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Taiwanese students' science learning self-efficacy and teacher and student science hardiness: a multilevel model approach

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Abstract This study aimed to investigate the factors accounting for science learning self-efficacy (the specific beliefs that people have in their ability to complete tasks in science learning) from both the teacher and the student levels. We thus propose a multilevel model to delineate its relationships with teacher and student science hardiness (i.e., the courage that is needed to turn stressful changes from burdens into advantageous growth in science education settings). The current research was conducted through collecting survey responses from both teachers (i.e., using the self-report teacher science hardiness questionnaire) and students (i.e., using the self-report student science hardiness and the self-report science learning self-efficacy questionnaires). A total of 45 Taiwanese science teachers were solicited from junior high schools. Also, we recruited students who were taught by these 45 teachers. In total, 1145 junior high school students whose ages ranged from 12 to 16, with a mean of 13.68 (SD = 0.90), were invited to take part in the study. Of these students, 268 were in the seventh grade, 430 were in the eighth grade, and 447 were in the ninth grade. The results of hierarchical linear modeling (HLM) confirmed our hypothesis that teacher science hardiness fostered student science hardiness, which in turn contributed to the students' science learning self-efficacy. The findings revealed that both teacher and student science hardiness play important roles in explaining the structure of science learning self-efficacy. To enhance science learning self-efficacy, educators should develop programs for teachers and students to increase their science hardiness.

Keywords Science learning self-efficacy · Teacher science hardiness · Student science hardiness · Commitment

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Introduction

To enhance student self-efficacy, educators and researchers are required to shed light on how it is constructed (Usher and Pajares 2008). However, with the growing investigation of the sources of self-efficacy (e.g., Chiou and Liang 2012; Kiran and Sungur 2012b; Palmer 2006), the mechanism underlying how self-efficacy is constructed remains unclear (Chiou and Liang 2012). Moreover, there is little research investigating the sources of self-efficacy considering both teacher and student factors or the mechanism of how teacher factors influence student factors (Kaya and Rice 2010; McNeill et al. 2013; Tran 2011). In addition, in previous studies (e.g., Hong and Lin 2011; Hong et al. 2012), Taiwanese junior high school adolescents have shown lower self-efficacy in learning science than elementary and senior high school students. Similarly, the results of the cross-cultural comparisons also revealed that Taiwanese eighth graders had lower science learning self-efficacy than their Singaporean counterparts (Lin et al. 2013). Accordingly, searching for its precursor factors and exploring the sources of science learning self-efficacy among both junior high school teachers and students in Taiwan demand immediate attention.

To achieve this goal, this study aimed to investigate the relationships among teacher science hardiness, student science hardiness, and science learning self-efficacy by proposing a multi-level model. Therefore, the current study was conducted in a science learning setting and adopted one teacher-level factor (i.e., teacher science hardiness) and one student-level factor (i.e., student science hardiness) to explore the multilevel relationships within the belief system of science learning self-efficacy.

Science learning self-efficacy and gender and grade level differences in science learning self-efficacy

Self-efficacy has been acknowledged as an important and comprehensive theory in accounting for people's learning behavior. It refers to the specific beliefs that people have in their ability to complete tasks or achieve goals and their expectations that certain behaviors will produce desirable outcomes (Bandura 1977, 1981). The former is called *personal efficacy*, while the latter is known as *outcome expectancy*.

Bandura (1977, 1981) further indicated that self-efficacy belief is a domain-specific rather than a global or universal construct. Researchers have recently applied this concept to specific learning settings such as science learning and have also developed relevant instruments investigating this conception in the field of science learning (Glynn et al. 2011; Thomas et al. 2008; Tuan et al. 2005). In addition, aiming for a more overarching framework, researchers have also attempted to develop multidimensional science learning self-efficacy instruments for high school and college students (e.g., Capa and Uzuntiryaki 2009; Lin and Tsai 2013; Uzuntiryaki and Capa 2009).

As for gender differences in self-efficacy, research has investigated gender differences in self-efficacy (e.g., Huang 2013; Junge and Dretzke 1995; Webb-Williams 2014; Weisgram and Bigler 2006). However, there are inconclusive findings as to whether male or female students display higher self-efficacy and this remains a topic of debate in the literature. For example, Huang (2013) conducted a meta-analysis of 187 studies on gender differences in academic self-efficacy. It was found that males exhibited higher mathematics, computer, and social sciences self-efficacy than females; however, females displayed higher language arts self-efficacy than males. Also, Webb-Williams (2014) conducted research among primary school students and found gender differences in self-efficacy, with the boys reporting a lower sense of self-efficacy than girls, coupled with lower performance. In addition, Junge and Dretzke (1995) investigated the mathematical self-efficacy gender differences of gifted adolescents. Their results indicated that males reported higher self-efficacy than females on more than one fourth of the items, whereas females had stronger self-efficacy only on stereotypical female activities. Nevertheless, research also found no gender difference concerning science self-efficacy (Kiran and Sungur 2012a) or mathematics self-efficacy (Goodwin et al. 2009).

As for the grade level differences in science learning self-efficacy (SLSE), previous research revealed that students' self-efficacy decreases as their grade level increases (Diseth et al. 2014; Güngören and Sungur 2009; Güvercin 2008). For example, Güngören and Sungur (2009) investigated students' self-efficacy for the subject of science and explored grade level differences in students' self-efficacy. It was found that sixth graders outperformed seventh graders and eighth graders. Also, Diseth et al.'s (2014) research suggested similar findings that the sixth graders' self-efficacy surpassed that of the eighth graders. Therefore, student grade level may be one of the important factors in explaining the sources of SLSE.

In this regard, since we aimed to investigate the mediational relationships among teacher science hardiness, student science hardiness, and science learning self-efficacy, we expected to control for possible confounders. Together, based on the previous research findings, we included the gender factor from both the teacher and student sides and student grade levels in the current model to rule out the effect of potential confounding variables.

Academic hardiness

Academic hardiness has been defined as the courage and motivation that are needed to turn stressful changes from burdens and disasters into advantageous growth in academic settings (Benishek et al. 2005; Benishek and Lopez 2001; Creed et al. 2013; Kamtsios and Karagiannopoulou 2013). In addition, hardiness is comprised of three cognitive appraisal processes, called the three Cs: commitment, challenge, and control. *Commitment* refers to the individual's tendency to be involved, to have a sense of purpose, and to find meaning in life. *Challenge* means the perception that change is an expected part of life, which is necessary for personal achievement. *Control* is the perception that individuals are able to achieve personal goals through effort and emotional self-regulation.

Most previous studies averaged the scores across the 3 Cs of commitment, control, and challenge to form a hardiness composite (Maddi et al. 2012), rather than adopting dimensional scores. Following the tradition of using a hardiness composite, a great deal of the research on academic hardiness has investigated its relationships with academic self-efficacy. For example, Maddi et al. (2009) found a higher degree of hardiness associated with academic self-efficacy. Similar results were found in the research of Benishek and Lopez (2001), who found positive relationships between academic hardiness and perceptions of academic self-worth.

In the current research, we adopted the commitment dimension to represent hardiness instead of the three dimensions as a hardiness composite. The reasons are twofold. First, we only used the commitment dimension because the nature of commitment is more appropriate for explaining teacher-student interactions in a multilevel study. According to Maddi (2013), no matter how bad things get, people with commitment tend to stay involved with whatever is happening, rather than sink into detachment and alienation. In addition, they tend to share their effort and learning in a supportive way with the significant others and institutions in their lives. That is, the commitment dimension, compared to the other dimensions, is more related to how people get involved and how they interact with the other people, things, and events around them. In the current research, we aim to explore the sources of self-efficacy from both teacher and student perspectives or, in other words, the mechanism of how teacher factors influence student factors. Therefore, the commitment dimension is more fit for the purpose of the study. Second, based on the previous findings, there was a stronger relationship between academic performance and commitment than there was between academic performance and either challenge or control (Sheard 2009; Sheard and Golby 2007). In Sheard's (2009) research, commitment was the most significant positive correlate of academic performance. Commitment significantly predicted the final degree GPA and the dissertation grade. In addition, Gill and Harris (1991) found that the best predictor of depressive symptoms was the commitment factor.

Together, to better understand the nature of hardiness in teacher-student study and also to enhance the parsimony of the current model, this current research only employed the commitment factor as the predictor of science learning self-efficacy.

A multilevel model of science learning self-efficacy based on teacher science hardiness and student science hardiness

Researchers have widely explored the sources of SLSE (e.g., Chiou and Liang 2012; Lin et al. 2013; Tsai et al. 2011). For example, Chiou and Liang (2012) also investigated the sources of science self-efficacy, examining the relationships among Taiwanese high school students' science self-efficacy, conceptions of learning science, and approaches to learning science. The results displayed that the students' conceptions of learning science had significant influences on their approaches to learning science, which in turn predicted their science self-efficacy. Obviously, it can be seen that the mechanism of how self-efficacy is constructed has attracted much attention.

However, most of the previous studies have focused on the student factors (e.g., Chiou and Liang 2012; Tsai et al. 2011) whereas few have highlighted both the teacher and student factors when it comes to exploring the sources of self-efficacy. Since Bandura (1977) suggested that the major factors accounting for self-efficacy are intra- and interpersonal experiences, in the current study, we adopted both intra- and interpersonal factors (student science hardiness and teacher science hardiness, respectively) by proposing a multilevel model to account for the sources of self-efficacy. We address the roles of these two factors as follows.

First, student science hardiness plays an important role in science learning self-efficacy. A considerable amount of research on academic hardiness has investigated its effect on academic self-evaluations. For example, Maddi et al. (2009) indicated a higher degree of hardiness associated with higher-level academic self-efficacy. Similarly, Benishek and Lopez (2001) found positive relationships between academic hardiness and perceptions of academic self-worth. However, some research has found that the effects are more salient for the commitment factor. For example, Sheard and Golby (2007) and Sheard (2009) found stronger relationships for commitment than for challenge or control. Together, based on the previous findings, the current research therefore predicts a positive correlation between student science hardiness and science learning self-efficacy.

Second, the factors from the teacher side may also have an influence on students' self-efficacy and learning performance. Historically, the role of the teacher has been overlooked when researchers have investigated the topic of student learning or student adjustment in school (Ball and Cohen 1996; McNeill et al. 2013; Troop-Gordon 2015; Yoon and Bauman 2014). However, the teacher factors are essential in examining student learning and performance in the classroom. No single student factor could influence student learning without considering the teacher and environment factors. The teaching methods, teaching experience, teacher personality, and the culture and atmosphere of the classroom may also impact students' development of conceptual understanding and learning performance (Ball and Cohen 1996; McNeill et al. 2013; Puntambekar et al. 2007). In this research, since teachers' number of years of experience might lead to students' motivation and performance, which we do not expect to highlight here, we included teaching experience in the current model as a control variable to rule out its effect as a potential confounder.

As for the effect of teacher characteristics on classroom or student outcomes in science education settings, Forbes and Davis (2010) indicated that teacher characteristics, such as the teacher's views of science, may influence the way in which teachers implement curricula in their classrooms, which in turn will have an impact on student learning. Also, Gibbs and Coffey (2004) found that a teacher's approach to teaching has been shown to be related to the students' approach to studying. However, few studies have explored how teacher science hardiness influences student science hardiness and science learning self-efficacy. The current research therefore aims to fill the research gap using a multilevel approach.

In addition, Bandura (1977) proposed that individuals acquire self-efficacy from the following four sources: *past performance*, an experience of their previous success or failure; *vicarious experiences*, an observation of others' accomplishments; *verbal persuasion*, others' encouragements of one's abilities; and *physiological cues*, one's emotional or physical states. Of these sources, it can be seen that social support and feedback as well as emotional state play important roles in fostering self-efficacy. In the current research, teacher science hardiness could be regarded as an interpersonal factor related to teachers which explains the sources of self-efficacy.

A hypothetical model

Based on the aforementioned literature review, a hypothetical model suggests that students' science learning self-efficacy is influenced not only by student science hardiness but also by teacher science hardiness. Moreover, student gender, student grade level, teacher gender, and teaching experience were included in the current model as the control variables. Together, based on what we inferred above, we hypothesized a cross-level mediational model in the sense that the relationship between teacher science hardiness and students' science learning self-efficacy may be mediated by student science hardiness. That is, teacher science hardiness may facilitate student science hardiness, which may in turn contribute to the students' science learning self-efficacy.

Method

Participants

A total of eight junior high schools were stratified into three demographic areas: Northern, Central, and Southern Taiwan. From these eight junior high schools, a total of 45 Taiwanese science teachers (57.8 % females) were solicited by convenience sampling. The teachers' ages ranged from 26 to 53, with a mean of 39.89 (SD = 7.03), and the number of years of teaching experience ranged from 1 to 31, with a mean of 14.67 (SD = 7.73).

Also, students who were taught by the 45 teachers introduced above were randomly invited to participate in the study. The number of students per teacher ranged from 16 to 32, with a mean of 25. In total, 1145 students (50.4 % females) whose ages ranged from 12 to 16 were included, with a mean of 13.68 (SD = 0.90). Of these students, 268 were in the seventh grade, 430 were in the eighth grade, and 447 were in the ninth grade.

Measures

Student-level measures

Student science hardiness The self-report student science hardiness measure, which was modeled after the original academic hardiness scale developed by Creed et al. (2013), measures students' resilience and capacity to manage and survive during periods of stress and failure in science learning. All items were modified to include a science learning setting. The translated version consists of three factors: commitment, challenge, and control. Of these factors, the current research only adopted the subscale of commitment due to its stronger associations with student learning (Sheard 2009; Sheard and Golby 2007). We made this decision also based on the psychometric properties of the commitment subscale. In this study, there was a higher correlation between the commitment dimension and the total scale ($r = 0.80$, $p < 0.001$) than there was between the challenge dimension and the total scale ($r = 0.58$, $p < 0.001$) as well as between the control dimension and the total scale ($r = 0.47$, $p < 0.001$).

The commitment factor refers to students' tendency to be involved, to have a sense of purpose, and to find meaning in science learning. Each item was presented in a five-point Likert mode, anchored at 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree. In addition, the internal consistency reliability coefficient (Cronbach's alpha) was 0.89 for 7 items. The expert validity tested for this measure showed the appropriateness of the content, suggesting that these factors had highly sufficient reliability and validity in assessing student science hardiness (see Appendix 1 for the student science hardiness questionnaire).

Science learning self-efficacy The self-report science learning self-efficacy (SLSE) measure, which was developed by Lin and Tsai (2013), aims to operationalize students' self-efficacy while learning science. In the current research, we adopted this measure to assess students' science learning self-efficacy due to its comprehensiveness. Also, the SLSE instrument has been proved to have satisfactory validity and reliability for measuring Taiwanese and Singaporean student populations (Lin et al. 2013; Lin and Tsai 2013).

SLSE features multidimensional assessments, consisting of five dimensions: (1) conceptual understanding (CU), which measures students' confidence in their ability to use cognitive skills in understanding the definitions of science concepts, laws, and theories; (2) higher-order cognitive skills (HCSs), which operationalizes students' confidence in their ability to employ more complex skills; (3) practical work (PW), which assesses students' confidence in their ability to accomplish laboratory activities included in both the cognitive and psychomotor domains; (4) everyday application (EA), which evaluates students' confidence in their ability to apply science concepts and skills to everyday events; and (5) science communication (SC), which addresses students' confidence in their ability to communicate or discuss with others.

Each item was presented in a five-point Likert mode, anchored at 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree. In addition, the internal consistency reliability coefficient (Cronbach's alpha) was 0.97 for 30 items. A confirmatory factor analysis was also conducted to analyze the construct validity and the structure of the SLSE questionnaire. With respect to the goodness of fit of the model, the fitness indices of the measured items (GFI = 0.89, AGFI = 0.87, RMSEA = 0.06) indicated a good model fit (Hair et al. 2006). It was suggested that these factors had highly sufficient reliability and validity in assessing science learning self-efficacy (see Appendix 2 for the science learning self-efficacy questionnaire).

Teacher-level measure

Teacher science hardiness The self-report teacher science hardiness measure, which was modeled after the original academic hardiness scale developed by Creed et al. (2013), measures teachers' resilience and capacity to manage and survive during periods of stress and failure in science teaching. All items were modified to include a science teaching setting. The translated version consists of three factors: commitment, challenge, and control. Of these factors, the current research only adopted the subscale of commitment due to its stronger associations with student learning (Sheard 2009; Sheard and Golby 2007). The commitment factor refers to teachers' tendency to be involved, to have a sense of purpose, and to find meaning in science teaching. Each item was presented in a five-point Likert mode, anchored at 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree. In addition, the internal consistency reliability coefficient (Cronbach's alpha) was 0.70 for 7 items. The expert validity tested for this measure showed the appropriateness of the content, suggesting that these factors had highly sufficient reliability and validity in assessing teacher science hardiness (see Appendix 3 for the teacher science hardiness questionnaire).

Analysis strategy and model descriptions

Due to the nature of our data structure, we analyzed the data using a hierarchical linear modeling (HLM, Raudenbush and Bryk 2002) framework. The program and version used in this study is the student edition of HLM7. HLM is appropriate in this situation because it enables an examination of how the indicators at the teacher level shed light on the relationships between the variables at the student level. The HLM approach also allows us to account for the non-independence of student-level measures from each group (i.e., each class).

We included the number of years of teaching experience and the school grade of the students as the control variables in the current model. Since student grade level is an ordinal variable and we further expected to see differences among the three groups, we constructed contrast coding to represent two sets of comparisons. According to the results of mean comparisons of student science hardiness and SLSE shown in Table 2, seventh graders and eighth graders did not significantly differ in terms of their science hardiness and SLSE. However, seventh graders showed higher science hardiness than ninth graders. Also, seventh graders and eighth graders displayed higher SLSE than ninth graders. Therefore, the first code we used was to compare seventh graders and eighth graders versus ninth graders (coded as 1, 1, -2) and the other was to compare seventh graders and eighth graders (coded as 1, -1, 0). Together, we regressed teacher science hardiness and student science hardiness on the SLSE after controlling for student gender, grades 7 and 8 versus 9, grade 7 versus 8, teacher gender, and teaching experience.

The level 1 equation used to explain science learning self-efficacy (Y) is

$$Yij = \beta 0j + \beta 1j(\text{student gender}) + \beta 2j(\text{grade 7 and 8 vs. 9}) + \beta 3j(\text{grade 7 vs. 8}) + \beta 4j(\text{student science hardiness}) + \varepsilon ij$$

The level 2 equations are

$$\beta 0j = \gamma 00 + \gamma 01(\text{teacher gender}) + \gamma 02(\text{teaching experience}) + \gamma 03(\text{teacher science hardiness}) + \gamma 04(\text{student science hardiness\_}M) + \mu 0j$$
$$\beta 1j = \gamma 10$$
$$\beta 2j = \gamma 20$$
$$\beta 3j = \gamma 30$$
$$\beta 4j = \gamma 40$$

In HLM, variables at the lowest level of the hierarchy (i.e., level 1) are nested within the higher-level (i.e., level 2) groups and shared in common the impact of level 2 variables. For example, students in a classroom share variance according to their common classroom and common teacher (Woltman et al. 2012). For this model, level 1 is the student level which comprises students' measures: the control variable (student gender, grades 7 and 8 vs. 9, and grade 7 vs. 8) and the mediator (student science hardiness). Level 2 is the teacher level which comprises teachers' measures: the control variable (teacher gender, teaching experience, student science hardiness_*M*) and the predictor (teacher science hardiness). For 2-1-1 models, which means those models involving a predictor in level 2, a mediator in level 1, and an outcome variable in level 1, Zhang et al. (2009) recommended the method—CWC(*M*)—to differentiate within-group versus between-group effects in a multilevel setting. This means that the variables in level 1 are required to be centered around their group means, and the subtracted means are reintroduced at level 2. Since the current study adopts a 2-1-1 model, the mediator in level 1 was thus CWC(*M*). This mediator was centered around the group mean, and the subtracted means (student science hardiness_*M*) were reintroduced at level 2. Both level 1 slopes are fixed.

In addition, in order to examine the mediational effects in the current research, we followed Baron and Kenny (1986) and Kenny et al.'s (1998) suggestions and conducted regression analyses of which several were tested and the significance of the coefficients was examined in each step.

Results

Preliminary analysis

Table 1 lists the means, standard deviations, and correlations for the major variables. As shown in Table 1, student grade (codes for grades 7 and 8 vs. 9 as grade 7 = 1, grade 8 = 1, and grade 9 = -2) was positively correlated with student science hardiness ($r = 0.08$, $p < 0.01$) and with SLSE ($r = 0.15$, $p < 0.01$), meaning that students in the ninth grade tended to report lower science hardiness and SLSE than students in the seventh and eighth grades. In addition, student gender (female = 1 and male = 0) was positively correlated with student science hardiness ($r = 0.17$, $p < 0.001$) but was negatively correlated with SLSE ($r = -0.06$, $p < 0.05$), indicating that female students showed higher science hardiness but lower SLSE as compared to their male counterparts. Also, student science hardiness and SLSE were positively correlated ($r = 0.49$, $p < 0.01$), indicating that students with higher science hardiness displayed higher self-efficacy in science learning.

As for the internal consistency for the scales used in the current study, the reliability coefficients were 0.89 for student science hardiness, 0.97 for SLSE, and 0.70 for teacher science hardiness, suggesting that these instruments are reliable for evaluating student science hardiness, SLSE, and teacher science hardiness.

Mean comparisons of student science hardiness and SLSE among student grade groups

To examine whether students differ in their science hardiness and SLSE based on different grade levels, the one-way (grade level) ANOVA with Tukey's post hoc honest significant difference (HSD) tests was conducted. Table 2 shows the results of the mean comparisons of student science hardiness and SLSE among student grade groups. As seen in Table 2, the results yielded significant effects on student science hardiness (F (2, 1142) = 4.64, $p < 0.05$) as well as on SLSE (F (2, 1142) = 13.34, $p <$ 0.001). The results of Tukey's post hoc HSD analyses further indicated where the differences occurred among groups. For the effects on student science hardiness, the students in the seventh grade outperformed those in the ninth grade. In addition, for the effects on SLSE, the scores of students in the seventh grade surpassed those of students in the ninth grade and the scores of students in the eighth grade were also higher than those of students in the ninth grade. Furthermore, the values calculated for effect size (e.g., Cohen's d) were generally small to medium, ranging from 0.23 to 0.32 ($d = 0.2$ as small effect size; $d = 0.5$ as a medium effect size; $d = 0.8$ as a large medium effect).

Table 1 Descriptive statistics and correlations among main factors

	Descriptive statistics		Correlations							
	Mean	SD	1	2	3	4	5	6	7	8
Level 1: student level										
1. Grade level (7 and 8 vs. 9)	−0.17	1.46	–							
2. Grade level (7 vs. 8)	−0.14	0.77	−0.15**	–						
3. Student gender	0.50	0.50	−0.02	0.01	–					
4. Student science hardiness	3.58	0.75	0.08**	0.03	0.17***	–				
5. SLSE	2.94	0.77	0.15**	−0.02	−0.06*	0.49**	–			
Level 2: teacher level										
6. Teaching experience	14.67	7.73						–		
7. Teacher gender	0.58	0.50						−0.23	–	
8. Teacher science hardiness	4.40	0.37						0.08	−0.11	–

No. of teachers = 45; no. of students = 1145

SLSE science learning self-efficacy

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table 2 Mean comparisons of student science hardiness and SLSE among three grade groups

	Student science hardiness			SLSE		
	Group mean (SD)	*F*	*df*	Group mean (SD)	*F*	*df*
ANOVA						
Grade level						
7 ($N = 268$)	3.68 (0.72)	4.64*	2	3.04 (0.73)	13.34***	2
8 ($N = 430$)	3.60 (0.73)			3.03 (0.75)		
9 ($N = 447$)	3.51 (0.77)			2.80 (0.78)		
Error			1142			1142
Total			1144			1144
	Mean difference		Cohen's *d*	Mean difference		Cohen's *d*
Tukey's post hoc test						
Grade 7 vs. grade 8	0.08			0.01		
Grade 7 vs. grade 9	0.17*	G7 > G9	0.23	0.24*	G7 > G9	0.32
Grade 8 vs. grade 9	0.09			0.23*	G8 > G9	0.30

*$p < 0.05$; ***$p < 0.001$

Multilevel mediational effects

Our hypothesis stated that teacher science hardiness may facilitate student science hardiness, which would then lead to a higher degree of science learning self-efficacy. As per the aforementioned models, to test the hypotheses of mediational effect, we conducted two regression analyses, as follows:

In analysis 1, use *M* (level 1: student science hardiness) as the criterion variable in a regression equation and *X* (level 2: teacher science hardiness) as the predictor and, in analysis 2, use *Y* (science learning self-efficacy) as the criterion variable in a regression equation and *X* (teacher science hardiness) and *M* (student science hardiness) as predictors. The results of analysis 1 and analysis 2 are explained as follows.

Analysis 1: teacher science hardiness predicting the mediator

We regressed the control variables (student gender, grades 7 and 8 vs. 9, grade 7 vs. 8, teacher gender, and teaching experience) and teacher science hardiness on the mediator (student science hardiness) using HLM. The results are shown in Table 3. The control variables were entered in step 1 and teacher science hardiness in step 2.

The results revealed the expected and significant effect of teacher science hardiness after controlling for all control variables ($\beta = 0.21$, $p < 0.05$). The findings suggest that teacher science hardiness leads to student science hardiness.

Analysis 2: cross-level mediational effects

To test the hypotheses of mediational effect, we regressed the control variables, teacher science hardiness, and student science hardiness on science learning self-efficacy through HLM. The results are shown in Table 4. The control variables were entered in step 1, teacher science hardiness in step 2, and student science hardiness in step 3.

Table 3 HLM analysis of teacher science hardiness predicting the mediator (student science hardiness)

Variables	Student science hardiness b (SE)	
	Model a	Model b
Level 1		
Student gender	0.27 (0.04)***	0.27 (0.04)***
Grade level (7 and 8 vs. 9)	0.05 (0.02)*	0.05 (0.02)*
Grade level (7 vs. 8)	0.03 (0.04)	0.03 (0.03)
Level 2		
Teacher gender	0.07 (0.07)	0.08 (0.06)
Teaching experience	−0.00 (0.00)	−0.00 (0.01)
Teacher science hardiness		0.21 (0.08)*

No. of teachers = 45; no. of students = 1145

*$p < 0.05$; ***$p < 0.001$

The results listed in Table 4 and in Fig. 1 support the hypothesis. The coefficient for the direct relationship between teacher science hardiness and science learning self-efficacy ranges from a significant 0.13 ($p < 0.05$) to 0.04 (ns) after accounting for the effects of student science hardiness ($\beta = 0.52$, $p < 0.001$). Also, the results of the Sobel test (*Sobel test* = 2.60, $p < 0.01$) suggest the significance of a mediational effect. Together, significantly correlated regression 1 (relationship between X and M), regression 2 (the relationship between M and Y), and the Sobel test establish the mediation (Kenny et al. 1998).

Discussion

This study was conducted to investigate the factors accounting for science learning self-efficacy and proposed a multilevel relationship among teacher science hardiness, student science hardiness, and science learning self-efficacy using a hierarchical linear modeling technique. The current research generated several key findings as follows.

First, gender differences in SLSE were found in this study. The results revealed that female students reported a lower sense of SLSE as compared to their male counterparts. The results are consistent with previous research findings. For instance, Huang's (2013) research indicated that males exhibited higher mathematics, computer, and social sciences self-efficacy than females; however, females displayed higher language arts self-efficacy than males. Research investigating gifted adolescences also indicated that males reported higher self-efficacy than females on more than one quarter of the items, whereas females had stronger self-efficacy only on stereotypical female activities (Junge and Dretzke 1995). These aforementioned findings may suggest that males, as compared with females, display a higher sense of self-efficacy for subjects related to science. However, several studies made different findings and indicated that males reported a lower sense of self-efficacy than females did (e.g., Webb-Williams 2014). Some studies, on the other hand, found no gender difference concerning science self-efficacy (Kiran and Sungur 2012a) or mathematics self-efficacy (Goodwin et al. 2009). Therefore, there are inconclusive findings on this topic, which remains a topic of debate in the literature.

Table 4 HLM analysis of teacher science hardiness and student science hardiness predicting science learning self-efficacy

Variables	Science learning self-efficacy b (SE)		
	Model a	Model b	Model c
Level 1			
Student gender	−0.09 (0.04)*	−0.08 (0.04)*	−0.23 (0.04)***
Grade level (7 and 8 vs. 9)	0.08 (0.02)***	0.08 (0.02)***	0.06 (0.02)**
Grade level (7 vs. 8)	−0.01 (0.03)	−0.01 (0.03)	−0.02 (0.03)
Student science hardiness			0.52 (0.03)***
Level 2			
Teacher gender	0.10 (0.05)†	0.11 (0.05)*	0.07 (0.04)
Teaching experience	−0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)
Teacher science hardiness		0.13 (0.05)*	0.04 (0.06)
Student science hardiness_*M*			0.44 (0.13)***

Student science hardiness was centered around the group mean and reintroduced the subtracted mean at level 2 (CWC(*M*)). No. of teachers = 45; no. of students = 1145

† $p < 0.10$; *** $p < 0.001$

Second, the results revealed significant grade level differences in student science hardiness and SLSE. For the differences in student science hardiness, the seventh graders outperformed the ninth graders. In addition, as for the differences in SLSE, the scores of the seventh graders surpassed those of the ninth graders and the scores of the eighth graders were also higher than those of the ninth graders. The current results are comparable with the findings in the related literature. For example, Güvercin (2008) investigated elementary students' motivation for science learning and found that sixth grade students' self-efficacy scores were higher than those of eighth grade students. In addition, Güngören and Sungur (2009) observed grade level differences in self-efficacy for the subject of science and found higher levels of self-efficacy among sixth graders than among seventh graders and eighth graders. Also, Gocer et al. (2011) found that as grade level increased, students' motivational traits in science became less positive. Similarly, Diseth et al. (2014) investigated the relation between self-esteem, self-efficacy and implicit theories of intelligence in a sample of sixth grade and eighth grade Norwegian students. It was found that the sixth graders' self-efficacy outperformed that of the eighth graders. These results all suggested that students' self-efficacy decreases as their grade level increases. Researchers have suggested that these results can be explained by reduced

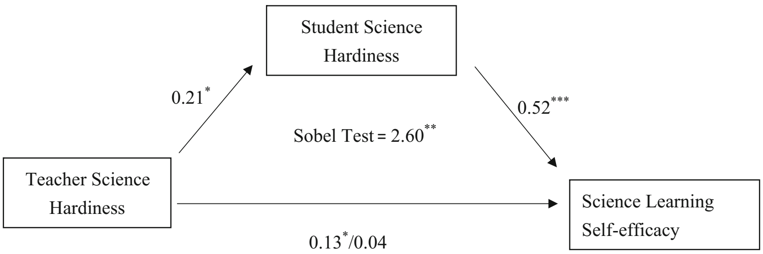

Fig. 1 The mediational effects of student science hardiness between teacher science hardiness and science learning self-efficacy

student autonomy and increased school control over the learning, thus leading to students' shift from task-focused vision to performance-focused vision (Lepper et al. 2005). In addition to the abovementioned reasons, the current results concerning the decrease in hardiness and self-efficacy across grade levels can be attributed to the Taiwanese educational system which is highly competitive and examination oriented. Ninth graders' lowest self-efficacy can probably be explained by the pressure exerted by the nationwide examination for ninth graders.

Considering the observed gender differences (girls with lower levels of SLSE) and grade level differences (ninth graders with lower sense of SLSE and of student science hardiness), the current research provides two implications for teachers' action with girls and ninth graders. First of all, to reshape and enhance girls' SLSE, teachers are supposed to avoid the hidden curriculum, where students are probably learned with gender inequalities. In secondary school settings, knowledge, values, and beliefs may be developed or gained with a negative connotation by educating students to implement different duties according to their gender roles. In this regard, educators could introduce more successful female scientists with their profiles or stories to convey the notion that girls are able to perform as well as boys do in terms of science. Second, since the current results regarding the ninth graders' lowest sense of hardiness and self-efficacy can be attributed to the Taiwanese educational system which is highly competitive and examination oriented, more adaptive instruction and multiple ways of assessments are recommended for future educational settings. For example, educators could develop a variety of instructional and assessment strategies according to the needs of different learners.

Last but not least, the main results revealed a multilevel mediational model, indicating that teacher science hardiness positively predicted student science hardiness, which in turn fostered science learning self-efficacy. Based on the findings of the current study, it is suggested that both the interpersonal factor (teacher science hardiness) and the intrapersonal factor (student science hardiness) are crucial in explaining the mechanism underlying how science learning self-efficacy is constructed.

The current results are consistent with the previous findings. For example, Benishek and Lopez (2001) found positive relationships between academic hardiness and perceptions of academic self-worth. In addition, Maddi et al. (2009) indicated that higher-level hardiness was correlated with a higher degree of academic self-efficacy. Furthermore, some research has found that the relationships between hardiness and self-efficacy are more salient if the commitment factor is adopted (Sheard 2009; Sheard and Golby 2007). However, although Sheard and Golby (2007) and Sheard (2009) indicated the positive correlations between hardiness commitment and science learning self-efficacy, consistent with the findings in the current research, they did not integrate both intra- and interpersonal factors into a more comprehensive framework. In this regard, the current research attempted to investigate the structures of science learning self-efficacy based on teacher science hardiness (the interpersonal factor) and student science hardiness (the intrapersonal factor) and was one of this study's contributions. Therefore, empirical data from teachers are expected to be included in a comprehensive framework for exploring teacher-student relationships or student learning performance. Future research investigating student learning should collect data from both teacher and student populations and further investigate how teacher factors influence student factors.

The findings of our cross-level mediational model in this study could provide suggestions for teachers. First of all, to promote students' science learning self-efficacy, student science hardiness should be developed. Furthermore, to foster student science hardiness, teachers are required to be equipped with higher-level teacher science hardiness. Accumulating evidence has shown that socially supportive interactions and feedback from individuals' efforts are effective in promoting hardiness attitudes (e.g., Khoshaba and Maddi 2001; Maddi 1987). Teachers with higher-degree teacher science hardiness may be more supportive of their students; thereby, students could perceive more positive interaction and thus strengthen their hardiness attitudes. Increasing hardiness attitudes accounts for much of the increase in students' science learning self-efficacy. Accordingly, both teacher and student hardiness play key roles in investigating the sources of science learning self-efficacy, so educators should develop programs for teachers and students to increase their hardiness.

Although no effort was spared to explore the effects described above, the results should be interpreted with caution. We list the study's limitations along with corresponding future research directions as follows.

First, there may be other mechanisms (i.e., other mediators or moderators) that can explain the sources of science learning self-efficacy. It is likely that the mediational relationship found in this study does not exist in some specific situations, and given that, exploring these boundary conditions is inevitably crucial for future research.

Second, it is difficult to perform a confirmatory factor analysis (CFA) to verify the construct validity of teacher science hardiness and student science hardiness instruments. The limitation of the study was due to the relatively small sample size for teachers ($N = 45$). Also, the current research only adopted the subscale of commitment so that the fit indices of the model did not indicate a good model fit.

Third, because this study examined participants using a single questionnaire design, its conclusions should be limited to this particular situation. Future research should collect data through interviews or actual interactions using longitudinal methods.

Finally, the current research did not collect data from students' real performance (e.g., academic scores). Since science hardiness and SLSE are probably factors influencing students' real performance, a possible future direction is to include the factors of students' real performance to complete the picture.

Appendix

Appendix 1: items of the student science hardiness questionnaire

1. I take my work as a student seriously.
2. I am a dedicated student
3. I work hard for grades.
4. I am involved in all my classes.
5. Regardless of the class, I do my best.
6. I make personal sacrifices to get good grades.
7. Grades aren't important to me.

Appendix 2: items of the SLSE questionnaire

1. I can explain scientific laws and theories to others.
2. I can choose an appropriate formula to solve a science problem.

3. I can link the contents among different science subjects (for example biology, chemistry and physics) and establish the relationships between them.
4. I know the definitions of basic scientific concepts (for example, gravity, photosynthesis, etc.) very well.
5. I am able to read scientific figures and tables.
6. I am able to critically evaluate the solutions of scientific problems.
7. I am able to design scientific experiments to verify my hypotheses.
8. I am able to propose many viable solutions to solve a science problem.
9. When I come across a science problem, I will actively think over it first and devise a strategy to solve it.
10. I am able to make systematic observations and inquiries based on a specific science concept or scientific phenomenon.
11. When I am exploring a scientific phenomenon, I am able to observe its changing process and think of possible reasons behind it.
12. I know how to carry out experimental procedures in the science laboratory.
13. I know how to use equipment (for example measuring cylinders, measuring scales, etc.) in the science laboratory.
14. I am able to read data from scientific experiments.
15. I know how to set up equipment for laboratory experiments.
16. I know how to collect data during the science laboratory.
17. I am able to explain everyday life using scientific theories.
18. I am able to propose solutions to everyday problems using science.
19. I can understand the news/documentaries I watch on television related to science.
20. I can recognize the careers related to science.
21. I am able to apply what I have learned in school science to daily life.
22. I am able to use scientific methods to solve problems in everyday life.
23. I can understand and interpret social issues related to science (for example nuclear power usage and genetically modified foods) in a scientific manner.
24. I am aware that a variety of phenomena in daily life involve science-related concepts.
25. I am able to comment on presentations made by my classmates in science class.
26. I am able to use what I have learned in science classes to discuss with others.
27. I am able to clearly explain what I have learned to others.
28. I feel comfortable discussing science content with my classmates.
29. In science classes, I can clearly express my own opinions.
30. In science classes, I can express my ideas properly.

Appendix 3: items of the teacher science hardiness questionnaire

1. I take my work as a teacher seriously.
2. I am a dedicated teacher.
3. I work hard on my teaching.
4. I am involved in all of the classes I teach.
5. Regardless of the class, I do my best.
6. I make personal sacrifices to teach well.
7. Teaching well is as important to me as it is to my parents.

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