations, difficulties persist within the broader society in articulating a unifying vision for how to grapple with pervading socio-scientific issues. At the core of this unease between citizens in their varying approaches to socio-scientific issues are foundational differences in worldview and perspectives about what behavior is ethically appropriate in the context of community, e.g., behavior regarding climate change (Holland, 2020; Sharma & Alvey, 2021; Tannock, 2021). Unanimity in the way science is perceived and conducted in society is further complicated by financial expectations and compliance with competing ethical, economic, social, and political values. Ortiz-Revilla et al. (2020) state:

> As Pleasants et al. (2019) highlight, "technologies exist in an economic context, which means that profitability is often an end that is actively pursued during technological development, sometimes at the expense of the other goals" (p. 579). Also, technology and engineering shift from the classical image of science as a value-free enterprise: technoscientific products of knowledge are explicitly valueladen—of epistemic, economic, socio-political and ethical values (Vincent & Loeve, 2018). Values are frequently in conflict, demanding assessment and regulation. (p. 872)

Although challenges remain, developing an understanding among students on how they can prepare themselves to meet the challenges of SSI as actively engaged citizens is now existentially essential. Delineating a process for cultivating and achieving such understanding, however, is not the intent nor within the scope of this study and is a topic for future investigation. Equally pressing, however—and the focus of this study—is the ability of educators to both identify and assess the extent to which science education is addressing the development of students' genuine individual interest in evaluating and voicing their own personal concerns about what it is they believe is "the right thing to do" when faced with the sweep of SSI situations (Jack et al., 2017; Chowdhury et al., 2020; Hodson, 2011). Studies have shown that science instructional strategies that include SSI have a positive effect on students' perceived sense of individual interest in learning science (Hewitt et al., 2019; Rahayu, 2019). However, the extent to which students' self-assessed evaluations of ecological stimuli impacting their ethical judgments effectively predict emotional learning enjoyment and cognitive learning interest in socio-scientific issues (SSI) is less understood.

The present investigation, therefore, operationalizes, constructs, and assesses a conceptual model to evaluate the predictive effects of Taiwanese high school student's self-perceived influence of three ecological stimuli: (1) textbooks, (2) family/classmates, and (3) news media on their content-driven learning interest in SSI, and examines how their emotion-driven learning enjoyment may mediate these influences.

2 Literature Review

Socio-scientific issues (SSI) are understood as emergent society-wide concerns about development and application of science and technology whose potential consequences outside the laboratory setting overshadow confidence in scientists' competence to effectively predict (Jack et al., 2017; Fang et al., 2019). As such, consensus derived from the diverse opinions and perspectives of citizens across both science and non-science communities are required for amenable resolution (Wan & Bi, 2019). In the context of formal education, learning activities focused on SSI have been demonstrated to promote students' critical thinking skills involving discourse, analysis, and debate in both science (Morris, 2014) and non-science (Damico & Panos, 2018) domains. Such critical thinking involves rationally weighing issues of harm, fairness, rights, and justice, which require the additional use of moral reasoning before an ethical judgment can be made regarding how to resolve these issues (Zeidler & Nichols, 2009). Using SSI as a catalyst to engage students, then, might generate learning interest and learning enjoyment not only in science but also in broader fields involving concerns relevant to both local and global communities.

Only a few studies investigating students' learning enjoyment and learning interest have examined socio-scientific issues in the context of ethical concerns. López-Fernández et al. (2021) used role-playing activities among secondary school students (grade 8) as a means for students to express personal, social, and ethical views regarding controversial sides of a relevant chemistry-related issue within a real-life social context. They discovered that engaging students in role-playing activities resulted in the students experiencing positive emotions (i.e., learning enjoyment) and enhanced interest (i.e., learning interest) in their exploration of SSI.

In their investigation examining science teachers' views about teaching of ethical issues in secondary school science, Garrecht et al.'s (2022) quote from Student Teacher 3E provides a good example of the spontaneity of the *Aha!* moment, when students'

learning interest is suddenly ignited by an unexpected discovery and the concomitant emotional sense of enjoyment that self-propels a personal motivation to "keep going [i.e., learning]" regardless of temporal constraints. As Garrecht et al. report from Student Teacher 3E:

> Because they know it's something that's important, 'cause they've heard about it, outside of the classroom, and they can see that it applies to real life, at any age that they're at, they know that it does. And once you show – once you put a newspaper headline up on the board, even if they haven't heard about, they go 'uh, it's in the news, it must be an important thing'. So that immediately kind of engages them and it's then I'm taking a scientifc [sic] concept and applying it to the outside world as well, so, for them, they see it as a real – it's not just a classroom subject, it's an actual real life subject. So, they get involved completely, they enjoy it, they often want to keep going and you're trying to get them out of the room by the end of the lesson. (p. 23)

The *Aha!* moment encapsulates and personalizes how real-life socio-scientific issues associated with ethical concerns incentivize students' learning of SSI and is the point of inflection where their learning interest in SSI becomes subjectively indistinguishable from the learning enjoyment they receive from the learning process itself. When learning interest merges with learning enjoyment in this way, genuine learning interest results (Dewey, 1903).

Two further examples are provided in Tomas et al.'s (2011) investigation among Grade 9 students and Tomas and Ritchie's (2012) investigation among Grade 12 students demonstrating how students' writing of hybridized scientific narratives about biosecurity with moral/ethical implications evoked interest and enjoyment in a specific SSI subject. Findings from both studies emphasize how engaging students' use of imagination to creativity write a narrative about SSI based on their own present understanding can ignite and sustain both their learning interest and learning enjoyment in science and their learning of a science-related social concern.

A final example is found in Jack et al., (2020), which demonstrate how learning interest and learning enjoyment were related to students' learning of SSI and provided evidence in support of Dewey's concept of genuine interest in learning. This study used data collected from Grade 10 students and additionally provided evidence of measurement invariance across traditionally recognized genders for the construct of genuine interest.

Summarizing, research literature repeatedly attests to the pedegogical importance of instructional strategies (e.g., role-playing activities, reading/listening about events of collective concern from news sources, writing hybridized scientific narratives) in promoting students' learning enjoyment and learning interest toward socio-scientific issues (SSI) associated with moral/ethical uncertainties. However, there are few studies that examine how ecological stimuli, recognized by educational experts who study the impact of social environments as crucial to a child's perceptual development and the shaping of ethical judgment, may predict students' genuine interest in socio-scientific issues. This investigation contributes to closing this gap by hypothesizing that (1) students' self-perceived learning enjoyment of SSI directly predicts their self-reported learning interest in SSI, and (2) students' perceptions of the importance of particular ecological stimuli indirectly predict their self-perceived learning interest in SSI when mediated by their learning enjoyment of SSI.

3 Theoretical Framework

Genuine interest and three ecological stimuli form the theoretical framework of this study. In this section, therefore, genuine interest first are described. Second, ecological stimuli recognized as fundamental in shaping secondary school students' moral judgments are presented. Lastly, the investigative aim of this study is delineated.

3.1 Genuine Interest

Education literature has documented the existence of genuine interest in learning since the nineteenth century. Genuine interest refers to a conditional subjective experience of coinciding emotional and cognitive satisfaction which intrinsically motivates a personal engagement to learn regardless of external coercions whether objectively rewarding or penalizing (Jack et al., 2020; Dewey, 1903; Howerth, 1912). This perspective is congruent with interest researchers' conceptualization of individual interest in learning as constituent of two principal elements: feeling-related interest and value-related interest (Jack & Lin, 2014; Hidi & Renninger, 2006; Schiefele, 1992; Schraw & Lehman, 2001). Schiefele (1992) posits that feeling-related interest is an "[a]ssociation of a topic or topic-related activity with positive feelings, especially enjoyment and involvement (feeling-related intrinsic valences of a topic)" (p. 155). This feeling-related interest is conceptually congruent with learning enjoyment (Tsai & Jack, 2019; Ferrell & Barbera, 2015). Such enjoyment, Ryan and Deci (2000) state, is closely associated with interest and is crucial to eliciting and sustaining a student's individual intrinsic motivation for learning. Schiefele (1992) further posits that value-related interest is the "[a]ttributing of personal significance to a topic (value-related intrinsic valences of a topic)" (p. 155). This value-related valence of a topic can be understood as a cognitive recognition of the topic as meaningfully relevant to the student's personal knowledge schema and life experience (Jack & Lin, 2014; Chowdhury et al., 2020). Genuine interest in learning, Dewey (1903) asserts, is but the natural and spontaneous complementarity of learning interest (value-related interest) and learning enjoyment (feeling-related interest) which arises independently of all external attempts at coercion and reward for compelling students' cooperative learning engagement.

Investigators have found that emotion (e.g., enjoyment, boredom, anxiety) affects cognitive outcomes, e.g., attention of interest, engagement, performance (Camacho-Morles et al., 2021). Emotional valence during learning can have a momentary or sustained positive or negative effect on the cognitive attention of interest a student experiences during learning (Pekrun, 2006). If this interest is both positive and maintained, amplification into individual interest (Hidi & Renninger, 2006) may actualize to become a permanent and integral part of the student's neurological seeking system motivating future learning behavior (Ainley & Hidi, 2014). As further corroborated by control-value theory, emotion states experienced during learning events are crucial to sustaining the neurological influences which support student's individual (i.e., enduring) interest in learning (Pekrun & Perry, 2014). This would suggest that measuring learning interest (e.g., value-related interest) isolated from a concurrent examination of learning enjoyment (e.g., feeling-related interest) may not provide adequate grounds for accurately judging the effectiveness of formal education strategies for

positively impacting students' long-term interest in either ethics-/moral-related issues or any other topic of societal and cultural concern.

Teppo et al. (2021) found that enjoyment is closely associated with interest and is a crucial component in eliciting and sustaining students' intrinsic motivation to apply their learning of science to decision-making toward real-life SSI. Recent studies have statistically demonstrated that enjoyment and interest in relationship to science learning are conceptually distinct (Jack et al., 2020; Hensen & Barbera, 2019). The present study investigates how three disparate ecological stimuli predict emotional learning enjoyment and cognitive learning interest crucial to genuine interest in ethics-related socio-scientific issues (SSI).

3.2 Ecological Stimuli

Assessed ecological stimuli potentially predictive of learning enjoyment and learning interest find support in Bronfenbrenner's (1979) "theory of ecology of human development" (Rosa & Tudge, 2013). Bronfenbrenner states:

> The ecology of human development involves the scientific study of the progressive, mutual accommodation between an active, growing human being and the changing properties of the immediate settings in which the developing person lives, as this process is affected by relations between these settings, and by the larger contexts in which the settings are embedded. (p. 21)

Reflected in this definition are three stressed characteristics Bronfenbrenner (1979) affirms as important considerations (pp. 21–22). First, an individual is constantly growing and changing as it moves within and affects its immediate ecological niche within an environment. Second, the environment within which the individual's ecological niche is embedded itself exerts a personal and direct countervailing influence upon the individual which requires mutual accommodation on the part of the individual. This kind of personal accommodation is congruent with Jean Piaget's theory of cognitive development wherein individual intelligence is developed through interaction with and adjustment to objects in the environment; the ever-evolving nature of these interactions and adjustments are essential to the construction of a personal understanding of how the world works (Eysenck, 2004). Third, the environment within which the individual's immediate ecological niche is embedded also includes the interconnections between those two immediate personal settings and the non-immediate non-personal influences emanating from a broader self-aggregating eco-systemic context. Thus, according to Bronfenbrenner, the term "ecology" implies a give-and-take relationship between the individual and surrouding environmental influences as they directly or indirectly affect personal growth.

In this study, the term "ecological stimuli" refers to specific interpersonal relationships and activities that Taiwanese high school students report as influential on their ethical judgment (Jack, 2018). These ecological stimuli include family/classmates, textbooks, and news media. Based on Bronfenbrenner' "bio-ecological systems theory of human development" (Rosa & Tudge, 2013), Yang (2021) posits that family, classmates (i.e., peers) and communications media are pivotal influences on Chinese students' moral development. The following section will present literature that recognizes the specific ecological stimuli tested in this current study as both congruent and consistent

with what is broadly identified in the literature as those ethics-related influences most fundamental in the shaping of secondary school students' ethical judgments.

3.2.1 Family/Classmates

The term family/classmates refers to a multiplex hybrid perspective of the concept of family as consisting solely of those people whose relationship is recognized by the student as personally important regardless of shared genetic background. In the current study, we understand that family/classmates coincide with the concept of a "framily," which has received broad popularization to represent a combined relational notion of friend with the concept of family (Bush et al., 2017) and conveys an essential psychological attachment state among people within a uniquely self-defined personal social network (Gillath et al., 2019). Redefining the more traditional view of family as consisting of a culturally recognized parentage (e.g., Bomar, 2003; Ruggles, 2010), members of multiplex family groups transcend genealogy through mutual recognition, sharing, support, and encouragement of individual concerns, interests, goals, and experiences.

As an influence on morality, multiplex relationships are stronger and provide greater assurance to an individual's sense of self-value (i.e., ego) and self-image (i.e., identity) than is personally recognized as available through traditional familial ties solely based on biological lineage (Bush et al., 2017; Perry et al., 2018). Development of this extended form of voluntary relationship can be seen most clearly among adolescents active on the Internet (Mesch & Talmud, 2006) as they digitally engage the people with whom they share mutual respect, intimacy, and expectations of behavioral reciprocity. In this way, ethical judgment and decision-making skills are simultaneously cultivated, shaped, and formed (Gibbs, 2013).

3.2.2 Textbooks

Anchored to specific education goals, textbooks are standardized educational material, whether in print or electronic form, designed to mediate students' interest and engagement in subject-specific content and classroom learning activities relevant to their current level of knowledge and life experience (Oates, 2014; UNESCO, 2016). Textbooks instill important domain-specific knowledge that includes rules, norms, and expected habits of behavior (DelFattore, 2013; Issitt, 2004; UNESCO, 2016). Issitt (2004) posits: "At the extreme, the textbook is the vehicle for the transmission of the authorized dogma. In its role as an essential site of learning, the textbook is a key mechanism for the production and reproduction of ideas" (p. 688).

Underlying the design of textbooks and other educating media content is some agenda or set of agendas, whether assumed or stated, supported by the sponsor/s involved. Such intention is not necessarily to proscribe what students think but to instead constrain presentations of issues and opinions upon which students' attention can be operationally framed and extended (e.g., Caravita et al., 2008; Hadar, 2017; Pngel, 2009). But students only become interested in classroom-provided content (e.g., textbook-based issues and opinions) as they understand the information as meaningfully relevant to their daily life experience and personal knowledge schema (Jack & Lin, 2014). This situation-sensitive receptiveness is synonymous with Walter Lippmann's description of how distant facts presented in newspapers are made interesting to the public. Lippmann (1922) states:

> the crucial part, of what looks to the worker and the reformer as deliberate misrepresentation on the part of newspapers, is the direct outcome of a practical difficulty in uncovering the news, and the emotional difficulty of making distant facts interesting unless, as Emerson says, we can "perceive (them) to be only a new version of our familiar experience" and can "set about translating (them) at once into our parallel facts (p. 350).

Lippmann's point here is that information must engage the reader in an encounter wherein their existing knowledge and everyday experience are absorbed into the content of the text; it is at this level of interaction that the reader opens up to a new understanding of the world not previously considered as now meaningfully relevant to their own life and sensitivities. In the educational context this kind of personal epiphany is referred to as a *transformative* encounter which illuminates as meaningfully relevant to the student's daily life some aspect of the world previously unconsidered (Pugh, 2011; Rosebrough & Leverett, 2011). In a scoping review of 10th grade civics and biology textbooks used by five Kaohsiung metropolitan high schools, Jack, (2017) found that textbook-presented information generally attempts to relate hypothetical scenarios to assumptions of students' economic and social circumstances and conditions, but without engaging them to consider who or what is or should be responsible for resolving ethics-related SSI connected to students' daily life as personally and actually experienced. However, evidence of whether such an ethics-related SSI agenda predicts students' learning interest and enjoyment in ethics-related topics currently is absent from the research literature. Examining students' learning enjoyment (LE) from SSI and learning interest (LI) in SSI through this approach would clarify how information presented in textbooks predicts learning interest and enjoyment in SSI.

3.2.3 News Media

News media frequently cover controversies involving moral considerations regarding the development or use of scientific technologies in society (Leung, 2022). Through the ubiquitous availability of cloud-connected smartphone access to unfettered information sources, students now can routinely control and adjust their exposure to countervailing viewpoints according to their own personal sympathies and intuitions of what they feel or believe to be right or wrong. For example, both smartphones and the news media are separately and conjunctively used today as conduits for becoming more actively informed about divisive and potentially divisive socio-scientific issues. Such use may or may not involve appropriate vetting of the science expertise of the conveying sources (Jack, 2018). The potential positive aspect of such freedom is that it provides visibility to a variety of opinions on important SSI topics of mutual global concern; the potential negative aspect of such freeform visibility includes exposure to the all-too-human propensity for spreading mis-, dis, or malinformation. This predicament has been proposed as a reason why science educators currently are stressing the importance of actively promoting re-engagement of school science for citizenship (e.g., Jack et al., 2017; Chowdhury et al., 2020). Engaging students' sympathies and intuitional reflexes in support of a science for citizenship model likewise finds support in Hahn et al. (2022), where they posit that "narrative media emphasizing moral intuitions can increase the salience of those intuitions in audiences" (p. 165). Haidt (2001) defines a moral intuition as "the sudden appearance in consciousness of a moral judgment, including an affective valence (good-bad, like-dislike), without any conscious awareness of having gone through steps of searching, weighing evidence, or inferring a conclusion" (p. 818). Haidt goes on to describe moral intuition as a posture of decision-making based on

"a gut feeling" as opposed to "an ex post facto rationalization of the gut feeling" (p. 817). Examining the extent to which students' self-perceived influences of news media predict their learning enjoyment from and learning interest in SSI would contribute to deepening science educators' and students' understanding of the importance of examining and critically evaluating real-life SSI reported by news media sources to facilitate learning of SSI that is genuinely interesting to high school students.

3.3 Investigative Aim

The investigative aim of this study is to construct and assess a conceptual model that assesses the role of learning enjoyment when predicting learning interest in the context of SSI (Fig. 1). Specifically, it assesses the direct effects of three latent ecological stimuli: self-perceived influence of textbooks, self-perceived influence of family/classmates, and self-perceived influence of news media on two latent outcomes: emotional learning enjoyment and cognitive learning interest in SSI. This model also assesses how learning enjoyment predicts learning interest in SSI, and how the latent ecological stimuli indirectly predict learning interest in SSI as mediated by learning enjoyment of SSI. This model was used to test four hypotheses:

H1: the self-perceived influence of textbooks (TX), family/classmates (FC), and news media (NM) on ethical judgment each has a positive direct effect on learning enjoyment (LE) from SSI.
H2: the self-perceived influence of textbooks (TX), family/classmates (FC), and news media (NM) on ethical judgment each has a positive direct effect on learning interest (LI) in SSI.
H3: learning enjoyment (LE) from SSI has a positive direct effect on learning interest (LI) in SSI.
H4: the self-perceived influence of textbooks (TX), family/classmates (FC), and news media (NM) on ethical judgment each has a positive, indirect effect on learning interest (LI) in SSI, as mediated by learning enjoyment from SSI (LE).

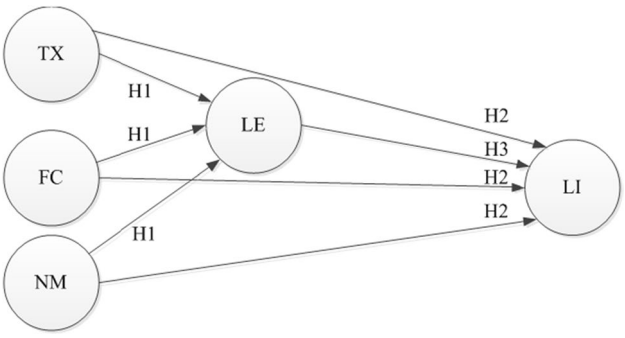

Fig. 1 Conceptual model illustrating the role of three ecological stimuli and learning enjoyment in predicting learning interest in the context of SSI. *Note*. Three ecological stimuli: TX, textbooks; FC, family/classmates; and NM, news media; LE, learning enjoyment; LI, learning interest

The LE construct in the conceptual model represents student learning enjoyment from SSI experienced during classroom instruction. The LI construct in the conceptual model represents student learning interest experienced during classroom instruction. An indirect predictive relationship between self-perceived influence of SSI on LI, as mediated by LE, would reflect a process of genuine learning interest in SSI.

4 Method

4.1 Participants

Grade 10 high school students from 29 classes within five metropolitan university-preparatory high schools located in southern Taiwan participated in this investigation. Once permissions to conduct the investigation were obtained from school authorities, surveys were distributed to the participating schools, with 1,167 surveys returned. After data screening, 201 surveys were excluded from further analysis due to either missing data or overly uniform response patterns (i.e., repeatedly choosing the same response option for each item in the scales). Thus, $N = 966$ valid surveys were retained. From this sample, 499 (51.66%) students identified themselves as male; 467 (48.34%) students identified themselves as female; no other self-identified sex- or gender-related types were reported. Four-hundred and twenty-seven (44.20%) students identified themselves as non-science majors and 539 (55.80%) students identified themselves as science majors.

4.2 Survey

Survey items used to collect data for this study were selected from the FEEL (Factors Effecting Ethics Learning) survey (Jack & Lin, 2018). These statements pertained to ethics-related social and socio-scientific issues. Each statement is paired with 4-point ordinal response options assessing either learning interest (1 = *absolutely no interest* to 4 = *highly interested*) or learning enjoyment (1 = *low agreement* to 4 = *high agreement*). In addition to these items, three succinct 2-item subscales were created to assess self-perceived influence of textbooks (TX), family/classmates (FC), and news media (NM) in informing ethical judgments, where each item consisted of statements pertaining to these information sources, and where each statement was paired with four ordinal response options ranging from 0 = *no influence* to 4 = *high influence*. Internal consistency reliability (Cronbach's α) estimates computed from the resulting data showed acceptable reliability, with all values of alpha at or above 0.70 (see Table 1). Table 2 provides the frequency distribution of responses to the items.

4.3 Statistical Analyses

Statistical analyses of the conceptual model employed the use of structural equation modeling (SEM). A measurement model (i.e., confirmatory factor analysis) first was specified and fitted to assess construct validity, followed by a structural model consistent with the conceptual model (Fig. 2).

Table 1 Observed variables in study as measured by FEEL survey items

Scale	Reliability	Item label	Item
TX	.78	TX1†	Biology textbooks affect my judgment related to ethics issues.
		TX2	Civics textbooks affect my judgment related to ethics issues.
FC	.75	FC1	Family members affect my judgment related to ethics issues.
		FC2	Classmates affect my judgment related to ethics issues.
NM	.70	NM1†	Local news programs affect my judgment related to ethics issues.
		NM2†	International news programs affect my judgment related to ethics issues.
LE	.88	LE1†	I like reading information about social issues arising from the use of new technologies.
		LE2	I really like to discuss with others how to solve the problems related to the application of new technologies in society.
		LE3†	I feel time passes very quickly when learning about social issues related to science and technology.
		LE4†	I like learning new knowledge about social challenges related to the use of new technologies.
LI	.91	LI1††	I am interested in learning social issues related to reducing carbon dioxide emissions.
		LI2	I am interested in learning social issues related to nuclear and thermal power plants.
		LI3	I am interested in learning social issues related to nuclear disasters. (Example: Fukushima, Japan)

†Item used by Tsai and Jack (2019); ††item used by Jack et al. (2020). *TX* textbooks, *FC* family/classmates, *NM* news media, *LE* learning enjoyment, *LI* learning interest

Table 2 Frequency distribution of responses to survey items

Response					
Item	0	1	2	3	4
LI1	0 (0.0%)	0 (0.0%)	80 (8.3%)	321 (33.2%)	376 (38.9%)
LI2	0 (0.0%)	0 (0.0%)	122 (12.6%)	354 (36.6%)	332 (3.3%)
LI3	0 (0.0%)	0 (0.0%)	89 (9.2%)	312 (32.3%)	373 (38.6%)
LE1	0 (0.0%)	0 (0.0%)	23 (2.4%)	148 (15.3%)	650 (67.2%)
LE2	0 (0.0%)	0 (0.0%)	30 (3.1%)	293 (30.3%)	501 (51.8%)
LE3	0 (0.0%)	0 (0.0%)	33 (3.4%)	340 (35.2%)	473 (48.9%)
LE4	0 (0.0%)	0 (0.0%)	28 (2.9%)	202 (20.9%)	551 (57.0%)
TX1	0 (0.0%)	144 (14.9%)	309 (32.0%)	309 (32.0%)	164 (17.0%)
TX2	0 (0.0%)	85 (8.8%)	210 (21.7%)	306 (31.6%)	269 (27.8%)
FC1	0 (0.0%)	36 (3.7%)	54 (5.6%)	188 (19.4%)	306 (31.6%)
FC2	0 (0.0%)	32 (3.3%)	72 (7.4%)	248 (25.6%)	360 (37.2%)
NM1	0 (0.0%)	100 (10.3%)	188 (19.4%)	300 (31.0%)	266 (27.5%)
NM2	0 (0.0%)	70 (7.2%)	114 (11.8%)	271 (28.0%)	332 (34.3%)

Note: LI1–LI3, learning interest items; *LE1–LE4*, learning enjoyment items; *TX1–TX2*, perceived influence of textbook items; *FC1–FC2*, perceived influence of family/classmates items; *NM1–NM2*, perceived influence of news media items. Response options are 1 = *absolutely no interest* to 4 = *highly interested* for learning interest items; 1 = *low agreement* to 4 = *high agreement* for learning enjoyment items; and 0 = *no influence* to 4 = *great influence* for self-perceived influence items

Given the ordinal nature of the observed variables, unweighted least squares (cat-LS) estimation was used, as suggested by Rhemtulla et al. (2012) when the model includes indicators containing four or fewer response options. Use of this estimation method requires no distributional assumptions about the data (e.g., normality assumptions). Further, tau-equivalent measurement models (i.e., equal factor loadings) were specified for the TX, FC, and NM constructs as recommended by Little et al. (1999) which, based on the authors' simulations, "leads to accurate recovery of the true construct centroids" under situations in which latent constructs are measured by two observed variables (p. 208). Analyses were carried out using Mplus v8.3. Because notable clustering (i.e., classroom) effects were present in the indicators for the two endogenous variables (LE and LI), with design effects ranging from 1.45 to 3.72, the chi-square statistic and

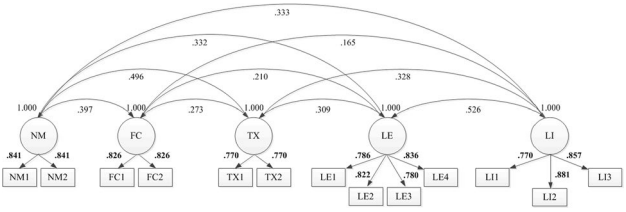

Fig. 2 Measurement model assessing the construct validity of the five latent variables from the conceptual model. *Note*. TX, textbooks; FC, family/classmates; NM, news media; LE, learning enjoyment; LI, learning interest. Standardized factor loadings ranged from .77 to .88 were statistically significant as shown in bold black color

standard errors of estimated parameters were adjusted for potential clustering bias using TYPE = COMPLEX estimation in Mplus.

Because model chi-square statistics are known to be sensitive to large sample sizes (Hu & Bentler, 1999), alternative fit criteria were used to assess goodness of data fit to the fitted models for this study. These included comparative fit index (CFI ≥ 0.90; Bentler, 1990), non-normed fit index (NNFI ≥ 0.90; Bentler, 1990), and root mean square error of approximation (RMSEA ≤ 0.06; Steiger & Lind, 1980). A decision criterion of 0.05 was used for all inferential tests and tests of individual parameter estimates.

5 Results

5.1 Measurement Model

Prior to examining the proposed structural model, the measurement model (Fig. 3) comprising five latent factors (TX textbooks, FC family/classmates, NM news media, LE learning enjoyment from SSI, and LI learning interest in SSI) was assessed. The model showed good fit to the data, with $\chi^2(58) = 132.70$, $p < 0.001$; CFI = 0.979, NNFI = 0.972, and RMSEA = 0.037. Standardized factor loadings for the observed variables supporting each latent factor were statistically significant (each $p < 0.05$) and ranged in value from 0.77 to 0.88.

5.2 Structural Model

Next, the structural model (Fig. 3) was fitted to the data. Results showed good fit of the model to the data, with $\chi^2(59) = 210.89$, $p < 0.001$; CFI = 0.958, NNFI = 0.945, and RMSEA = 0.052. Examination of structural parameter estimates showed that the latent LE construct had a statistically significant, positive direct effect on LI ($\beta = 0.45$, $p < 0.001$). When the effects of the self-perceived influence of various sources of information were examined, there were statistically significant, positive direct effects of TX ($\beta = 0.18$, $p < 0.001$), FC ($\beta = 0.08$, p = 0.040), and NM ($\beta = 0.21$, $p < 0.001$) on LE.

These predictors accounted for 14.6% of the variation in learning enjoyment ($R^2 = 0.146$). In contrast, while TX and NM showed statistically significant, positive direct effects on LI ($\beta = 0.12$, $p = 0.008$ and $\beta = 0.11$, $p = 0.019$, respectively), FC showed no statistically significant direct effect on this outcome ($\beta = -0.01$, $p = 0.770$). These predictors accounted for 29.9% of the variability in LI ($R^2 = 0.299$). Finally, when the indirect effects of TX, FC, and NM on learning interest in SSI were examined, each indirect effect was statistically significant, with $\beta = 0.08$, $p < 0.001$; $\beta = 0.04$, $p = 0.044$; and $\beta = 0.08$, $p < 0.001$, respectively. A subsequent structural model fitted to the data that omitted the direct effect of FC on LI showed results and levels of statistical significance for the obtained structural parameters that paralleled the first analysis.

These results support hypotheses 1, 3, and 4, and partially support hypothesis 2. Based on the fitted model, the self-perceived influence of textbooks (TX) and news media (NM) had indirect effects on learning interest in SSI, as mediated by learning enjoyment. However, each of these two stimuli simultaneously exerted direct effects on this outcome (i.e., exerted effects that were not mediated by learning enjoyment). In comparison, the self-perceived influence of family/classmates also had an indirect effect on learning interest, but

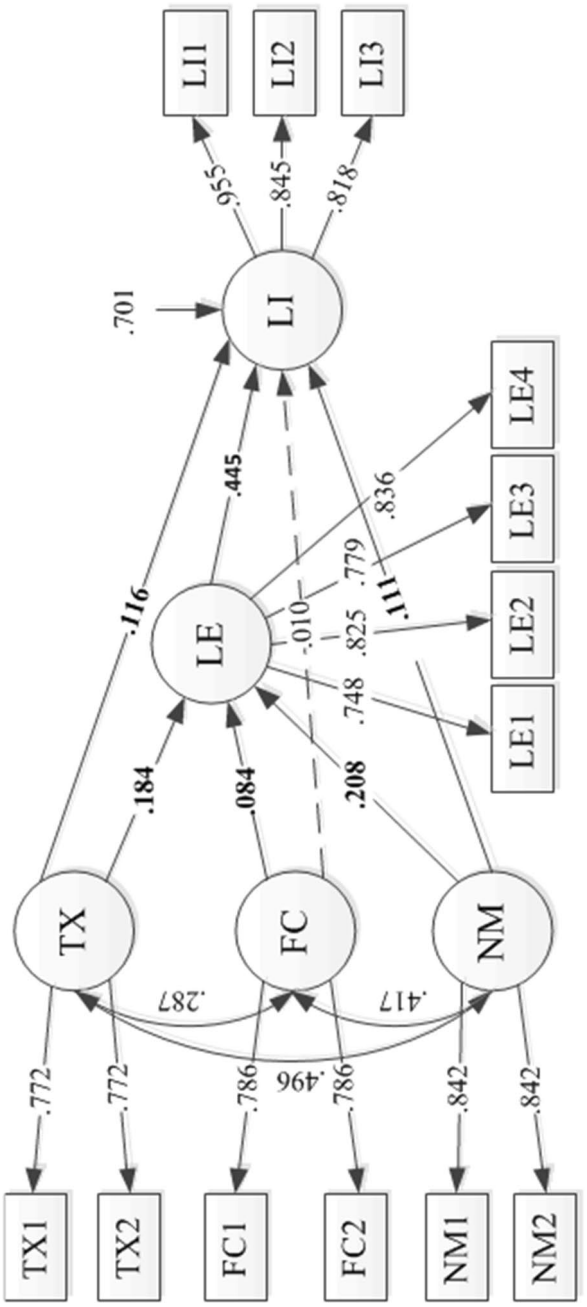

Fig. 3 Structural model assessing the predictive relationships of three ecological stimuli to learning interest by learning enjoyment in the context of SSI. *Note*. TX, textbooks; FC, family/classmates; NM, news media; LE, learning enjoyment; LI, learning interest. With the exception of the pathway from FC to LI showing no statistically significant direct effect, the results of all other pathways were statistically significant as shown in bold black color

no direct effects of this stimulus on learning interest were observed. Additionally, learning enjoyment in SSI showed a positive direct effect on learning interest in SSI. These three latent predictors showed significant and moderate associations with one another, as would reasonably be expected.

6 Discussion

The investigative aim of this study was to construct a conceptual model to assess the effects of three latent predictors: self-perceived influence of textbooks (civics and biology), self-perceived influence of family/classmates, and self-perceived influence of news media (local news programs and international news programs) on the two latent outcomes of emotional learning enjoyment and cognitive learning interest in socio-scientific issues. The conceptual model designed for this study demonstrated fitness of the predicted relationships among the five factors and was observed to be robust and supportive of the statistical validity and reliability of the proposed predicted relationships among these factors.

Two results from this study appear noteworthy. The first result of note is that the self-perceived influence of TX and NM exerted direct effects on learning enjoyment of SSI and indirect effects on learning interest in SSI. This result is congruent with Rose et al.'s (2019) findings among adults regarding their attitudes toward science issues as shaped by two sources of public knowledge: (1) news media, disseminators of familiar/subjective-type knowledge; and (2) textbook formulated channels of information, which provide detailed factual/objective-type knowledge. In their study, Rose et al. found a distinctly greater impact from news media on the ethical concerns of adults toward the use of genetically modified foods (GMO) than was evidenced by adults' whose primary source of information was restricted to factual/objective-based knowledge of the issue. In the current study, however, we found relatively equal direct effects of textbooks and news media on both enjoyment of SSI and interest in SSI. The value of Rose et al.'s study is that it presents a clear distinction between the effects of familiar knowledge and factual knowledge on the ethical concerns reported by citizens regarding the use of GMO in society (i.e., a socio-scientific issue). In extending the potential impact of learning resources from textbook and news media identified by Rose et al., the value to educators from the findings of this present study comes by way of providing quantitative evidence and empirical clarification for how factual/objective-based knowledge learned from textbooks and news media may be utilized to predict and shape students' learning enjoyment and learning interest in socio-scientific issues involving the development and use of new technologies.

The second notable result is that while TX and NM exerted both direct and indirect effects on learning interest in SSI, FC exerted only an indirect effect, with no direct effect. The structural model (Fig. 3) reveals two types of learning interest in SSI: (1) concerned learning interest as evidenced by the direct (i.e., unmediated) effects of TX and NM on LI, and (2) genuine learning interest evidenced by the indirect effects of TX and NM on LI, as partially mediated by LE. Unlike TX and NM, FC had no direct effect on LI, and instead was fully mediated by LE. A potential reason for this distinction in effects might be that family and classmates, involving a more distinctly social component, engage mechanisms of enjoyment by fulfilling basic human needs for relational interaction. These interaction and constituent enjoyment, in turn, generate increased learning interest. In contrast, textbooks and news media remain less interactive forms of information. Thus, although they may activate enjoyment mechanisms to some extent, they more easily "bypass" enjoyment

to exert direct effects on learning interest in SSIs. But whether partially or fully mediated by LE, each of the three ecological stimuli significantly contributed to students' LI in SSI. This demonstrates that TX, FC, and NM contribute significantly to students' genuine learning interest in SSI. The value of this result is empirical affirmation of the role of learning enjoyment in the development of students' learning interest. Enjoyment is closely associated with interest and is a crucial component in eliciting and sustaining students' intrinsic motivation to learn (Cho & Chiu, 2021). Consideration of learning interest without concomitant consideration of learning enjoyment is insufficient to illuminate the state of students' genuine learning interest or its possible manifestation in individual motivations to learn (Jack, 2018).

Results of this investigation suggest that perceptions of the influence of textbooks, family/classmates, and news media on ethical judgments significantly predict students' learning enjoyment, which henceforth predicts their learning interest. This mediation reflects a process of genuine interest among Taiwanese students, enhancing the likelihood that they will enter society as adults mindfully interested in considerations of socio-scientific issues. The result that FC had no direct effect on student learning interest and instead was fully mediated by learning enjoyment can be partially explained by the cognitive empathy posited by Zeyer and Dillon (2019). These two researchers assert that with a deliberate intellectual effort, cognitive empathy enables students to engage in the mental process of adopting another individual's (e.g., family members' or classmate peers') perspectives. More importantly, Zeyer and Dillon's study may also provide empirical grounds for a benchmarking of high school students' science learning supportive of the relevance of a cognitive empathy approach to formal science education practice.

While this study demonstrates evidence confirming how ecological stimuli (e.g., textbooks, family/classmates, and news media) are predictively related to students' learning enjoyment and learning interest in socio-scientific issues, there are several limitations that should be addressed in future investigations. First, the sample was relatively homogeneous. Participants in this study were selected from university-preparatory high schools located in southern Taiwan. Conducting a similar investigation among students from university-preparatory high schools located in other parts of the island or who are located in vocational high schools should be pursued to corroborate or challenge the obtained results. Second, not all pivotal ecological factors (e.g., embedded social/religious norms) identified by Bronfenbrenner (1979) were considered in this study for examination as potential influences among Taiwan students on their ethical judgments related to SSI. In addition, the aspect "textbook" examined in this study is a very specific narrowing and itemization of Bronfenbrenner's more sweeping aspect embodied by his signifier "school." Third, readers are reminded that there are challenges in using self-report data, especially when applied to investigattions of long-term effects such as teacher professional development (Herrington et al., 2016). Despite the fact that the investigation of this study is not focused on long-term effects, additional studies to collect evidence using alternative data collection approaches to confirm this study's conceptual model are recommended. Finally, the results herein reported are limited, and some of the significant predicting effects on the structural model are small. Future studies involving interviews or qualitative examinations could shed further light on the causal relationship between ecological stimuli and students' science learning enjoyment and learning interest related to SSI.

7 Conclusion

With the use of structural equation modeling, this study examined how the ecological stimuli of textbooks, family/classmates, and news media predict student enjoyment of and interest in learning socio-scientific issues (SSI). The conceptual model developed by this study suggests that reading textbooks, listening to local and international news programs, and interactions with family members or classmates each are supportive to the development of students' interest in and enjoyment of learning SSI. In addition, learning enjoyment exerts a significant mediating role in the relationship between the ecological stimuli and student interest in learning SSI.

This study contributes to research acknowledging different approaches in understanding students' self-perceived influence on their interest in ethics-related social and socio-scientific issues (SSI), e.g., OECD (2018). Utilizing empirical methods, this study posits that juxtaposing ethics-related issues with learning enjoyment/learning interest can assist in providing educational interest experts, policy-makers, and other education-related professionals a broader grounding of empirical evidence from which to assess the extent to which high school students are becoming adequately prepared to enter adult society as genuinely interested citizens, mindfully willing to address the shared challenges associated with contemporary and SSI from local, national, and global perspectives.

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Data Availability The data that support the findings of this study are available upon request.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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