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Exploring the relationship between perceived technology-assisted teacher support and technology-embedded scientific inquiry: the mediation effect of hardiness

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ABSTRACT

This study examines the correlations between perceived technology-assisted teacher support; student hardiness (i.e. individual commitment, challenge, and control); and technology-embedded scientific inquiry (TESI) using a mediational model approach. Data were gathered from the series of questionnaires administered to 1566 Chinese students with an average age of 11.5. Structural equation modelling (SEM) analysis results confirmed our assumption that when students perceived technology-assisted teacher support, this promoted their TESI hardiness, indirectly increasing their perceived TESI. Perceived technology-assisted teacher support and TESI were found to be positively correlated in this structural model. However, by including TESI hardiness in the mediational mechanism, its direct relationship with both perceived technology-assisted teacher support and perceived TESI was insignificant, while the mediating effects remained significant. Therefore, TESI hardiness is of considerable importance for delineating the relationship between perceived technology-assisted teacher support and perceived TESI. It was revealed that both the interpersonal variable (perceived technology-assisted teacher support) and the individual variable (TESI hardiness) are vital in determining the effectiveness of TESI. These findings enhance the understanding of and approach to the promotion of students' perception of scientific inquiry by emphasising the value of technology-assisted teacher support and hardiness.

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KEYWORDS
Inquiry; teacher support; hardiness; augmented reality; conceptual understanding; communication

Introduction

In the past few decades, scientific inquiry has become a core value in science-related education (Anderson, 2002; Bell et al., 2010). Scientific inquiry refers to a learning

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approach in which scientific methods and the nature of science are used to make observations; design experiments; and investigate, collect, and interpret data in order to solve contextualised problems (Bell et al., 2010). Previous research has examined the use of inquiry-based learning and innovative technologies for scaffolding students' science learning (Çalik, 2013; Kyza & Georgiou, 2019). Such technologies include transducers, detectors, internet forums, and websites that enable technology-embedded scientific inquiry. Technology-embedded scientific inquiry (TESI) is a term coined by Ebenezer et al. (2011) and describes an instructional scaffolding that allows teachers to design technology-enhanced learning activities that serve to facilitate scientific inquiry (Çalik et al., 2014).

It may be difficult for students to conduct scientific inquiries because this requires higher-order thinking skills, including forming a scientific hypothesis, interpretation, and argumentation (e.g. Chang et al. 2015; Çalik, 2013). For instance, studies conducted by Çalik (2013) and Hwang et al. (2012) revealed that most students experienced difficulties in applying what they learned when solving real-world scientific inquiry problems. These studies indicated that it was critical for students to demonstrate resilience in order to succeed when deciding on a research topic, inquiry task, and argumentation of the research findings. 'Hardiness' is recognised as a vital individual characteristic that defines a student's resilience in the face of difficulties in science learning (Wang & Tsai, 2016). Hwang et al. (2012) showed that the provision of teachers' support via social media platforms was valuable for students in scientific inquiry.

It is no surprise that when learners perceived an increase in perceived teacher support of any kind, they also reported a more favourable perception of technology-embedded science learning. However, previous research found that learners with an increased perception of teacher support do not necessarily possess advanced science learning self-efficacy (Wang & Tsai, 2019). On the contrary, some students perceived that teacher support may mean they learn science in order to meet the expectations of others, thus leading to reproductive-oriented TESI. Therefore, the current research proposes a possible mediator (hardiness) to help researchers determine the internal mechanism between perceived technology-assisted teacher support and perceived TESI. Additionally, we included TESI hardiness as a factor in the theoretical framework for the following reasons: to investigate why individuals exhibited perseverance in the face of difficulties and/or delays in achieving success, to determine individuals' control in regaining self-regulation (Lin et al., 2018), and to incorporate change as a challenge rather than a threat in scientific learning, where consistent efforts are required to perform tasks.

However, there are few studies regarding students' perceptions of teacher support and students' hardiness in science learning settings (Wang & Tsai, 2019). Therefore, the present study aimed to find precursory variables and explore the relationships of these with technology-embedded scientific inquiry in elementary and junior high school. The variables comprised one interpersonal variable (i.e. perceived technology-assisted teacher support) and one individual variable (i.e. TESI hardiness). TESI refers to core scientific inquiry learning approaches such as in-depth investigation, conceptual understanding, and scientific communication that are effectively facilitated by technological innovations (Ebenezer et al., 2011). Hardiness refers to an individual's capability for resilience and for overcoming difficulties through self-control, accepting challenges, and a commitment to dedicating themselves to the TESI process (Kobasa, 1979). Perceived technology-assisted teacher support refers to the extent to which students perceive the level of teacher support via social networks (e.g. Facebook, WhatsApp, and Twitter) and other technologies (e.g. email, internet forums, and TESI websites) following the disclosable progress of scientific inquiry.

Drawing on constructivism and Bandura's self-efficacy theory, we thus hypothesised that students' perceived technology-assisted teacher support might relate to their TESI hardiness, and in turn contribute to their perceived TESI. When a student perceives a high level of technology-assisted teacher support, they may exhibit a higher degree of hardiness when learning science, leading to an advanced perception of TESI. Particularly, the hypothesis validation requires a higher degree of hardiness (i.e. commitment, control, and challenge) because conducting scientific inquiry is often time-consuming and the results might not be positive. To successfully complete technology-embedded scientific inquiry tasks, students also need to have a high degree of hardiness in order to dedicate themselves to the inquiry, and control and regulate their feelings following a stressful or failed scientific inquiry.

Research questions

This study was guided by three research questions:

1. By questionnaire analysis: What is the relationship between students' perceived technology-assisted teacher support, hardiness, and perceived TESI?
2. By structural equation modelling (SEM) analysis: What predictive roles do students' perceived technology-assisted teacher support and hardiness play in their perceived TESI?
3. By follow-up interviews: What are students' perspectives regarding technology-embedded scientific inquiry?

Literature review

Technology-embedded scientific inquiry (TESI)

TESI refers to the technology-enhanced scientific inquiry approaches designed by teachers that students can selectively apply to complete scientific inquiry tasks, conceptualise subject knowledge, and communicate in the learning science process (Ebenezer et al., 2011). TESI is considered to be a useful, integrative model for explaining factors addressing learner behaviour, cognition, and social inquiry. Kuo et al.'s (2015) assertion that scientific inquiry should be categorised merely as skills and the cognitive ability to incorporate such skills into science knowledge echoes the findings of Çalik (2013). Utilising Ebenezer et al.'s (2011) definition of TESI, researchers have employed the framework for interpreting technologically enhanced learning activities such as scientific reasoning and collaborative learning.

To facilitate a more supportive scientific inquiry process, students can discuss their ideas with peers and teachers via social media platforms (Cheikh-Ammar & Barki, 2016; Wang & Hannafin, 2008), and this can help them to interpret experimental data and draw conclusions. For instance, empirical evidence produced by a study conducted by Cheikh-Ammar and Barki (2016) indicated that social network-based scientific communication, particularly regular communication with teachers through social networks, could stimulate learners' attitudes and beliefs through timely guidance, thereby improving the achievement level of scientific inquiry.

Precursor factors for TESI

Perceived technology-assisted teacher support

As the findings from Lin et al. (2016) and Cheikh-Ammar and Barki (2016) show, online scientific communication can be vital for facilitating the scientific inquiry process, especially in the context of technology-embedded or technology-assisted inquiry processes. The student's perceived technology-assisted teacher support can be provided through various types of media including instant text, email, SMS, and social networking applications (e.g. WhatsApp, WeChat, and Twitter).

The role of teacher support in student learning outcomes has attracted a lot of research attention (Kim & Hannafin, 2011; Sakiz, 2017). One particular finding suggests that perceived teacher affective support contributes to the enhancement of students' self-efficacy in scientific inquiry (Sakiz, 2017). It is thus worthwhile to consider the interpersonal factor of perceived technology-assisted teacher support as a precursor for TESI. Empirical results from a study by Kim and Hannafin (2011) suggest that perceived technology-assisted teacher support played a significant role in fostering students' inquiry learning achievements. Lin et al. (2016) proposed that perceived support provided or received through social networks could increase the depth of online collaboration and interaction among participants. Therefore, we were encouraged to investigate the link between perceived teacher support and TESI as a promising addition to the established models.

Hardiness

Kobasa (1979) first suggested the concept of hardiness as a personal characteristic. Hardiness is a trait that leads to an individual's willingness to accept challenges and manage pressure (Creed et al., 2013). Recent educational research takes hardiness into consideration in the learning process and investigates the interaction between hardiness and a range of factors that include self-efficacy, learning performance, and learning burdens (Wang & Tsai, 2016; Sheard, 2009). These studies reveal an overall positive effect of learning hardiness on the related factors.

Creed et al. (2013) developed a three-factor framework for learning hardiness including commitment, control, and challenge. In the context of scientific inquiry, students may feel pressured and encounter difficulties. Commitment refers to a state of being where the individual is continuously dedicated to inquiry learning goals and has a willingness to participate in scientific inquiry to achieve goals. Control refers to an individual's intention to attain learning goals through self-discipline and self-directed learning. Finally, challenge is defined as an individual's purposeful efforts in more difficult learning tasks to achieve a scientific inquiry goal. In other words, hardy students are willing to withstand the pressure of learning and have the courage to risk failure and regard their frustrations as necessary for achieving learning goals.

Previous studies have demonstrated a correlation between science learning hardiness and students' perceived science learning self-efficacy (Wang & Tsai, 2019). Hardiness is an important factor in facilitating success in academia through willingness to participate in challenging and germane tasks. Surface participation in inquiry learning is insufficient (Kang et al., 2019). In addition, a lack of self-control (including setting long-term goals, resisting temptation, and delaying hedonism) (Hwang et al., 2012) and work abandonment can occur in the face of difficulties and failures during the inquiry processes (Cheikh-Ammar & Barki, 2016). Therefore, it is important that students possess the level of hardiness (i.e. commitment, control, and challenge) necessary to achieve successful implementation of TESI in K–12 schools.

Theoretical background

The design of TESI

In recent decades, constructivism has had a profound influence on science and technology-enhanced education (Oh & Jonassen, 2007). Science educators have advocated the implementation of constructivist-oriented instruction (Baviskar et al., 2009). The constructivist theory says that instruction needs to carefully elicit learners' prior knowledge as well as create cognitive dissonance, and it should properly encourage the application of knowledge along with feedback from peers and teachers' interactions (Baviskar et al., 2009). Thus, the design of this study is mainly guided by constructivism and is divided into two parts: the construction of constructivist-oriented TESI environments and the role that scaffoldings play in the TESI process.

Technology-enhanced learning environments

The rapid development of information technology and its applications to education, especially of internet-based technologies, has given rise to insights into the construction of constructivist-oriented learning environments. In line with the constructivist paradigm, previous studies have introduced an ideal constructivist, technology-enhanced learning environment by employing online peer-assessment systems, online discussion boards, and online inquiry-based platforms to enhance science learning and instruction (Hwang et al., 2012; Kuo et al., 2015; Wu et al., 2013). If a technology-enhanced learning environment is properly designed, learners can access multiple sources of information and epistemological orientations (Tsai & Liang, 2009; Kim & Hannafin, 2011), and they can implement reflective thinking within the constructivist epistemology. It has been confirmed that learners within a constructivist epistemology have better learning outcomes than those within less advanced epistemology in technology-enhanced environments (Tsai & Liang, 2009).

In line with the aforementioned studies, the TESI environment addresses the use of the ideal features in a technology-enhanced learning environment based on constructivism in the scientific inquiry practice. In addition, our prior work employed mobile (Lin, Deng, et al., 2019) devices and social networks to construct a mobile learning environment (m-learning) that allows students to conduct scientific inquiry in different authentic contexts, such as in a museum or botanical garden (Lin, Tang, et al., 2019; Hwang et al., 2012). Therefore, we believe that the nature of the scientific inquiry enabled by the TESI environment is the student's legitimate central participation in the scientific inquiry practice. The

TESI environment creates authentic and meaningful problem situations and exploration spaces for students, where they can immerse themselves in a world of exploration, observation, and validation.

Technology-enhanced scaffolding

The constructivist paradigm stresses that knowledge is actively constructed by each learner (Oh & Jonassen, 2007). To facilitate a student's inquiry, there may be several attempts to expand technology-enhanced scaffolding, for instance by using *WebQuests*' teacher-prescribed inquiry steps (Wang & Hannafin, 2008); technology-enhanced teacher support for reflection during project-based learning (Land & Zembal-Saul, 2003); *CSCA*'s online synchronisation and argumentation prompts (Oh & Jonassen, 2007); and *TraceReaders*' augmented visualisations of concepts (Kyza & Georgiou, 2019). In the TESI process, the teacher is one member of the scientific inquiry community who provides technology-enhanced scaffoldings in real-time and helps students to overcome difficulties in the open inquiry learning process to improve learning outcomes.

The role of perceived technology-assisted teacher support in TESI

Sakiz (2017) and Kiryak and Çalik (2017) suggest that students' perceptions of their teachers' emotional support significantly contributes to learning outcomes in science learning. Although perceived responses to close relationships like friendships have received much attention in previous studies (Demir et al., 2017), the main reasons why we adopted perceived technology-assisted teacher support to predict students' TESI skills follow.

Bandura (1997) proposed that the sources of an individuals' self-efficacy come from past performance, vicarious experiences, physiological cues, and verbal persuasion. Social support and affective feedback (i.e. verbal persuasion coming from encouragements) are crucial for promoting self-efficacy and result in higher-level learning outcomes. In the present study, perceived technology-assisted teacher support could be construed as verbal persuasion (praise and encouragements) that supports inquiry in the TESI model.

The relationship among perceived technology-assisted teacher support, hardiness, and TESI

To illustrate the relationship between perceived technology-assisted teacher support and TESI, we adopted perceived technology-assisted teacher support and TESI hardiness as precursor factors for explaining students' TESI performance.

Schmid and Bogner (2017) found that students' long-term achievements are positively associated with career commitment (i.e. hardiness) and self-efficacy; this, in turn, indicates that students' higher TESI hardiness can indicate higher TESI achievement. Wang and Tsai (2019) noted that students' perceptions of teachers' support were associated with science learning hardiness. Therefore, our study hypothesises that students' hardiness will be strengthened if they perceive support from their teachers regarding their learning outcomes in technology-embedded scientific inquiry (i.e. Path H1 in Figure 1 may exist).

Furthermore, previous research findings suggested a positive relationship between Active Constructive responses of teacher support and learning achievement (Kiryak & Çalik, 2017; Sakiz, 2017). We accordingly hypothesise that students' awareness of teachers' technology-assisted support may promote TESI (see Path H2 in Figure 1).

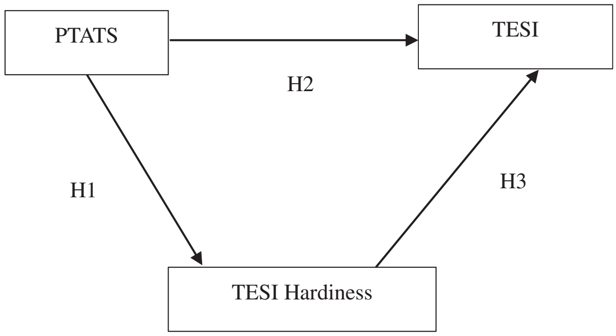

Figure 1. Hypothesized model. Note. PTATS, Perceived Technology-Assisted Teacher Support Scale; TESI, technology-embedded scientific inquiry; TESI Hardiness, technology-embedded scientific inquiry hardiness.

Many studies have investigated the correlation between hardiness and self-evaluation in academic settings. Sheard (2009) confirmed a strong correlation between hardiness and self-worth. Consistent with Sheard's (2009) findings, Wang and Tsai (2019) found strong correlations between hardiness and science learning self-efficacy. Consequently, we hypothesise a positive relationship between learning hardiness and TESI learning outcomes in the structural model based on the findings of previous studies (i.e. Path H3 in Figure 1). These studies can thus serve as a basis for the assumption that hardiness may mediate the correlation between perceived technology-assisted teacher support and TESI in this study.

By using SEM, the present study found that both individual (TESI hardiness) and interpersonal (perceived technology-assisted teacher support) variables predicted TESI. Figure 1 presents a model that reveals the correlation between students' perceived technology-assisted teacher support, hardiness, and TESI. The underlying assumption of this study is that students' perceived technology-assisted teacher support and hardiness contribute to their TESI outcomes. Students' perceived technology-assisted teacher support may also have an impact on their TESI hardiness. We thus hypothesise that students' perceived technology-assisted teacher support might directly affect their hardiness, which may indirectly influence their TESI.

Methods

Participants

A total of 1566 students (59.3% middle school students and 40.7% primary school students) completed the questionnaire from December 2017 to January 2018. All participants were in grades 4 through 8 ($M = 6.50$, $SD = 1.12$) and were required to take part in technology-embedded scientific inquiry according to the science curriculum reform standards for K–12 education in China. A convenience sample was drawn from 26 public primary and middle schools that had voluntarily undertaken the TESI project for one year. Among the participants, 44.5% were boys and 54.5% were girls, with an average age of 11.5 years. Participation was on a voluntary basis and could be terminated at any time during the survey.

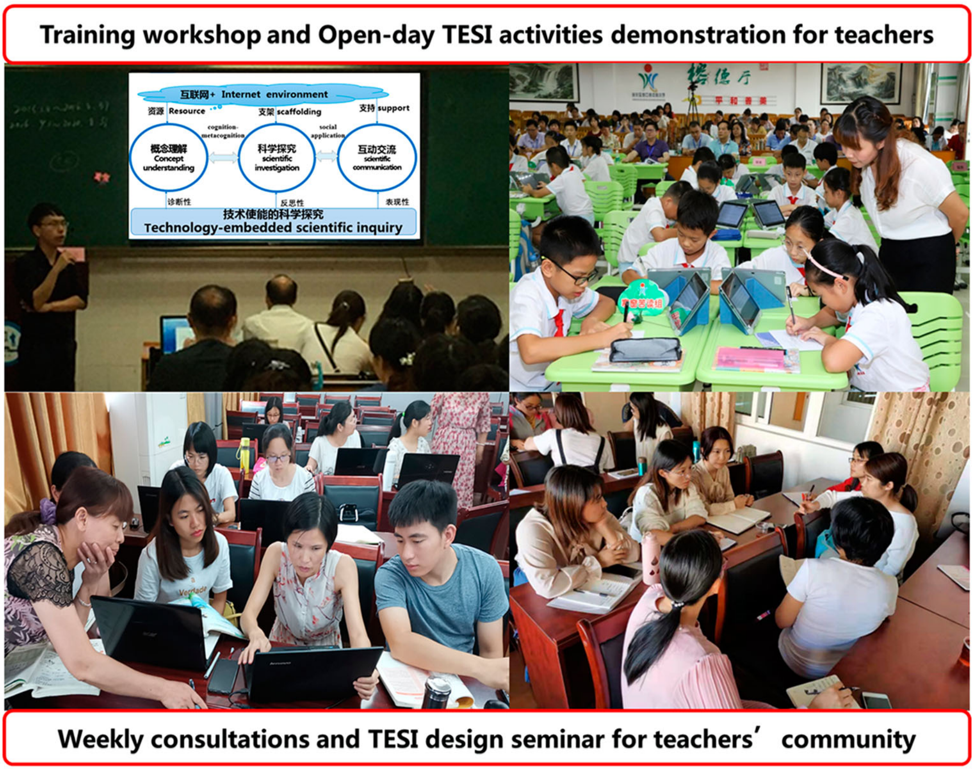

Figure 2. Training workshop and consultations for teachers to develop proper TESI activities.

A long-term TESI project supported by the Department of Education in south China (from October 2016 to November 2017) was conducted for this study with the goal of helping teachers implement TESI activities into scientific inquiry activities with a proposed TESI system. Previous research has suggested that extreme variability can be prevented during TESI activities by incorporating expert suggestions into the TESI process (Chang et al., 2015). Training projects were thus conducted to enhance the level of teacher design knowledge of TESI principles while providing the teachers with the necessary skills for successful design (Figure 2). Appropriate expert consultations were also integrated to support teacher practices. Teachers were thus provided with a basic conception of how TESI could be incorporated with both pedagogy and subject content. The common features among the inquiry activities that the 26 schools’ students engaged in were the recommended activities of TESI, TESI resources from the TESI system, and training workshops and regular consultations. All participants were exposed to the project for more than two-thirds of the course.

Context

Teachers designed four kinds of instructional activities to help students’ scientific inquiry according to the recommended principles of TESI. First, students learn science in classes or a school environment. Students can form a sense of scientific knowledge, and then are encouraged to apply the knowledge in completing the inquiry tasks. The second activity involves individual investigation. Students have to explore scientific knowledge or problems in the inquiry tasks. They have to take photos, videos, and notes about these tasks and upload photos and notes onto the TESI system (i.e. ISEED system), which contains every scientific inquiry module. This can help them compare the differences between the notes of practical scientific inquiry and the prior knowledge on their own. Activity three involves communication about inquiry findings that are located online. Students comment and modify their classmates' posts to the ISEED system. The fourth activity is meant to enhance students' scientific knowledge. Teachers choose topics about scientific knowledge or problems, and students discuss these topics together in class, developing new ideas and knowledge. Technology-assisted teacher support was provided during the activities by various types of media including text communication, email, and social networks such as WeChat and QQ, which are similar to WhatsApp and Twitter.

As shown in Figures 3 and 4, the TESI activities incorporate two kinds of scaffolding, technology-assisted teacher support and reflective scaffolding, to facilitate inquiry and transformation of misconceptions. Different types of media are used for technology-assisted teacher support in the TESI project, including email and social network applications. Students have the opportunity to perceive their teacher's support online rather than face-to-face in the classroom. In the TESI context, a teacher can provide an active constructive response as an intervention when a student is experiencing inquiry learning difficulties instead of disclosing the answer and may not directly respond to questions or make suggestions and corrections regarding work that the students cannot finish. For instance, an intervention may be 'You should select the optimal solution after you conduct search and debate about the relevant information. I think you can achieve this'. When students gain a certain level of achievement and progress, teachers can provide active destructive responses and thus guide students to reflect, summarise, sort out, and adjust their inquiry practices. For instance, 'Your data collection was rather slow. You should work faster by using data-gathering technology in the next stage' (Figure 3).

As shown in Figure 4, the ISEED system provides a TESI reflective scaffolding for the students. The science concepts of control variable (i.e. water, air, temperature, and sunlight) of seed germination are embedded in the reflective scaffolding of the seed germination experimental inquiry. As indicated by *Variables*, the values of the condition of seed germination can be different depending on selections by the students. The reflective scaffolding requires students to select the control conditions, input the values of each condition, and take notes on the inquiry findings. Therefore, through the reflective scaffolding, students can examine the given conditions and make their decisions regarding the essential conditions of seed germination.

We took the scientific issue 'exploring the essential conditions of seed germination' as the example to express scaffoldings and affordances regarding the TESI activities. Augmented reality videos or 3D models regarding the concept of seed germination are presented via the ISEED system to build a TESI environment and immersive experience for the students (Figure 3). This can encourage students to think deeply about the process of seed germination and allows teachers to check whether students have properly understood the concept of essential conditions of seed germination. Further, students perform an experimental inquiry to control the variable of seed germination with a reflective scaffolding (Figure 4). Therefore, they can discover their misunderstandings of seed

Figure 3. The interface of the ISEED system for students' perception of teacher support.

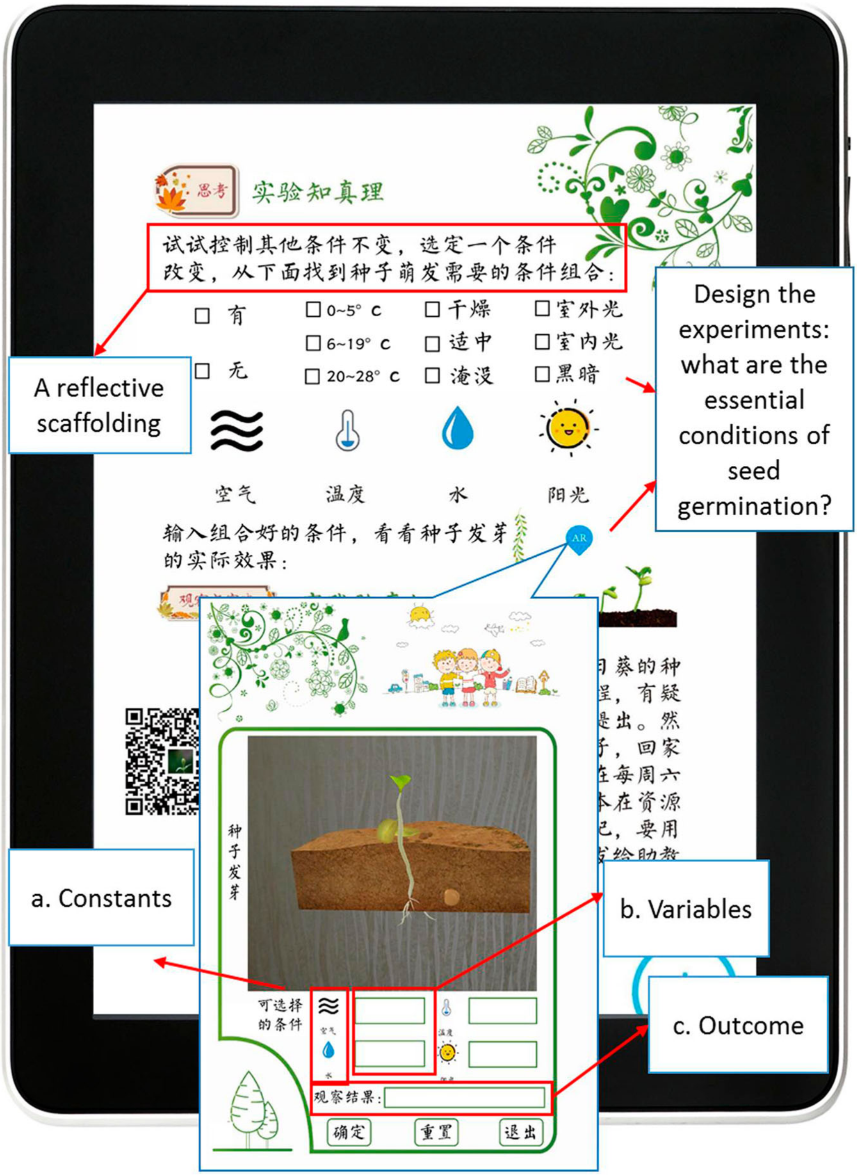

Figure 4. The ISEED system interface of the seed generation experimental inquiry.

germination through comparing the differences between their prior experience and field observation from the experimental inquiry. The reasons for seed germination are then proposed and discussed so that misconceptions can be corrected with teacher support. Teachers guide students' exploration of that process and verify that seed germination does not require sunlight, which helps to modify students' misunderstandings and previous knowledge. In short, teachers and researchers developed TESI activities containing reflective scaffoldings and technology-assisted teacher support to help students understand the natural science of seed germination.

Measures

A translation back-translation method was employed when all English-based measures were translated into Chinese. Table 1 illustrates the coefficient alpha for each scale.

Perceived technology-assisted teacher support scale

Students' perceived technology-assisted teacher support was measured with 12 items modelled after the original Perceived Responses to Capitalisation Attempts scale (Çalik & Reis, 2010; Demir et al., 2017), which includes four dimensions: Active Constructive, Passive Constructive, Active Destructive, and Passive Destructive, each containing three items. Active Constructive responses denote the enthusiastic support of the scientific inquiry. Passive Constructive responses also offer a positive support that, nonetheless, lacks enthusiasm. Active Destructive responses express a desire to provide a negative support, and Passive Destructive responses ignore or criticise the event (Smith & Reis, 2012). Among these four response types, active responses (i.e. Active Constructive and Active Destructive) were found to be related to the enhancement of positive support and enthusiasm (Demir et al., 2017; Smith & Reis, 2012).

The perceived responses to capitalisation attempts framework contains four dimensions. However, only two dimensions (i.e. Active Constructive and Active Destructive responses) were addressed in the current study for two reasons. First, contrary to passive responses, which are implicit and indirect, active responses are direct and enthusiastic; this may indicate more significant findings related to perceived technology-assisted teacher support. Second, compared with one-to-one close relationships, such as those shared by couples, teacher-student relationships are usually one-to-many, especially in TESI contexts. Consequently, most students seemed deeply troubled by the lack of responses from teachers they did not feel very close to or those teachers with whom they had infrequent interactions. Responses were anchored on a 5-point Likert-type scale (1 = strongly disagree, 5 = strongly agree). Results on two subscales—Active Constructive and Active Destructive—were targeted in the present study. These two dimensions are specified as follows:

(1) An Active Constructive response means that the responder expresses excitement, enthusiasm, or desire to participate in an event (e.g. 'When I tell my teacher that I had performed well in learning, he or she usually responds eagerly to my good performance').

Table 1. The CFA analysis of the perceived technology-assisted teacher support scale.

Construct and Questionnaire Items	Factor loadings (Standardized Estimates)	*t*-value
Active constructive		
1	.71	46.33**
2	.79	59.02**
3	.81	63.80**
Active destructive		
4	.74	50.97**
5	.79	59.97**
6	.78	57.92**

Note. $^{**}p < 0.01$.

(2) An Active Destructive response means that the responder is focused and involved yet gives a negative feedback (e.g. 'When I tell my teacher that I had performed well in learning, he or she reminds me that everything has a negative side').

TESI hardiness scale

Students' technology-assisted academic hardiness was assessed using the Technology-embedded Scientific Inquiry Hardiness Scale, which consists of three dimensions: commitment, challenge, and control. The scale was adapted from the Hardiness Scale developed by Creed et al. (2013) and the content was validated by experts. To adapt the scale to the context of the study, 16 items were retained and modified into three constructs: commitment, challenge, and control. All items were rated on a 5-point Likert-type scale (1 = strongly disagree, 5 = strongly agree). These three dimensions are as follows:

(1) Commitment refers to the dedication of students to a particular purpose or context to make sense of the scientific inquiry process, and it contained seven items (e.g. 'I attach great importance to learning in science courses').
(2) Challenge refers to students' purposeful efforts that they believe to be important in achieving higher learning goals in terms of more demanding tasks or experiences, and it consisted of four items (e.g. 'I like the challenge of a difficult science learning activity').
(3) Control refers to learners' belief that they can reach their desirable educational goals through hard work and self-direction, and it consisted of six items (e.g. 'It's hard for me to recover from the frustration of science learning activities').

TESI scale

Students' perceptions of TESI were measured using a TESI scale developed from Ebenezer et al. (2011). These studies have shown satisfactory validity and reliability levels of such instruments for examining primary and secondary school students' perceived technology-assisted scientific inquiry (Çalik, 2013; Ebenezer et al., 2011). These instrument scales included investigation, young adult ethos, conceptual understanding, involvement, student cohesiveness, and scientific cooperation. Moreover, we considered Chang et al.'s (2015) framework of technology-supported learning environments for creating pedagogical designs; it consists of six constructs: technical, content, cognitive, metacognitive, social, and affective. To establish a multi-dimensional model, we further modified the TESI scale to include two latent constructs in Chang et al.'s (2015) framework: Cognition-metacognition scientific inquiry and social application of scientific inquiry. Of all factors, scientific investigation, conceptual understanding, and young adult ethos were classified into cognition-metacognition scientific inquiry as they assess students' TESI for scientific investigation, problem-solving, and reasoning; on the other hand, involvement, student cohesiveness, and scientific cooperation were included in social application of scientific inquiry as these factors assess students' capability to use concepts and competences in scientific inquiry. This was intended to reveal the differences in TESI regarding cognition-metacognition scientific inquiry and social application of scientific inquiry. This is a 30-item self-report scale with 5 items for each dimension. Participant responses were measured on a 5-point Likert-type scale (1 = strongly disagree, 5 = strongly agree). These six subscales are as follows:

(1) The scientific investigation subscale measures students' perceptions of the degree to which they are given the opportunity to learn skills and knowledge from various channels that can be employed in the TESI process (e.g. 'I'm inclined to figure out the answer to a question using a computer or the Internet.').
(2) The conceptual understanding subscale measures students' perceptions of the degree to which they integrate ICT into the conceptualisation of subject-matter knowledge in the TESI process (e.g. 'It is worthwhile to think deeply about my approaches to learning.').
(3) The young adult ethos subscale measures students' perceptions of the degree to which they believe that TESI gives them awareness and responsibility and leads them to better achievement of their inquiry learning (e.g. 'It is my responsibility to ensure that the task is completed in scientific inquiry.').
(4) The involvement subscale measures students' perceptions of the degree to which they believe they are able to focus and participate in TESI (e.g. 'I am attentive and interested in participating in complex, real-life environments, complete planned activities, and focus on the subject.').
(5) The scientific cooperation subscale measures students' perceptions of the degree to which they have the opportunity to express and exchange their ideas with each other in TESI (e.g. 'I am inclined to seek opportunities to talk to other students in scientific inquiry.').
(6) The student cohesiveness subscale measures students' perceptions of the degree to which they are willing to support their peers to use learning technology in TESI (e.g. 'I am willing to support my peers in using the learning technology.').

Data analysis

To ensure validity, three instruments were drafted and sent to three educational technology professors for expert validation and to five students for content validation (Wu et al., 2013). Based on their comments and suggestions, we revised the wording and items where necessary to improve the scale quality. Furthermore, Mplus 7.4 was used to perform confirmatory factor analysis (CFA) to validate the constructs of each scale. Then, SPSS version 23.0 was used to conduct descriptive statistics, correlation analyses, and reliability analyses. Moreover, structural equation modelling was used to analyse the mediating effects with maximum likelihood estimation. We used the measurement model and the structural model to test the hypothesised models. The model fit was assessed using the following indicators: (a) Tucker-Lewis Index (TLI), (b) Comparative Fit Index (CFI), and (c) the standardised root mean square residuals (SRMR). Based on Marsh et al. (2004), a CFI of at least 0.90, a TLI of at least 0.90, and an SRMR < 0.08 together would suggest a good fit between the hypothesised model and the data.

Semi-structured interviews

To better probe students' perspectives of TESI, this study conducted follow up semi-structured interviews with a focus on their perceived technology-assisted teacher support and the role of hardiness on their perceived TESI, as we wanted to further interpret the findings in relation to the different types of data (i.e. self-reported questionnaire and interview). Example interview questions included 'Are you interested in the TESI activity, and why?', 'What have you learned from the TESI process?', 'What is your favourite part of technology-assisted teacher support, and what is your least favourite part?', and 'How did you complete the TESI tasks when you found it difficult or challenging to persist in the inquiry, and can you specifically describe any changes in feelings during that period?' The follow-up interviews were guided by the six qualitative interview collection and analysis procedures proposed by Johnson and Christensen (2019) to support the reliability of the researchers' coding and categories.

Results

Validity and reliability of the instruments

CFA was used to validate the factorial structure of each scale, and the coefficient alpha was used to test the reliability of all the scales.

CFA for the perceived technology-assisted teacher support instrument

The measurement model of perceived technology-assisted teacher support (Table 1) consisted of two study factors (Active Constructive and Active Destructive). In terms of the goodness of fit of this model, CFI = 0.99, TLI = 0.98, and SRMR = 0.018 were obtained and suggest the model is well constructed (Table 5). In the study, the reliability coefficients of Active Constructive and Active Destructive are both 0.81, and the overall reliability coefficient is 0.90, showing that this instrument is reliable.

CFA for the TESI hardiness instrument

The challenge subscale was removed from TESI hardiness (Table 2) due to its low coefficient alpha value. Thus, two subscales (Commitment and Control) were used in this study. In addition, we removed items with low factor loadings ($\lambda < 0.3$). After this reduction, the commitment subscale had six remaining items, and the control subscale

Table 2. The CFA analysis of the technology-embedded scientific inquiry hardiness scale.

Construct and Questionnaire Items	Factor loadings (Standardized Estimates)	*t*-value
Commitment		
1	.76	58.78**
2	.79	68.69**
3	.81	76.74**
4	.79	68.50**
5	.75	58.34**
6	.55	28.80**
Control		
7	.61	32.89**
8	.47	21.04**
9	.70	44.92**
10	.77	58.12**
11	.78	60.94**
12	.72	48.38**

Note. $^{**}p < 0.01$.

had five. As shown in Table 5, the measurement model of TESI hardiness exhibited acceptable fit indices (CFI = 0.91, TLI = 0.89, SRMR = 0.089), which indicate a valid construct. In this study, the reliability coefficients of Commitment and Control are 0.88 and 0.83, respectively, and the whole reliability coefficient is 0.87, indicating that this instrument is reliable.

CFA for the TESI instrument

The measurement model of TESI (Table 3) was also tested for construct validity of six factors (Scientific investigation, Conceptual understanding, Young adult ethos, Involvement, Scientific cooperation, and Student cohesiveness), each consisting of five items. The findings indicated that all scales exhibited acceptable fit indices (CFI = 0.94, TLI = 0.93, SRMR = 0.029) with acceptable factor loadings (Table 5). Moreover, as indicated by the results shown in Table 4, the loadings of the first-order latent variables on the second-order factors exceed 0.90 (all loadings are significant at $p < 0.01$). The results

Table 3. The CFA analysis of the perceived technology-embedded scientific inquiry scale.

Construct and Questionnaire Items	Factor loadings (Standardized Estimates)	*t*-value
Scientific investigation		
1	.72	52.27**
2	.71	51.08**
3	.73	54.60**
4	.75	60.76**
5	.79	73.74**
Conceptual understanding		
6	.78	69.56**
7	.80	78.46**
8	.80	76.80**
9	.82	83.67**
10	.79	72.81**
Young adult ethos		
11	.78	69.43**
12	.68	45.99**
13	.72	53.17**
14	.82	81.67**
15	.80	74.44**
Involvement		
16	.77	67.63**
17	.81	80.67**
18	.81	81.71**
19	.80	77.43**
20	.75	59.61**
Student cohesiveness		
21	.72	53.71**
22	.80	74.66**
23	.81	80.41**
24	.81	78.97**
25	.77	65.58**
Scientific cooperation		
26	.76	63.35**
27	.82	83.25**
28	.82	85.07**
29	.78	66.63**
30	.73	54.64**

Note. $^{**}p < 0.01$.

Table 4. The CFA second-order coefficients of the perceived technology-embedded scientific inquiry scale.

Construct and Questionnaire Items	Factor loadings (Standardized Estimates)	*t*-value
Cognition-metacognition scientific inquiry, composite reliability = 0.99		
scientific investigation	.90	85.86**
conceptual understanding	.90	95.37**
young adult ethos	.89	88.08**
Social application of scientific inquiry, composite reliability = 0.90		
involvement	.89	94.27**
student cohesiveness	.86	78.89**
scientific cooperation	.84	73.54**

Note. **$p < 0.01$.

Table 5. The CFA results for all scales.

Scale	χ^2	df	CFI	TLI	SRMR
PTATS	57.17	8	.99	.98	.018
TESIs	2493.69	390	.94	.93	.029
TESI Hardiness	833.72	53	.91	.89	.089

Note. PTATS, Perceived technology-assisted teacher support scale; TESIs, Technology-embedded scientific inquiry scale; TESI Hardiness, Technology-embedded scientific inquiry hardiness scale

confirmed the second-factor model of TESI, which included cognition-metacognition scientific inquiry and social application of scientific inquiry. In the study, the reliability coefficients of six subscales range from 0.86–0.90, and the reliability coefficient of TESI is 0.97, suggesting that this instrument is reliable.

Descriptive statistics

The results of the descriptive statistics and correlation analyses of all study variables are shown in Table 6. The correlations among Active Constructive, Active Destructive, and students' technology-enhanced scientific inquiry were all positive and statistically significant at the $p < 0.01$ level. TESI hardiness was found to be positively related to Active Constructive ($r = 0.50$, $p < 0.01$), Active Destructive ($r = 0.46$, $p < 0.01$), and students' technology-enhanced scientific inquiry ($r = 0.54$, $p < 0.01$). Table 7.

Analysis of mediating effect

We followed a two-step procedure to test the mediating effect (see Table 8 M1 and Figure 5). In Step 1, we examined the direct effect. The direct path coefficients from Active Constructive and Active Destructive to the cognitive and metacognitive processes of scientific inquiry in the absence of a mediator variable were found to be significant ($c1 = .30$, $p < 0.001$, $c2 = .31$, $p < 0.001$, respectively). Taken together, these results provide support for Path H3 in Figure 1; namely, perceived technology-assisted teacher support was found to be positively associated with students' TESI. In Step 2, fitness of the structural model M1 with students' TESI hardiness as a mediating variable was tested. The results indicate that this model provided an acceptable fit to the data (see Table 9 M1), with significant mediating effects ($a{*}b1 = .08$, $p < 0.01$, $a{*}b2 = .16$, $p < 0.001$). However, the direct effect

Table 6. Means, standard deviations, and correlations.

	X ± S	1	2	3	4	5	6	7	8	9	10	11	12	13
1.Com	3.81 ± .86	**.88**												
2.Con	3.34 ± .94	.41**	**.83**											
3.AC	3.63 ± .98	.50**	.45**	**.81**										
4.AD	3.67 ± .96	.46**	.47**	.64**	**.81**									
5.SC	3.89 ± .90	.50**	.29**	.46**	.45**	**.89**								
6.SI	3.87 ± .87	.49**	.34**	.45**	.46**	.76**	**.86**							
7.CU	3.97 ± .88	.48**	.30**	.42**	.42**	.76**	.79**	**.90**						
8.IV	3.94 ± .88	.44**	.27**	.38**	.37**	.61**	.65**	.67**	**.90**					
9.SCO	3.91 ± .89	.41**	.29**	.37**	.39**	.56**	.61**	.62**	.79**	**.89**				
10.YAE	3.94 ± .87	.44**	.31**	.38**	.37**	.61**	.61**	.65**	.76**	.78**	**.87**			
11.TESIH	3.58 ± .76	.82**	.86**	.56**	.56**	.47**	.49**	.46**	.42**	.41**	.44**	**.87**		
12. PTATS	3.65 ± .88	.53**	.51**	.91**	.90**	.50**	.50**	.47**	.41**	.42**	.41**	.62**	**.90**	
13.TESI	3.92 ± .75	.54**	.35**	.48**	.48**	.84**	.86**	.87**	.87**	.85**	.86**	.52**	.53**	**.97**

Note. Coefficient alpha are reported along the diagonal. Com, Commitment; Con, Control. AC, Active Constructive; AD, Active Destructive.; SC, scientific cooperation; SI, scientific investigation; CU, conceptual understanding; IV, involvement; SCO, student cohesiveness; YAE, young adult ethos, PTATS, perceived technology-assisted teacher support. TESI, technology-embedded scientific inquiry; TESIH, technology-embedded scientific inquiry hardiness. The square root of the AVE value is bold on the diagonals are the Pearson correlations of the constructs.

**$p < 0.01$.

Table 7. The goodness of fit index of mediating model.

Model	χ^2	*df*	RMSEA	CFI	TLI	SRMR
The mediational model-M1	406.58***	84	0.05	.98	.97	.028
The mediational model-M2	373.80***	84	0.05	.98	.97	.026

Note. ***$p < 0.001$.

Table 8. Mediation effect of the technology-embedded scientific inquiry hardiness.

	CMSI		SASI	
Variables	M1a	M1b	M2a	M2b
AC	0.30*** (0.06)	0.15** (0.05)	0.25*** (0.06)	0.41*** (0.06)
AD	0.31*** (0.06)	0.23*** (0.05)	0.28*** (0.06)	0.20*** (0.06)
Com		0.38*** (0.04)		0.34* (0.04)
Con				

Note. CMSI, cognition-metacognition scientific inquiry; SASI, social application of scientific inquiry; AC, active constructive; AD, active destructive; Com, Commitment; Con, Control.
*Marginal significance $p < 0.07$; **$p < 0.01$; ***$p < 0.001$.

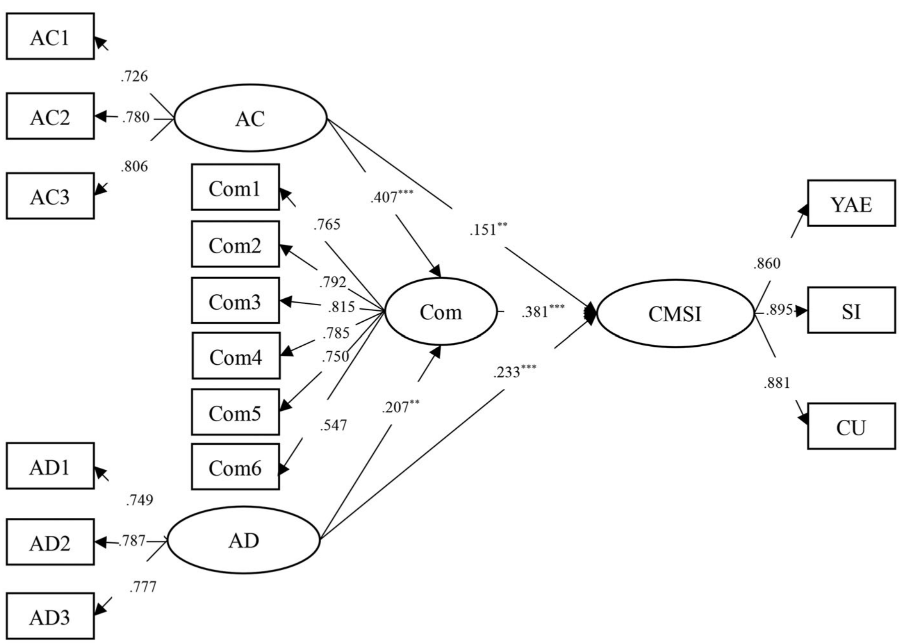

Figure 5. The mediational model-M1. Note. Com, commitment; CMSI, cognition-metacognition scientific inquiry; AC, active constructive; AD, active destructive; SI, scientific investigation; CU, conceptual understanding; YAE, young adult ethos. **$p < 0.01$; ***$p < 0.001$.

was not significant ($c' = .38, p > .001$). Furthermore, the bootstrap results indicate a significant mediation effect (see Table 9 M1). Commitment is thus a partial mediator between the variables of Active Constructive, Active Destructive, and the cognition-metacognition scientific inquiry. The mediation model derived from the results is presented in Figure 5.

Table 9. Bootstrap of the mediational effect.

Model	Rountie	a*b	95%CI	Mediate effect
The mediational model-M1	AD-Com- CMSI	0.079**	(0.031, 0.127)	25.240%
	AC-Com- CMSI	0.155***	(0.100, 0.210)	50.987%
The mediational model-M2	AD-Com- SASI	0.068**	(0.027, 0.116)	24.549%
	AC-Com- SASI	0.124***	(0.086, 0.193)	50.000%

Note. CMSI, cognition-metacognition scientific inquiry; SASI, social application of scientific inquiry; AC, active constructive; AD, active destructive; Com, Commitment.
** $p < 0.01$; *** $p < 0.001$.

Further, in our analysis in Step 1, we found that the direct path coefficients from Active Constructive and Active Destructive to the social application of scientific inquiry in the absence of a mediator were significant ($c1 = .25$, $p < 0.001$; $c2 = .28$, $p < 0.001$; see Table 8 M2 and Figure 6). Thus, these results provide support for Path H3 in Figure 1, i.e. perceived technology-assisted teacher support was positively associated with students' TESI performance. In Step 2, fitness of the structural model M1 with students' TESI hardiness as a mediating variable was tested. The results indicate that this model provided an acceptable fit to the data (see Table 9 M2), with significant mediating effects ($a*b1 = .70$, $p < 0.01$, $a*b2 = .12$, $p < 0.001$). However, the direct effect was not significant ($c' = .34$, $p > 0.01$). In addition, the bootstrap results indicate a significant mediation effect (see Table 9 M2). Therefore, commitment partially mediated the relationship between the variables of Active Constructive, Active Destructive, and the social application of scientific inquiry in school. We constructed the second mediation model (Figure 6) from the results.

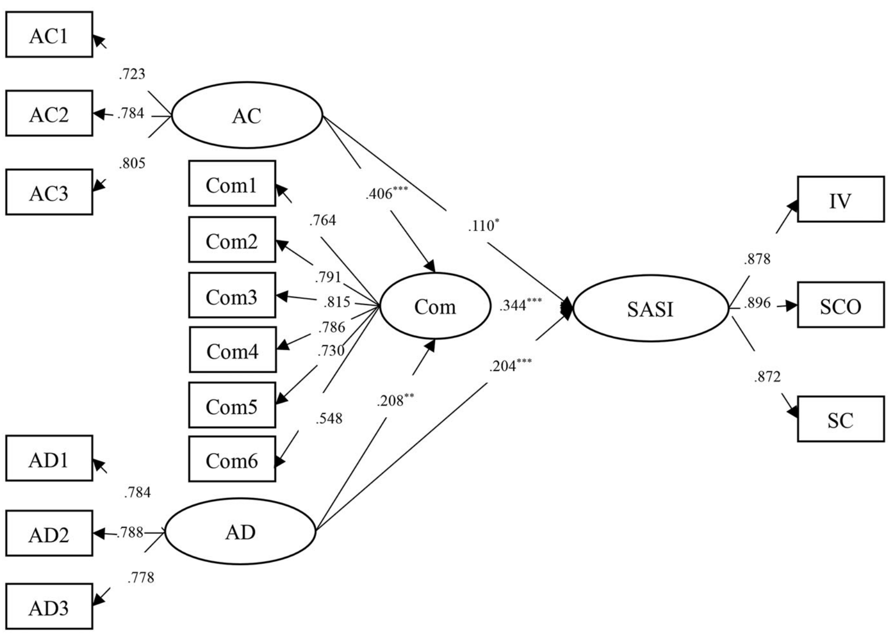

Figure 6. The mediational model-M2. Note. Com, commitment; SASI, social application of scientific inquiry; AC, active constructive; AD, active destructive; SC, scientific cooperation; IV, involvement; SCO, student cohesiveness. *Marginal significance $p < 0.06$; ** $p < 0.01$; *** $p < 0.001$.

Interview analysis

The findings partially confirmed that perceived technology-assisted teacher support was not a direct predictor of students' perceived TESI, as some previous studies had suggested (e.g. Hwang et al., 2012). TESI hardiness would mediate the relationship between students' perceived technology-assisted teacher support and perceived TESI. To further explore the role of students' perceived technology-assisted teacher support and hardiness in TESI activities, we conducted 15 sample (six males and nine females) follow-up interviews. The students were selected based on their TESI proficiency throughout the activity period (5 highly proficient students, 5 medium-proficient students, and 5 low-proficient students). The interview analysis results are listed in Table 10, which focuses on the possible influencing factors on students' perceived TESI, including learning competence of TESI, perceived technology-assisted teacher support, and the role of hardiness.

Regarding learning competence of TESI, the students expressed technology-embedded scaffoldings that facilitated their learning and inquiry, which included five aspects, namely investigation founded on data and timely interactions and communications with peers and teachers online, deep understanding of the concept, responsibility and rigor, involvement in a real context, abundant attractive information, and engagement in student cohesiveness (i.e. 1.1–1.5). Moreover, all the students considered the TESI task as challenging in nature, and one student said 'I think TESI is a very sacred project. It is very difficult and challenging to act like a scientist (e.g. 3.5)'.

Regarding the role of students' perceived technology-assisted teacher support and hardiness in TESI, the interviews indicated that students of different hardiness levels perceived technology-assisted teacher support in varying degrees, which may explain why they perceived different levels of TESI. Despite the perceived challenges, the interviews found that many medium- and low-proficient students expressed a higher resilience in relation to scientific inquiry stresses and a sense of autonomy and satisfaction after perceived technology-assisted teacher support. They felt greater autonomy and satisfaction and demonstrated more hardiness. They explain that they 'feel optimistic and become more satisfied when my teachers cheer at my inquiry progress through virtual facial expressions (e.g. emojis) on the social network, and I then practice and try again (e.g. 2.3)' and felt a sense of accomplishment because they experienced 'a scientific spirit of inquiry and enthusiasm after receiving my teachers' support, and I did not feel tired anymore (e.g. 3.3)'. Because of the role of hardiness, medium- and low-proficient students were also more likely to perceive a high level of involvement in TESI, as one reported 'I was enjoying the activity because the task was real, and there was abundant new and attractive information through the TESI system', and this gradually increased engagement in the activity (e.g. 1.4). However, highly proficient students 'perceived negative feedback as more convincing (e.g. 2.2)' compared to positive responses and preferred the destructive version: 'Your data collection was rather slow. You should work faster by using data-gathering technology in the next stage (e.g. 3.1)'. This evidence from the interviews suggests that the role of hardiness in inquiry learning is a critical factor in sustaining long-term involvement (See more interview quotes in Table 10).

Table 10. Categories of students' perspectives regarding technology-embedded scientific inquiry.

Conceptions	Values	Examples
1. Competence related to conducting TESI	1.1. Investigation founded on data, evidence, and interaction 1.2. Deep understanding of concept 1.3. Responsibility and rigour 1.4. Involvement/ participation 1.5 Student cohesiveness	1.1. I think the investigation's conclusion is highly based on statistical data and it is needed to interact timely with peers and teachers online about those evidences before making conclusions. 1.2. I think searching for solid fact and literature through Internet and Wikipedia is necessary; doing this seems to show a good understanding of knowledge so… 1.3. I prefer to see the progress of TESI work in reserved tone. I feel this reflects the responsibility and rigour in inquiry learning. 1.4. I was enjoying the activity later because the task was real and there was abundant new and interesting information through TESI system. I tend to be tentative till the completion of the task … 1.5. I think I could not complete the task in the end. However, my companions have been waiting for me, helping me until I found the answer. At that time, I felt moved that he could take me to the finish line regardless of his own performance.
2. Attitudes towards technology-assisted teacher support	2.1. Perceived active destructive responses 2.2. Perceived negative feedback more convincing 2.3. Perceived attractive in improving scientific inquiry	2.1. I think the strong stance of teachers' criticism regarding our inquiry is better, which will be accepted by most students… 2.2. It is no doubt that direct and negative feedback is more convincing. Although some expressions I would not prefer, I feel less anxious that perceived teacher' negative support through the online channels instead of face-to-face ones. 2.3. I feel optimistic and become more satisfied when my teachers cheered at my progress of inquiry through virtual facial expressions on social network, then practiced and tried again.
3. The role of hardiness in TESI	3.1. Absolute/authority 3.2. Decisive action 3.3. Autonomy need satisfaction 3.4. Perseverance 3.5. Challenge 3.6. Aggressive	3.1. It has a more absolute tone, but compared to 'Well Done!' (Positive support), I prefer the version 'Your data collection was rather slow. You should work faster by using data-gathering technology in the next stage'. 3.2. If I really have to make an immediate decision and action, it makes more sense if it is negative feedback. 3.3. Inquiry is a way to test an individual's hardiness. When a progress is nearly completed, although exhausted, I can experience the scientific spirit of inquiry and enthusiasm after receiving my teachers' support. Then I' m not that tired anymore. Looking back, I' m really satisfied and proud. 3.4. In fact, the most important thing for completing the inquiry is perseverance. My peers and I kept encouraging each other to persist a little bit longer. 3.5. I think TESI is a very sacred project. It is very difficult and challenging to act like a scientist. I am afraid that I cannot complete it, but I want to challenge myself. 3.6. Whenever I complete a stage of inquiry, I feel that the whole body is better than before that I feel great. I like to be more involved.

Discussion

The present study explored the direct effects of perceived technology-assisted teacher support and hardiness on students' perceived TESI, as well as the indirect effects of hardiness by adopting an SEM analysis. The results of the SEM analysis revealed that hardiness mediated the effects of perceived technology-assisted teacher support on

TESI. These results imply that students perceived that active responses from their teachers could improve their hardiness, which indirectly promoted their TESI performance. It was revealed that both the interpersonal variable (perceived technology-assisted teacher support) and the individual variable (hardiness) are vital in determining students' TESI performance.

The existing literature has documented that students with affective support will achieve superior science learning outcomes. For example, the results of Sakiz (2017) and Wang and Tsai (2019) show that emotional support provided by the teacher creates an optimistic connection to students' science learning self-efficacy. Consistent with these findings, the results of the present study indicate that students' perceived technology-assisted teacher support was a significant factor in the interpretation of their perceived TESI. Moreover, the findings regarding TESI hardiness in the present study are consistent with those of previous studies. For instance, previous research has shown that socially supportive reciprocity and feedback regarding individuals' efforts (paralleled with perceived technology-assisted teacher support in the current model) increased hardiness (e.g. Cheikh-Ammar & Barki, 2016).

In addition, Çalik (2013) examined the relationships among scientific conceptualisation, scientific investigation, and scientific communication and found that individuals' scientific beliefs triggered higher-level scientific investigation, which, in turn, fostered scientific communication and pre-service teachers' self-efficacy in TESI. Furthermore, Isik-Ercan (2020) found that technology-embedded scientific tutorials consisted of inquiry-based investigations and STEM interactive courses. In a later study, Çalik et al. (2014) revealed that individual scientific conceptualisations directly led to enhanced ways of scientific investigation; this, in turn, indirectly promoted scientific communication, understanding of environmental chemistry concepts/issues, and positive attitudes towards online chemistry courses. Although previous studies have proposed structural models accounting for improvement in students' scientific inquiry learning performance, they have only discussed either individual or interpersonal variables, while few have considered both types of variables in a more holistic framework. Thus, the present study is one of a few to develop an encompassing conceptual model on the interaction between TESI and both interpersonal (perceived technology-assisted teacher support) and individual (hardiness) variables.

It is interesting to note that the feedback and concerns of authority figures in the education system form teachers' expectations and views, and this may not directly result in an increase in perceived TESI. The findings reveal students who receive more feedback from their teachers are likely to demonstrate higher TESI hardiness, which in turn facilitates their further involvement in innovative scientific inquiry. The current study confirmed that the extent to which students tended to be resilient and diligent in their scientific inquiry process mediates the relationship between their perceived technology-assisted teacher support and perceived TESI.

There are several possible cultural reasons that explain our mediational model. For example, feedback from teachers could activate students' sense of responsibility (Hwang, 1999). In Chinese culture, teachers not only encourage students to promote themselves by emphasising positivity, but also direct them towards unfinished aspects of their work to persuade them to try harder. Because of this, students who perceive more support from their teachers could be encouraged to regard stress or failure in scientific inquiry as advantageous growth.

In addition, Active Destructive responses of teacher support were positively correlated with both TESI hardiness and perceived TESI, which were equivalent to the effects of Active Constructive responses. With its emphasis on 'positivity', teacher support is likely to encourage students to work harder and endeavour to improve their performance, thereby promoting TESI. Therefore, it is likely that both Active Constructive and Active Destructive technology-assisted teacher support promotes hardiness, an in turn contribute to their perceived TESI in the Chinese cultural context.

Taken from the interview analysis, highly proficient students' perceived Active Destructive responses of teacher support mainly resulted from eliciting a sense of commitment (one construct of hardiness) for immediate action. The medium- and low-proficient students perceived Active Constructive responses of teacher support and gradually increased their hardiness levels for autonomy and needs satisfaction throughout the activity. In other words, perceived Active Destructive responses may elicit a gap between the initial commitment level and resulting actions for highly proficient students, and this may increase immediate action (e.g. 3.1 and 3.2), and in turn facilitate perceived TESI. Active Constructive responses boost students' hardiness through autonomy and needs satisfaction, and in turn result in an increase in TESI (e.g. 3.3). The evidence from the interviews suggests that the role of hardiness in inquiry learning is a critical factor in mediating the relations between perceived technology-assisted teacher support and perceived TESI.

Consequently, in Chinese culture, a multi-angle view of issues may play a greater role in promoting students' perceived TESI. It is interesting to note that through the mediating role of scientific academic hardiness, perceived technology-assisted teacher support can promote scientific inquiry in Chinese cultures. Thus, hardiness is essential for explaining the correlation between perceived technology-assisted teacher support and TESI.

Conclusions, implications, and limitations

This study examined the role of perceived technology-assisted teacher support and hardiness in TESI using both interpersonal and individual variables. The findings of this study have some important implications.

First, hardiness was introduced in the TESI context, and its importance to scientific inquiry was verified. The study's findings provide considerable insight into the hardiness attribute of Chinese students. It was demonstrated by the collected evidence that supportive interactions and feedback on individuals' attempts are meaningful when it comes to increasing hardiness (e.g. Creed et al., 2013; Kang et al., 2019). Commitment (i.e. one construct of hardiness) is the most significant factor in exerting a mediation effect, which implies that increasing learners' commitment to technology-assisted hardiness may improve their overall technology-enhanced scientific inquiry learning. Based on this finding, we encourage online instructors to combine various technology-enhanced scientific inquiry learning tools and focus on increasing their students' commitment level by implementing corresponding strategies. Students will thus become more engaged in the online learning environment. Educators should also focus on improving the quality of students' commitment during technology-supported learning by providing them with more opportunities for committed involvement in learning procedures (Hwang et al., 2012). The development of students' hardiness could result in the improvement of students' TESI performance.

Second, teachers should aim to create a supportive atmosphere and provide interactive feedback for cultivating students' TESI hardiness. As scientific inquiry and learning media have been digitised and web-based, more learners have expressed their concerns about creating a scientific inquiry environment with teachers' support and interactive feedback. Moreover, in order to foster TESI hardiness, teachers are supposed to create an atmosphere of encouragement and collaborative feedback. Growing evidence suggests that social support and feedback contribute to the enhancement of people's hardiness (e.g. Wang & Tsai, 2019; Creed et al., 2013). Thus, learners can expect to improve their TESI skills through fostering their hardiness. Compared to students with lower perceived technology-assisted teacher support, students who perceive more positive teacher responses may find it easier to develop innovative scientific inquiry skills through improved learning hardiness. Consequently, educators should take measures to strengthen students' hardiness, which is key to unlocking another possible mechanism for the correlation between perceived technology-assisted teacher support and perceived TESI.

Some limitations of this study, along with corresponding directions for future research, are also worth noting. First, other possible mediators or moderators that influence TESI practices remain to be addressed. For instance, the content of students' perceptions of their teachers, and their close classmates' responses in TESI practices, should be highlighted in interpreting this structural relationship. The present findings imply that future studies should pay more attention to the significant role of students' perception of teachers' responses in their TESI process instead of teachers' responses alone. Thus, exploring the interaction effects of students' perceptions of teacher support and their own learning hardiness on their TESI performance is a promising area for future research. The findings from our mediation model also hold implications for teachers. We proposed a structural model in the present study with the hope of proposing an analytical approach for future studies to explore the mechanism underlying the methods for forming and structuring TESI.

Second, it is recognised that self-reported survey results alone may not be applicable beyond the study context. We suggest that future studies discuss or examine the relationship and outcome of TESI practices via different types of data (questionnaires, interviews, student artefacts, or behaviours). To confirm the applications of our findings, future research should examine different additional sources of data, such as data from science communication content, qualitative data along with student artefacts or inquiry tasks, and interactive behaviour sequences.

Disclosure statement

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