科技部補助專題研究計畫報告

臺灣高中生之科學學習投入研究：兼探科學知識觀信念與科學學習自我效能(第2年)

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本研究具有政策應用參考價值：■否 □是，建議提供機關
（勾選「是」者，請列舉建議可提供施政參考之業務主管機關）
本研究具影響公共利益之重大發現：□否 □是

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中 文 摘 要 ： 本研究計畫之成果主要可以分成四個部分，均以「科學學習投入」為主軸，探討可能的影響因素與關係。第一部分的研究成果主要探討280位臺灣高中學生對於「求知」知識觀信念與其科學學習投入之關係。藉由開發「科學學習投入問卷」工具與「科學求知信念」工具，藉以了解五個重要的科學學習投入面向（認知投入、行為投入、情緒投入、主體投入、社交投入）與科學求知信念（知識多元性、求知的辯證與求知的目的）之間的關係。主要研究結果指出「求知的目的」能夠正向預測五個科學學習投入面向，是相當重要的影響因素；另外，「求知的辯證」亦能夠正向預測學生的認知、情緒與社交投入。第二部分的研究成果主要了解326臺灣高中學生的科學學習自我效能與科學學習投入之間的關係，藉由第一部份效化過後的「科學學習投入問卷」與計畫主持人先前開發的多面向「科學學習自我效能問卷」探求此兩構念。研究結果發現，若要有效提昇學生的科學學習投入狀況，促進其不同面向的科學學習自我效能是相當重要的第一步。第三部分的研究成果主要深入了解631位臺灣高中學生的科學知識觀信念樣貌情形，找出不同的知識觀屬性類別，並進一步比較不同類別之間在科學學習投入的情形。主要研究結果指出，這些學生的科學知識觀可以分成：類型一「高不確定性但低目標性」、類型二「成熟但高確定性」與類型三「不成熟」。進一步比較這些類型在科學學習投入的面向可以得知，在認知投入面向，類型二展現出最高的認知投入、其次是類型一，而類型三為最低；但是在其他面向（行為投入、情緒投入、主體投入、社交投入），類型二均是最高分且顯著高於類型一與類型三，但值得注意的是，類型一與類型三在這些面向皆無顯著差異。第四部分的研究成果主要了解726臺灣國小學生的科學學習投入面向，並探討性別在這些面向上與結構關係組成是否有所差異。主要研究結果顯示，這些國小學生在五個科學學習投入面向的分數均無顯著差異。在結構關係的部分，以認知投入與情緒投入當作前因，其他面向認知投入當作結果，發現男女生的結構關係上非常相似。然而，男生在科學學習投入面向之結構關係上，情緒投入比起女生更能預測其行為投入。

中 文 關 鍵 詞 ： 科學學習投入、科學學習自我效能、科學知識觀信念

英 文 摘 要 ： The results of this research project contain four studies. The first study (study 1) was to initially understand the relationships between 280 Taiwanese senior high school students’ epistemic views about the nature of knowing and their science learning engagement. In particular, in order to capture multiple forms of science learning engagement, a newly-developed instrument named “Science Learning Engagement Instrument (SLEI)” were used to assess the students’ five categorical dimensions of engagement, including Cognitive engagement, Behavioral engagement, Emotional engagement, Social engagement, and Agentic engagement. The main findings indicated that the SLEI is valid and reliable to assess the Taiwanese five forms of science learning engagement. Besides, the Purpose of

knowing dimension is a positively significant predictor across all the five SLEI dimensions. In addition, the predictive effects of the Justification for knowing were only found in Cognitive engagement, Emotional engagement, and Social engagement. Furthermore, the main purpose of study 2 was to initially explore the relations between 326 senior high school students' science learning self-efficacy and engagement from a multi-dimensional perspective. Furthermore, this study also aims to differentiate the predictive powers of multi-faceted science learning self-efficacy on various forms of science learning engagement. By adopting two well-established survey instruments concerning science learning engagement and self-efficacy, this study provided evidence that to deeply engage learners in science learning, promoting their science learning self-efficacy from various aspects is of great importance. Also, this study further identified the multifaceted effects of self-efficacy on the manifold aspects of learning engagement in the literature. Moreover, the study 3 aimed to understand Taiwanese high school students' epistemic knowledge profiles and learning engagements in science. Two survey instruments, including SLEI and the Epistemic Knowledge of Science Instrument (EKSI), were distributed to 631 Taiwanese junior high school students. Three epistemic knowledge profiles, including Highly uncertain yet low purpose (profile 1), Informed yet highly certain (profile 2), and Uninformed (profile 3) were identified. Further ANOVA tests revealed that, for the Cognitive engagement, the students in profile 2 had higher mean values than those in the other two profiles. Besides, the students in the profile 1 scored higher than those in profile 3. Second, for the rest of SLEI dimensions, including Behavioral, Agentic, Emotional and Social engagement, the students in the profile 2 had significantly higher scores than the other two profiles. Yet, the students in profile 1 and profile 2 did not show significant differences. Study 4 was to explore the gender differences of a total of 726 Taiwanese elementary school students' structural relationships among the five forms of science learning engagement. The t-test statistics showed no gender difference among science learning engagement for elementary school students. The interplay between Cognitive-Emotional engagement and engagement outcomes (Behavioral, Agentic, and Social engagement) was similar across gender groups except for Behavioral engagement. It is found that Emotional engagement contributed to Behavioral engagement more for males than for females.

英文關鍵詞： Science learning engagement, Science learning self-efficacy, Scientific epistemic beliefs

Study 1: Probing the relationships between the Taiwanese high school students' beliefs about knowing and learning engagement in science

Introduction

Learning engagement has been regarded as the foremost factor affecting students' learning processes and outcomes. As frequently mentioned in the literature (e.g., Fredricks, et al, 2016; Reeve & Tseng, 2011), a componential perspective of engagement has been advocated, including *cognitive* engagement (i.e., cognitive strategy use on learning tasks), *behavioral* engagement (i.e., actions in learning activities), *emotional* engagement (i.e., affective sense of learning value), *social* engagement (i.e., social forms of interactions around classroom tasks and classmates), and *agentic* engagement (i.e., constructively contributes to the flow of instruction). A handful of researchers have claimed that epistemic cognition is one of the influential factors in how an individual chooses to engage in learning process (Sinatra, Heddy, & Lombardi, 2015). In other words, how individuals come to know and conceive themselves as knowers may have noticeable impacts when learners are engaged in their own learning. Yet, nearly no empirical evidence has supported this claim in the field of science education. Thus, to fill this particular research gap, the guiding research question of this preliminary study is, "*What is the role of beliefs about knowing in the Taiwanese high school students' learning engagement in science?*"

Methods

In this study, a total of 280 students from six senior high schools across Taiwan were selected. There were 163 males and 117 females. The age of these students ranged from 15 to 18 years old. The participants were invited to answer the two survey instruments with respect to epistemic beliefs about knowing and science learning engagement. In order to assess the students' beliefs about knowing, three dimensions from the "Scientific Epistemic Beliefs Instrument" (Lin & Tsai, 2017)", including *Multiplicity of Knowledge* (5 items), *Justification for Knowing* (9 items), and *Purpose of Knowing* (4 items) were selected. Besides, a newly-developed instrument named "Science Learning Engagement Instrument (SLEI)" were used to assess the students' five categorical dimensions of engagement, including *Cognitive engagement* (5 items), *Behavioral engagement* (6 items), *Emotional engagement* (5 items), *Social engagement* (4 items), and *Agentic engagement* (7 items). This SLEI was mainly developed based on the relevant literature and instruments (e.g., Fredricks, et al, 2016; Reeve & Tseng, 2011). All the survey items in this study were presented with bipolar strongly agree/ strongly disagree options on a 5-point Likert scale. The strongly agree response was assigned a score of 5, while the strongly disagree response was designated a score of 1.

Since the SEBI has been carefully validated in the study of Lin and Tsai (2017), the exploratory factor analysis (EFA) was utilized to validate the factor structure and construct validity of SLEI. Then, to initially explore the relationships between the Taiwanese students' beliefs about knowing and science learning engagement, a series of Pearson correlation analyses was performed. Furthermore, in order to identify the predictive power of each dimension of beliefs about knowing on the five dimensions of science learning engagement, a series of stepwise regression analyses were conducted.

Results

The EFA results on the SLEI show that all the designed items were retained and grouped into five hypothesized factors of science learning engagement. The total variance explained was 75.77% and the

Cronbach's alpha coefficients ranged from 0.85 to 0.95, respectively, and the overall alpha was 0.96, indicating that these factors had satisfactory internal consistency for evaluating the students' science learning engagement. Next, the results of Pearson correlation analyses indicated that the *Justification for knowing* and *Purpose of knowing* were positively correlated with the five dimensions of science learning engagement (r = 0.16~0.46, $p < 0.01$). Yet, the *Multiplicity of Knowledge* dimension was not significantly associated with any SLEI dimensions. Furthermore, the regression results indicated that, first, the *Purpose of knowing* dimension is a positively significant predictor across all the five SLEI dimensions (*ß* = 0.17-0.27). Second, the predictive effects of the *Justification for knowing* were only found in the *Cognitive engagement*, *Emotional engagement*, and *Social engagement* (*ß* = 0.31, 0.22, 0.29, respectively).

Study 2: Multifaceted effects of self-efficacy on the Taiwanese high school students' learning engagement

Introduction

In addition, learning engagement can be defined as learners' involvement in school learning activity in school. Although the conceptualization of learning engagement may be varied by researchers, a consensus has appeared that learning engagement can be characterized as a multi-dimensional construct as well as a domain-specific attribute (Sinatra, Heddy, & Lombardi, 2015). In this line of research, a handful of interrelated types of learning engagement such as cognitive, behavioral, emotional, social engagement are commonly mentioned. Reeve and Tseng (2011) further proposed a novel type of engagement named agentic engagement which occurs when students proactively contribute into the flow of the teachers' instruction. It should be noted that, although relevant theoretical perspectives and statements have been proposed, most of the empirical studies are mainly concerned with the associations between a certain type of engagement (cognitive engagement mainly) and other crucial learning factors such as self-efficacy without a more comprehensive examination. Sinatra et al. (2015) have also stated that researchers should avoid measuring just one dimension without taking other dimensions into considerations. Thus, based on the aforementioned, the main purpose of this study is, first, to initially explore the relations between senior high school students' science learning self-efficacy and engagement from a multi-dimensional perspective. Furthermore, this study also aims to differentiate the predictive powers of multi-faceted science learning self-efficacy on various forms of science learning engagement.

Method

In this study, a total of 326 students from six senior high schools across Taiwan were selected. There were 170 males and 156 females. The age of these students ranged from 15 to 18 years old. The participants were invited to complete the two survey instruments with respect to science learning self-efficacy as well as engagement. In order to assess the students' science learning self-efficacy, the Science Learning Self-Efficacy (SLSE) instrument was chosen (Lin & Tsai, 2013). Regarding the 32-item SLSE instrument, five dimensions with sample items are presented as follows: *Conceptual Understanding* (5 items/ I know the definitions of basic scientific concepts very well.), *Higher-order Cognitive Skills* (6 items/ I am able to critically evaluate the solutions of scientific problems.), *Practical Work* (7 items/ I know how to collect data during science laboratories.), *Everyday Application* (8 items/ I am able to apply what I have learned in school science to daily life.), and *Science Communication* (6 items/ I am able to use what I have learned in science classes to discuss with others.).

Besides, a newly-developed instrument named the "Science Learning Engagement Instrument (SLEI)" were used to assess the students' five categorical dimensions of engagement, including: *Cognitive engagement* (5 items/ Before starting an assignment for science class, I try to figure out the best way to do it), *Behavioral engagement* (6 items/ I put a lot of effort into science class), *Emotional engagement* (5 items/ I enjoy learning new things in science class), *Social engagement* (4 items/ I try to work with others who can help me in science.), and *Agentic engagement* (7 items/ During science class, I express my preferences and opinions). This SLEI was mainly developed based on the available literature and instruments (e.g., Fredricks, et al, 2016; Reeve & Tseng, 2011). All the survey items in this study were presented with bipolar strongly agree/ strongly disagree options on a 5-point Likert scale. The strongly agree response was assigned a score of 5, while the strongly disagree response was designated a score of 1. Since the SLSE instrument has been carefully validated in the previous studies (e.g., Lin & Tsai, 2013; 2018), the exploratory factor analysis (EFA) was utilized to initially validate the factor structure and construct validity of SLEI. Then, to explore the relationships between the Taiwanese students' science learning self-efficacy and science learning engagement, a series of Pearson correlation analyses were performed. Furthermore, in order to identify the predictive power of each dimension of SLSE on the five dimensions of SLEI, a series of stepwise regression analyses were conducted.

Findings

The EFA results on the SLEI show that all the designed items were retained and grouped into five hypothesized factors of science learning engagement. The total variance explained was 75.77% and the Cronbach's alpha coefficients ranged from 0.85 to 0.95, respectively, and the overall alpha was 0.96, indicating that these factors had satisfactory internal consistency for evaluating the students' science learning engagement. Next, the results of Pearson correlation analyses indicated that all the five SLSE dimensions were correlated positively and significantly with the five distinct dimensions of SLEI (r =0.54~0.71, $p < 0.01$). In other words, the students who reported higher levels of self-efficacy in understanding the definitions, formulae, and theories of science concepts, utilizing higher-order scientific approaches, accomplishing laboratory and hands-on activities, applying what they have learned in school science to daily life, and communicating and discussing with others tended to demonstrate deeper behavioral, agentic, cognitive, emotional, and social engagement while learning science in the classrooms.

Moreover, stepwise multiple regression analyses were conducted to identify the predictive effects of the SLSE dimensions on the five engagement dimensions of the SLEI. For each regression analysis, the five SLSE dimensions served as predictor variables, while each dimension of the SLEI was processed as an outcome variable. For both the *Behavioral engagement* and *Agentic engagement* of the SLEI, the two SLSE dimensions of *Higher-order Cognitive Skills* ($ß$ = 0.39, 0.39, respectively) and *Practical Work* ($ß$ = 0.32, 0.31, respectively) are the significant and positive predictors. Next, the two SLSE dimensions of *Everyday Application* ($ß$ = 0.44) and *Conceptual Understanding* ($ß$ = 0.38) can significantly and positively predict the SLEI dimension of *Cognitive engagement*. Similarly, in addition to the SLSE dimensions of *Everyday Application* ($ß$ = 0.34) and *Conceptual Understanding* ($ß$ = 0.30), the SLSE dimension of *Science Communication* ($ß$ = 0.19) also can positively and significantly predict the SLEI dimension of *Emotional engagement*. Finally, for the SLEI dimension of *Social engagement*, three SLSE dimensions, including the *Science Communication*, *Practical Work*, and *Conceptual Understanding* are the positive and significant predictors ($ß$ = 31, 0.27, 0.23, respectively).

Study 3: Taiwanese high school science learners' epistemic knowledge profiles and their learning engagement

Introduction

Students' engagement in learning has been an important research topic in education and numerous studies have been conducted and aggregated in relevant literature. However, in the past, most of the studies are mainly concerned with the associations between a certain type of engagement without expanding the possibilities of other potential aspects of learning engagement. Sinatra et al. (2015) also stated that researchers should avoid measuring just one dimension without taking others into consideration. Moreover, personal epistemology researchers have stressed the necessity of expanding the dimensions of epistemic beliefs. In science education, for example, Lin and Tsai (2017) have included epistemic aims (i.e. people's goals for inquiry) to understand learners' scientific epistemic beliefs. The issue with respect to the nature and purpose of knowledge has been an important aspect in the personal epistemology research (Hofer & Pintrich, 1997). Recently, a handful of researchers have claimed and advocated that epistemic beliefs is one of the influential factors in how an individual chooses to engage in learning process (Sinatra, Heddy, & Lombardi, 2015). In other words, the relationships between the two constructs should be investigated more in depth to better understand the role of learners' epistemic beliefs in their various aspects of science learning. Thus, the main purpose of this study was to understand Taiwanese high school students' epistemic knowledge profiles and learning engagements in science. To this end, the aims were mainly twofold:

1. To identify the epistemic knowledge profiles based on the Taiwanese students' understanding about the nature and purpose of science knowledge
2. To scrutinize the Taiwanese students' multidimensional science learning engagement with different attained epistemic knowledge profiles

Methods

Participants

In this study, a total of 631 high school students from six senior high schools in four main regions of Taiwan (i.e., Northern, Central, Southern, and Eastern) were invited. There were 375 males and 256 females. The age of these students ranged from 15 to 18 years with an average age of 16.84. The participants were invited to answer the two survey instruments with respect to epistemic knowledge of science and science learning engagement. The age of these students ranged from 15 to 18 years old.

Instruments

In order to assess the students' understanding of epistemic knowledge of science, the Epistemic Knowledge of Science Instrument (EKSI) was developed. Three dimensions of epistemic knowledge of science adopted from Lin and Tsai (2017) were selected to evaluate the students' understanding of epistemic knowledge of science, including *Uncertainty of Knowledge* (6 items), *Development of Knowledge* (6 items), and *Purpose of Knowledge* (6 items). Besides, an instrument named "Science Learning Engagement Instrument (SLEI)" (Lin, under review) were used to assess the students' five dimensions of learning engagement, including *Cognitive engagement* (5 items), *Behavioral engagement* (6 items), *Emotional engagement* (5 items), *Social engagement* (4 items), and *Agentic engagement* (7 items), which was mainly developed based on the relevant literature and instruments (e.g., Fredricks, et al, 2016; Reeve & Tseng, 2011). All survey items of the two instruments in this study were presented with bipolar strongly agree/ strongly disagree options on a 5-point Likert scale. The strongly agree response was assigned a score of 5, while the strongly disagree response was designated a score of 1.

Data analysis procedure

To evaluate the validity and reliability of the EKSI and SLEI, a confirmatory factor analysis was conducted. After ensuring the factor structure of the EKSI instrument, the k-means method of clustering analysis was conducted to identify meaningful and distinct clusters. In addition, differences between clusters were also explored for their significance using the analyses of variance (ANOVA) test in order to draw a clear line between different epistemic knowledge profiles. After identifying the participants' various profiles, a series of ANOVA tests were calculated to examine the role of these profiles in the five forms of science learning engagement.

Results

Factor structures of the EKSI and SLEI

To ensure the factor structures of the EKSI and SLEI, two confirmatory factor analyses were conducted respectively. The validation results indicated that all items were retained and grouped based on the proposed theoretical frameworks. That is, EKSI contains three main factors, including *Uncertainty*, *Development* and *Purpose* of Knowledge, while SLEI incorporates five hypothesized factors of science learning engagement. The fitness indices for EKSI (chi-square per degree of freedom = 4.96, RMSEA = 0.07, GFI = 0.95, NFI = 0.94, and CFI =0.93) and SLEI (chi-square per degree of freedom = 3.89, RMSEA = 0.05, GFI = 0.96, NFI = 0.97, and CFI =0.96) suggest a satisfactory fit to the data. Besides, all the factor loading coefficients were statistically and higher than the cut-off value of 0.5. The AVE values in the two instruments also showed that EKSI and SLEI had sufficient convergent validity of the proposed factors. In terms of reliability, the CR values for each factor in EKSI and SLEI suggest that the two instruments had high internal consistency for assessing the Taiwanese students' epistemic knowledge of science as well as science learning engagement.

Clustering epistemic knowledge profiles

The method of cluster analysis was conducted to yield distinct epistemic knowledge profiles based on the students' responses on the EKSI. In turn, the three-cluster solution was decided due to the distinct characteristic among each cluster. The results of the ANOVA comparisons indicated that there were significant differences among the three clusters for the Uncertainty of Knowledge ($F = 327.06$, $p < 0.001$), Development of Knowledge ($F = 237.93$, $p < 0.001$), and Purpose of Knowledge ($F = 265.47$, $p < 0.001$). The follow-up post hoc tests further confirmed that the three clusters could be employed to interpret the differences among the three aspects of crucial epistemic knowledge of science.

The students in cluster 1 (N = 233) scored significantly higher on the Uncertainty of Knowledge (M = 4.31) than the other two clusters. In terms of the EKSI dimensions of Development as well as Purpose of Knowledge (M = 4.28, 3.60, respectively), the students in cluster 1 had significant lower scores than those of cluster 2, while these students scored significantly higher than those of cluster 3. Thus, the students in cluster 1 were characterized as "*Highly uncertain yet low purpose*" epistemic knowledge profile, suggesting that they tended to believe that science knowledge as tentative and as a revelation of reality contrasting the students in other clusters. The students in the second cluster (N = 198) had significantly higher scores on the Development and Purpose of Knowledge dimensions of EKSI than those in the other two clusters (M = 4.72, 4.48, respectively). Yet, their scores on the Uncertainty of Knowledge dimension were significantly lower than those of cluster 1, while the scores on the same dimension were significantly higher than cluster 3. In other words, the students in this cluster, on the one hand, were prone to believe science knowledge as constantly changing and as interpretations of the natural world. On the other hands, they still regarded science knowledge as decontextualized with a single correct answer. Although the cluster 2 students may reflect an informed orientation toward the Development and Purpose of Knowledge aspects, they demonstrated a distinct belief that science knowledge is fixed and certain. Thus, the cluster 2 could be described as "*Informed yet highly certain*" epistemic knowledge profile. Moreover, the third cluster consisted of 200 students whose scores on the two EKSI dimensions including Uncertainty (M = 3.07) and Development (M = 3.76) were both significantly lower than those of cluster 1 and 2. However, there were no significant differences on the *Purpose of Knowledge* dimension (M = 3.53) between the students in this cluster and cluster 1. In general, the students in this cluster tended to show an immature orientation with respect to the nature of scientific knowledge. That is, they were prone to believe that scientific knowledge is fixed with an absolute right answer, static without evolving, and for the purpose of revealing reality. Consequently, this cluster could be regarded as "*Uninformed*" epistemic knowledge profile, representing that they had naïve beliefs about the nature of science knowledge.

The comparisons of science learning engagement among attained epistemic knowledge profiles

For the Cognitive Engagement, the students in profile 2 (*Informed yet highly certain*) had higher mean values than those in the other two profiles (*Highly uncertain yet low purpose* and *Uninformed*). Besides, the students in the *Highly uncertain yet low purpose* profile scored higher than those of *Uninformed* profile. Second, for the rest of SLEI dimensions, including *Behavioral*, *Agentic*, *Emotional* and *Social* engagement, the students in the *Informed yet highly certain* profile had significantly higher scores than the other two profiles. Yet, the students in the *Highly uncertain yet low purpose* and *Uninformed* profiles did not show significant differences.

Study 4: Exploring the Taiwanese elementary school students' science learning engagement: Gender differences

Introduction

The United Nation launched Sustainable Developmental Goals (SDGs) in 2015 to set the agenda for 2030 to shift the world onto a sustainable and resilient path (UN General Assembly, 2015). Under the 17 broader goals, Goal 4 (inclusive and equitable quality education) and goal 5 (gender equality and empowerment) stress the role of female's participation in education and employment. Several recent reports and studies; however, showed that the women remained underrepresented in science, technology, engineering, and mathematics (STEM) collogues and careers (Brotman & Moore, 2008; Marsh et al., 2019; Patall, Steingut, Freeman, et al., 2018). Although there is some promising evidence of the growing trend of (1) closing the gender gap and gender differences (Zhao et al., 2005), (2) new pedagogies and extra-curriculum activates facilitating STEM education (Schmidt et al., 2020; Sullivan & Bers, 2019), students' experiences in science learning still plays a critical role in forming their attitude to STEM, science identity and identification, and career choice (Meece & Jones, 1996; Pattison & Dierking, 2019; Schneider et al., 2016).

Among different sources of science learning experiences, science learning engagement can be seen as an essential indicator to evaluate students' participation in science-related activities and to predict the critical outcome of their situational interest, attitude toward science, and identity formation (Ohland et al., 2008;

Schmidt et al., 2020). Moreover, prior studies of learning engagement have proved its high association with significant learning-related antecedents and outcomes, such as intrinsic/extrinsic motivation (Walker et al., 2006), longitudinal changes in classroom motivation (Reeve & Lee, 2014), academic performance (Brown et al., 2008; Slof et al., in press), adaptive coping and persistence (Skinner et al., 2016) and ideal identity (Robson, 2017). However, the measurement of science learning engagement remains unclear due to different theoretical foundations (person-oriented, person-in-context, and context-oriented) and research design (observation, experience sampling, response time, trace behaviors) (Sinatra et al., 2015). Despite diverse perspectives measurement bringing fruitful outcomes and realities, a comprehensive, valid, and reliable science learning engagement scale is necessary to measure students' science learning's holistic engagement aspects and compare the gender, ethicality, culture, and policy differences around the world. Unfortunately, much to our knowledge limited published, reliable, the validated scale of science learning engagement can be found to measure elementary school students in a Chinese-speaking context. Besides, with the growing interest in gender difference among different age groups, developing and validating scale with multi-dimensions and gender invariance become a foundation stone for future cross-cultural studies of science learning and education.

This study aims to develop and validate a Chinese-version with respect to science learning engagement scale (SLES) to compare the gender difference of science learning engagement on Taiwanese elementary school students. In particular, we attempt to develop a multi-dimensional engagement model with gender measurement invariance using multiple-group confirmatory factor analysis. Given the nature of measurement quality for group comparison, several measurement invariance assumptions should be considered to ensure the appropriation of factor structure, loading, and intercept. This is an essential step before testing gender differences because a partially or non-invariant instrument stands for distinctive meanings and forms unidentical gender groups (Vandenberg & Lance, 2000). Therefore, the present study considers four measurement invariance assumptions in terms of configural, weak, strong, and strict invariance to evaluate the measurement quality before conducting gender difference of elementary school students' science learning engagement. In general, our study proposed the following research questions:

- Is the five-factor Science Learning Engagement Scale valid and reliable?
- Are the constructs of science learning engagement gender invariant in terms of configural, weak, and strong measurement invariances?
- Are there gender differences in terms of the mean scores or the structural relationships among the five forms of science learning engagement?

Method

Participants

Through researchers' contact, five elementary schools from northern Taiwan were invited to join this study. The homeroom or science teacher distributed our anonymous survey questionnaires to students. Each student would take 15-20 minutes to accomplish this survey. We noted that participating in this study is entirely voluntary and will not affect their science class scores. Finally, we distributed our survey to thirty science classrooms nested in five public elementary schools. A total of 726 participants completed this survey. However, we screened their responses and removed 134 invalid responses (who do not fully complete the survey or not cognitively involved in the survey questions, such as randomly answering). Eventually, five hundred and ninety-two participants are included in this study, including 303 males (51.18%) and 289 females (48.82%). Among all the participants, 24.32 % (N= 144) have attended science camp(s), and 10.47 % (N= 62) have participated in the science fair. The average age of the participants is 10.89 [SD= 0.35].

Instrument

In this study, we based on the self-determination theory perspective of student engagement and believe that student engagement is the outcome of student motivation (inherent and acquired sources of motivation) (Reeve, 2012) and motivationally-supported classroom conditions (Reeve, 2013). This distinction specifies the significant difference between motivation and engagement. We adopted a validate four-factor learning engagement scale from Reeve (2013). The original scale is to evaluate students' overall engagement in the classroom. We modified the original items under the science learning context for elementary school students. We did this because this study's focus was to accurately capture the variance of students' science learning engagement and compare the gender differences in Taiwan. In addition to the original four-factor, we added one more factor, social engagement, into the original engagement scale. Social engagement can be seen as a significant engagement in the science learning curriculum (Bae et al., 2020; Bae & Lai, 2020), such as social interaction, group project, and lab experiment. Therefore, there are five dimensions in the Science Learning Engagement Scale (SLES). We use a six-point Likert scale, ranging from 1 (strongly disagree) to 6 (strongly agree). Each dimension's composite scores refer to students' specific engagement scores [higher scores denote higher engagement]. Below, we provide the conceptual definitions and sample items for each dimension.

- Behavioral engagement refers to the on-task attention and effort in the science classroom. A sample item is "When I'm in this science class. I listen very carefully."
- Agentic engagement is defined as students' proactive, intentional, and constrictive contributions to the instruction flow. A sample item is "I let my teacher kn0ow what I am interested in".
- Cognitive engagement is defined as using sophisticated, in-depth, and cognitive involved strategies to seek conceptual understanding rather than surface knowledge. A sample item is "I try to make all the different ideas fit together and make sense."
- Emotional engagement refers to the presence of task-facilitating emotion during science learning (e.g., interest, curiosity, and enthusiasm). A sample item is "I enjoy learning new things in science class."
- Social engagement is defined as considering others' ideas and perspectives and working with peers toward a common goal in the science classroom (Bae & Lai, 2020). A sample item is "I build up my idea based on others' ideas in this course."

The internal consistency is highly satisfactory and reaches the suggested threshold (above 0.7). The Cronbach’s α is 0.967 for overall scales, 0.945 for behavioral engagement, 0.928 for agentic engagement, 0.925 for cognitive engagement, 0.944 for emotional engagement, and 0.864 for social engagement.

Data analysis

To ensure the validity and reliability, we first conduct the descriptive statistics and correlation analysis to see the distribution and interplay between the variables using the composite score. Then, we run a series of multi-group comparison analysis using confirmatory structure equation (SEM) modeling to evaluate the overall fit statistics, composite reliability (CR), average variance extraction (AVE), and measurement invariance (MI), including configural, metric, and scalar invariance. To evaluate the quality of the measurement model, the Satorra-Bentler rescaled chi-square ($\chi 2$) model fit test statistic and fit indices (i.e., CFI, TLI, RMSEA, and SRMR) were used to test the model goodness-of-fit (Hu & Bentler, 1999). Because of the sensitivity of the differential chi-square statistic (i.e., $\Delta\chi 2$) to the sample size, we follow Wu and Cheng's (2019) procedure to include four additional criteria to evaluate the MI assumptions, including changes in CFIs, TLIs, RMSEAs, and SRMRs. Stringent thresholds were used to test the MI assumptions: The comparative model is seen as statistically equivalent if ΔCFI $\leq$ .02 (Cheung & Rensvold, 2002), ΔTLI $\leq$ .05 (Little, 1997), and ΔRMSEA$\leq$ .015, and ΔSRMR$\leq$ .01 (Chen, 2007). If most criteria satisfy the suggested thresholds, the measurement invariance assumptions hold (Vandenberg & Lance, 2000; Wu & Cheng, 2019; Wu & Hughes, 2015). If model comparison showed an unsatisfactory outcome, we used modification indices to detect non-invariant items by allowing partial invariance (setting item free) using a multivariate score test or by associating latent to the underlying association between items.

Results

Descriptive statistics and the correlation

The average scores of science learning engagement ranged from 3.930 to 4.609. Among all the science learning engagement, the behavioral engagement is the highest (Mean = 4.609, Median = 4.667, SD = 1.092) whereas agentic engagement is comparatively lowest (Mean = 3.930m Median = 3.833, SD = 1.269). Therefore, maximum likelihood estimation could be used to estimate the parameters.

The bivariate correlation indicated that all subscales of the engagement hold significantly moderate to high correlation. This initial evidence shows that the five-factor model can be reflected in the science learning engagement construct. Also, following Anderson and Gerbing's threshold (1988), the correlation *r* and 95% confidence intervals between constructs do not include 1 or -1, showing the initial support of the five factors model's differential validity.

Single and Multiple-group confirmatory factor analysis

We first conduct single-group CFA to see the model fit statistics. A confirmatory factor analysis (CFA) revealed an adequate model fit to the data (χ^2 = 988.253, df = 289, p = .001, CFI = 0.951, TLI = 0.945, RMSEA = 0.064, SRMR = 0.035). Standardized factor loading ranged from 0.771 to 0.928, AVE ranged from 0.619 to 0.773, and CR 0.866 to 0.946. The above results showed appropriate reliability and validity for the single group CFA (Fornell & Larcker, 1981; Hu & Bentler, 1999). Next, we ran a multiple-group CFA to evaluate the nested model using gender as a grouping variable. Once again, the model fit for the nested model is satisfactory (χ^2 = 1484.743, df = 594, p < .001, CFI = 0.939, TLI = 0.933, RMSEA = 0.071, SRMR = 0.045). The standardized factor loadings for both males and females are above .70. Every item's z score is significant, indicating that the items significantly contributed to every subconstruct of science learning engagement. The results of single and multiple group SEM reveal that the five-factor model is a statistically meaningful concept and the model fit statistics of either single or multiple groups CFA reached appropriate construct validity (divergent and convergent validity) and reliability.

Measurement invariance of science learning engagement across gender

Configural invariance

We first test the configural MI assumption by fixing the number of the factors and the loco-factor loadings CFA model the locations same across gender. The model-fit statistics and indices for the five-factor CFA model were χ^2 = 1465.216, df = 578 with p < .001, CFI = 0.939, TLI = 0.932, RMSEA = 0.072 and SRMR = 0.042.

Metric invariance (weak invariance)

Given that the configural invariance reach appropriate model fit, we conducted metric invariance model by further fixing the factor loadings equal across groups. The model fit indices were χ^2 = 1486.781, *df* = 599 with p < .001, *CFI* = 0.939, *TLI* = 0.934, *RMSEA* = 0.071 and *SRMR* = 0.045. The model comparison between configural and metric invariance models using chi-squire test is insignificant (p = 0.4249). The changes of the fit statistics were $\Delta\chi^2$ = 21.5650, *Δdf* = 21, *ΔCFI* = 0.000, *ΔTLI* = 0.002, *ΔRMSEA* = −0.001, and *ΔSRMR* = 0.003. The values and changes of the fit indices were with suggested thresholds, indicating the assumption of weak invariance is not rejected.

Scalar invariance (strong invariance)

Scalar invariance assumes that the measurement fixing both factor loadings and item intercepts equal across gender groups. The model fit statistics for science learning engagement is appropriate (χ^2 = 1549.458, *df* = 620 with p < .001, *CFI* = 0.936, *TLI* = 0.933, *RMSEA* = 0.071 and *SRMR* = 0.046). The changes of the fit statistics were $\Delta\chi^2$ = 62.677, *Δdf* = 21, *ΔCFI* = -0.003, *ΔTLI* = -0.001, *ΔRMSEA* = 0.000, and *ΔSRMR* = 0.001. Although the chi-square comparison showed significant results (p < 0.00), the changes of all the other fit indices were within the suggested thresholds (Wu & Hughes, 2015). Accordingly, scalar invariance (strong invariance) of science learning engagement was supported by the statistical results. This indicated that the composite scores of science learning engagement (of each subconstruct) convey the same meaning across different gender groups.

Invariant uniqueness (strict invariance)

Based on scalar models' model adequacy, invariant uniqueness was further tested by fixing factor loadings, item intercepts, and item residual variances equal across different gender groups. The fit indices were χ^2 = 1685.303, *df* = 646 with p < .001, *CFI* = 0.929, *TLI* = 0.928, *RMSEA* = 0.074 and *SRMR* = 0.047. The changes of the fit statistics were $\Delta\chi^2$ = 135.845, *Δdf* = 26, *ΔCFI* = -0.008, *ΔTLI* = -0.005, *ΔRMSEA* = 0.003, and *ΔSRMR* = 0.001 and the chi-square test showed significant difference p < 0.00. Because of the sensitivity of the chi-square change with sample size, we considered the four other changes of fit indices and found they do not exceed the suggested changed values. Accordingly, we do not reject the null hypothesis of invariant uniqueness. That is, the measurement is equivalent to males and females.

Gender differences in science learning engagement

Mean score comparison

After testing the measurement invariance of the SLES, the results showed that the measurement reaches strict invariance, indicating that each construct's composite scores can be compared among different gender groups. To understand the gender differences between males and females, we conducted an independent sample t-test to compare the differences. The results showed no gender difference of the students' science learning engagement including behavioral engagement (*t* = -0.628), agentic engagement (*t* = 0.465), cognitive engagement (*t* = -0.110), emotional engagement (*t* = 1.034), and social engagement (*t* = -1.373). The 95% CI interval all includes 0, indicating that the null hypothesis cannot be rejected.

Multiple-group structural model comparison [coefficient]

Along with the self-regulation perspective, we argue that cognitive and emotional engagement could be seen as the sources of the other three engagement (behavioral, agentic, and social engagement). We first conducted the single group SEM and then conducted multiple group SEM. Both models showed satisfactory model fit. The fit indices for the single group SEM were χ^2 = 990.022, *df* = 289 with p < .001, *CFI* = 0.951, *TLI* = 0.945, *RMSEA* = 0.064 and *SRMR* = 0.036 and for the multiple-group SEM were χ^2 = 1549.458, *df* =

620 with $p < .001$, *CFI* = 0.936, *TLI* = 0.933, *RMSEA* = 0.071 and *SRMR* = 0.046. The results showed that cognitive and emotional engagement could significantly predict behavioral engagement and social engagement, but agentic engagement can only be predicted by cognitive engagement ($r = 0.63^{***}$) (not emotional engagement ($r = 0.071^{n.s.}$)). Also, the association between engagement across similar interplay except for behavioral engagement. We found that emotional engagement is more related to behavioral engagement for male ($r = 0.564^{***}$) than for female ($r = 0.373^{***}$). However, this finding does not mean that cognitive engagement is not essential. Instead, the results showed that cognitive engagement is critical for both agentic engagement and social engagement.

References

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin*, *103*(3), 411-423.

Bae, C. L., & Lai, M. H. C. (2020). Opportunities to Participate in Science Learning and Student Engagement: A Mixed Methods Approach to Examining Person and Context Factors. *Journal of Educational Psychology*, *112*(6), 1128-1153.

Bae, C. L., DeBusk-Lane, M. L., & Lester, A. M. (2020). Engagement profiles of elementary students in urban schools. *Contemporary Educational Psychology*, *62*, 101880.

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology*, *52*, 1-26.

Brotman, J. S., & Moore, F. M. (2008). Girls and Science: A Review of Four Themes in the Science Education Literature. *Journal of Research in Science Teaching*, *45*(9), 971–1002.

Brown, S. D., Tramayne, S., Hoxha, D., Telander, K., Fan, X., & Lent, R. W. (2008). Social cognitive predictors of college students' academic performance and persistence: A meta-analytic path analysis. *Journal of Vocational Behavior, 72*(3), 298–308.

Carlone, H. B., Johnson, A., & Scott, C. M. (2015). Agency Amidst Formidable Structures: How Girls Perform Gender in Science Class. *Journal of Research in Science Teaching*, *52*(4), 474–488.

Chinn, C. A., Buckland, L. A., & Samarapungavan, A. (2011). Expanding the dimensions of epistemic cognition: Arguments from philosophy and psychology. *Educational Psychologist*, *46*, 141-167.

DeBacker, T. K., & Nelson, R. M. (1999). Variations on an expectancy-value model of motivation in science. *Contemporary Educational Psychology*, *24*(2), 71–94.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39–50.

Fredricks, J. A., Hofkens, T., Wang, M.-T., Mortenson, E., & Scott, P. (2018). Supporting girls' and boys' engagement in math and science learning: A mixed methods study. *Journal of Research in Science Teaching*, *55*(2), 271–298.

Fredricks, J. A., Wang, M. T., Linn, J. S., Hofkens, T. L., Sung, H., Parr, A., & Allerton, J. (2016). Using qualitative methods to develop a survey measure of math and science engagement. *Learning and Instruction*, *43,* 5-15.

Ho, H.-N. J., & Liang, J.-C. (2015). The relationships among scientific epistemic beliefs, conceptions of learning science, and motivation of learning science: A study of Taiwan high school students. *International Journal of Science Education*, *37*, 2688-270

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. Review of Educational Research, 67, 88-140.

Holzberger, D., Reinhold, S., Luedtke, O., & Seidel, T. (2020). A meta-analysis on the relationship between school characteristics and student outcomes in science and maths—Evidence from large-scale studies. *Studies in Science Education*, *56*(1), 1–34.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55.

Lin, T.-J. & Tsai, C.-C. (2017). Developing instruments concerning scientific epistemic beliefs and goal orientations in learning science: A validation study. *International Journal of Science Education*, *39*, 2382-2401.

Lin, T.-J. & Tsai, C.-C. (2018). Differentiating the sources of Taiwanese high school students' multidimensional science learning self-efficacy: An examination of gender differences. *Research in Science Education*, *48*, 575-596.

Lin, T.-J., & Tsai, C.-C. (2013). A multi-dimensional instrument for evaluating Taiwan high school students' learning self-efficacy in relation to their approaches to learning science. *International Journal of Science and Mathematics Education*, *11*, 1275-1301.

Marsh, H. W., Martin, A. J., & Cheng, J. H. S. (2008). A multilevel perspective on gender in classroom motivation and climate: Potential benefits of male teachers for boys? *Journal of Educational Psychology*, *100*(1), 78–95. https://doi.org/10.1037/0022-0663.100.1.78

Marsh, H. W., Van Zanden, B., Parker, P. D., Guo, J., Conigrave, J., & Seaton, M. (2019). Young Women Face Disadvantage to Enrollment in University STEM Coursework Regardless of Prior Achievement and Attitudes. *American Educational Research Journal*, *56*(5), 1629–1680.

Martin, A. J., & Collie, R. J. (2019). Teacher–student relationships and students' engagement in high school: Does the number of negative and positive relationships with teachers matter? *Journal of Educational Psychology*, *111*(5), 861–876.

Meece, J. L., & Jones, M. G. (1996). Gender differences in motivation and strategy use in science: Are girls rote learners? *Journal of Research in Science Teaching*, *33*(4), 393–406.

Ohland, M. W., Sheppard, S. D., Lichtenstein, G., Eris, O., Chachra, D., & Layton, R. A. (2008). Persistence, Engagement, and Migration in Engineering Programs. *Journal of Engineering Education*, *97*(3), 259–278.

Patall, E. A., Steingut, R. R., Freeman, J. L., Pituch, K. A., & Vasquez, A. C. (2018). Gender disparities in students' motivational experiences in high school science classrooms. *Science Education*, *102*(5), 951–977.

Patall, E. A., Steingut, R. R., Vasquez, A. C., Trimble, S. S., Pituch, K. A., & Freeman, J. L. (2018). Daily autonomy supporting or thwarting and students' motivation and engagement in the high school science classroom. *Journal of Educational Psychology*, *110*(2), 269–288.

Patall, E. A., Vasquez, A. C., Steingut, R. R., Trimble, S. S., & Pituch, K. A. (2016). Daily interest, engagement, and autonomy support in the high school science classroom. *Contemporary Educational Psychology*, *46*, 180-194.

Pattison, S. A., & Dierking, L. D. (2019). Early childhood science interest development: Variation in interest patterns and parent-child interactions among low-income families. *Science Education*, *103*(2), 362–388.

Reeve, J. (2012). A Self-determination Theory Perspective on Student Engagement. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 149–172). Springer US.

Reeve, J. (2013). How students create motivationally supportive learning environments for themselves: The concept of agentic engagement. *Journal of Educational Psychology*, *105*(3), 579–595.

Reeve, J., & Lee, W. (2014). Students' classroom engagement produces longitudinal changes in classroom motivation. *Journal of Educational Psychology*, *106*(2), 527–540.

Reeve, J., & Tseng, C. M. (2011). Agency as a fourth aspect of students' engagement during learning activities. *Contemporary Educational Psychology*, *36*, 257-267.

Robson, J. (2017). Performance, structure and ideal identity: Reconceptualising teachers' engagement in online social spaces: Teachers' engagement in online social spaces. *British Journal of Educational Technology*.

Schmidt, J. A., Beymer, P. N., Rosenberg, J. M., Naftzger, N. N., & Shumow, L. (2020). Experiences, activities, and personal characteristics as predictors of engagement in STEM-focused summer programs. *Journal of Research in Science Teaching*.

Schneider, B., Krajcik, J., Lavonen, J., Salmela-Aro, K., Broda, M., Spicer, J., Bruner, J., Moeller, J., Linnansaari, J., Juuti, K., & Viljaranta, J. (2016). Investigating optimal learning moments in US and finnish science classes. *Journal of Research in Science Teaching*, *53*(3), 400–421.

Shaby, N., & Vedder-Weiss, D. (2020). Science identity trajectories throughout school visits to a science museum. *Journal of Research in Science Teaching*, *57*(5), 733–764.

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. *Educational Psychologist*, *50*, 1-13.

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. *Educational Psychologist*, *50*, 1-13.

Skinner, E. A., Pitzer, J. R., & Steele, J. S. (2016). Can student engagement serve as a motivational resource for academic coping, persistence, and learning during late elementary and early middle school? *Developmental Psychology*, *52*(12), 2099–2117.

Slof, B., van Leeuwen, A., Janssen, J., & Kirschner, P. A. (in press). Mine, ours and yours, whose engagement and prior knowledge affects individual achievement from online collaborative learning? *Journal of Computer Assisted Learning*.

Sullivan, A., & Bers, M. U. (2019). Investigating the use of robotics to increase girls' interest in engineering during early elementary school. *International Journal of Technology and Design Education*, *29*(5), 1033–1051.

Uçar, F. M., & Sungur, S. (2017). The role of perceived classroom goal structures, self-efficacy, and engagement in student science achievement. *Research in Science & Technological Education*, *35*(2), 149–168.

UN General Assembly. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development* (A/RES/70/1). http://www.un.org/ga/search/view_doc. asp?symbol=A/RES/70/1&Lang=E (United Nations, 2015)

Vandenberg, R. J., & Lance, C. E. (2000). A Review and Synthesis of the Measurement Invariance Literature: Suggestions, Practices, and Recommendations for Organizational Research. *Organizational Research Methods*, *3*(1), 4–70.

Walker, C. O., Greene, B. A., & Mansell, R. A. (2006). Identification with academics, intrinsic/extrinsic motivation, and self-efficacy as predictors of cognitive engagement. *Learning and Individual Differences*, *16*(1), 1–12.

Wu, J.-Y., & Cheng, T. (2019). Who is better adapted in learning online within the personal learning environment? Relating gender differences in cognitive attention networks to digital distraction. *Computers & Education*, *128*, 312–329.

Wu, J.-Y., & Hughes, J. N. (2015). Teacher Network of Relationships Inventory: Measurement invariance of academically at-risk students across ages 6 to 15. *School Psychology Quarterly*, *30*(1), 23–36.

Xie, K., Vongkulluksn, V. W., Lu, L., & Cheng, S.-L. (2020). A person-centered approach to examining high-school students' motivation, engagement and academic performance. *Contemporary Educational Psychology*, *62*, 101877.

Zhao, C. M., Carini, R. M., & Kuh, G. D. (2005). Searching for the peach blossom Shangri-La: Student engagement of men and women SMET majors. *Review of Higher Education*, *28*(4), 503-525.

本計畫之相關研究結果發表如下：

國際研討會論文

Chiu, Y.-J., Hsu, C.-Y., Liang, J.-C., Lin, T.-J., & Tsai, C.-C. (2018, June). *The role of elementary school students' scientific epistemic beliefs in a digital game-based learning environment*. Paper will be presented at the EdMedia + Innovate Learning International Conference (EdMedia 2018), Amsterdam, Nederland.

Lin, T.-J. (2019, November). *An exploratory study on the Taiwanese high school students' beliefs about knowing and learning engagement in science*. Paper presented at the Third International Conference for "Personal Epistemology and Learning in Digital Age," Taipei, Taiwan.

Kuo, T. M.-L., Lin, T.-J. & Wang, J.-C. (2019, December). *Developing and validating the learning engagement with chatbot service scale (LECSS) for evaluating educational chatbot service*. Paper presented at the 2nd International Conference of Innovative Technologies and Learning (ICITL 2019), Tromso, Norway.

Lin, T.-J. (2020, June). *Multifaceted effects of self-efficacy on Taiwanese high school students' learning engagement*. Paper presented the 2020 annual meeting of Australasian Science Education Research Association (ASERA), Wollongong, NSW, Australia.

國際 SSCI 期刊論文（審查中）

Lin, T.-J. (under review). Multi-dimensional explorations into the relationships between Taiwanese high school students' science learning self-efficacy and engagement. *International Journal of Science Education*.

Lin, T.-J. (under review). Taiwanese high school science learners' epistemic knowledge profiles and their multifaceted learning engagement. *Research in Science Education*.

附件五

科技部補助專題研究計畫出席國際學術會議心得報告

日期：107 年 7 月 5 日

計畫編號	MOST 107-2511-S-003 -004 -MY2		
計畫名稱	臺灣高中生之科學學習投入研究：兼探科學知識觀信念與科學學習自我效能(1/2)		
出國人員姓名	林宗進	服務機構及職稱	國立臺灣師範大學學習科學學士學位學程
會議時間	107 年 6 月 25 日至 107 年 6 月 29 日	會議地點	荷蘭阿姆斯特丹
會議名稱	(中文) 2018 教育媒體與創新學習國際研討會 (英文) EdMedia + Innovate Learning International Conference 2018		
發表題目	(中文) 國小學生科學知識觀信念在數位遊戲學習中之角色 (英文) The role of elementary school students’ scientific epistemic beliefs in a digital game-based learning environment		

一、參加會議經過

本人此次參加的會議為教育媒體與創新學習國際研討會（EdMedia + Innovate Learning International Conference 2018），從 1987 年舉辦以來，目前已經有 30 年的歷史，已是國際上重要的世界性學術論壇之一。該研討會也是數位學習或教學媒體界重要且歷史悠久的學術論壇，每年從世界不同各地前來參與的教育工作者與教育研究者人數相當眾多，規模亦相當龐大。而今年為第 30 屆，於 2018 年 6 月 25 日至 6 月 29 日在荷蘭首都阿姆斯特丹舉行，該會議的舉辦地點在 Renaissance Amsterdam Hotel。本次會議的研究主題共涵蓋了 9 大主題，包括：

1. Advanced Technologies for Learning and Teaching
2. Assessment and Research

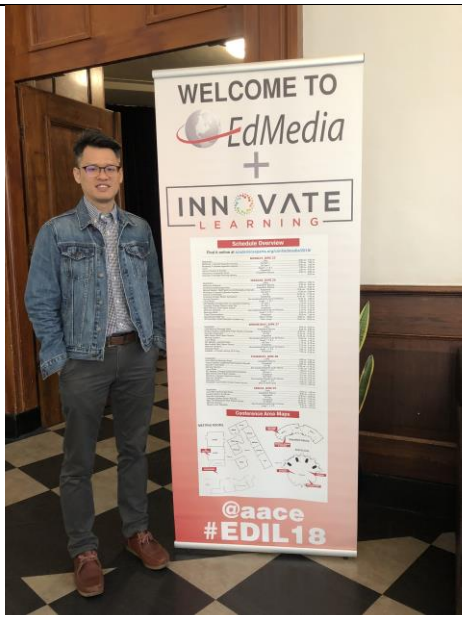
3. Educational Reform, Policy, and Innovation
4. Evaluation and Quality Improvement Advances
5. Global Networks, Partnerships, and Exchanges
6. Innovative Approaches to Learning and Learning Environments
7. Open Education
8. Technologies for Socially Responsive Learning
9. Virtual and Distance Education

本人此次與博士班研究生與其他教授共同發表的論文題目為"The role of elementary school students' scientific epistemic beliefs in a digital game-based learning environment"， 屬於主題六子項目中的 Game-based learning 範疇。主要探討臺灣小學生在進行數位教育遊戲時，其科學知識觀信念所扮演的角色。該論文發表於 6 月 26 日下午 4 時發表於會場的 Jordaan 廳。參與的人數超過 30 位，有許多世界不同國家的研究者一同共襄盛舉，整體而言，發表的過程相當順利，在報告結束後，在場的與會者也提出了自己的心得與想法，讓大家能夠有深度的學術交流。由於大家對於科學知識觀信念較為不清楚，也藉由問題與討論的時間能有進一步的說明，與會者也對於相關的研究相當有興趣，在報告結束後亦有深入的討論。

除了口頭發表的行程外，本人也參與了大會所安排的其他議程，如專題演講之一，是來自 Founder of Steve Jobs Schools 的 Maurice de Hond，演講的主題為"The Challenge of Personalized Learning in Schools"，由於數位科學變化的速度越來越快，未來的公民要如何做好準備，面對這個快速變遷的世界，他強調單純將科技導入至正式教育中是不足夠的，擁有新技術但卻是過時的組織僅是一個昂貴的過時組織，因此，科技研發者與教育工作者應該將重心轉換到考慮軟硬體整合的適切性，並且朝向個人化、適性化的學習與課程管理系統。簡而言之，藉由參與這樣的國際會議，能夠讓研究者了解國際社群間的發展現況與未來趨勢，並且能與相關領域且有共同

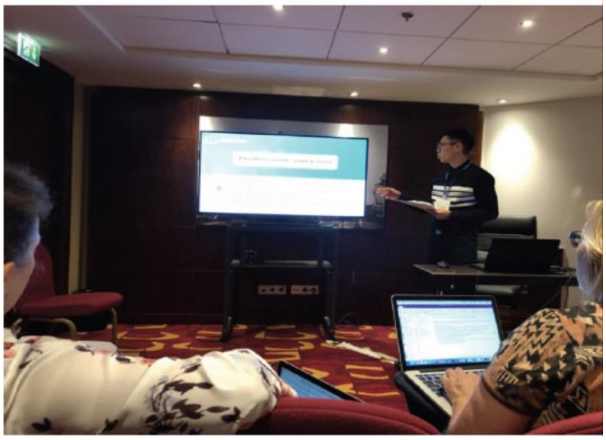
興趣的專業人才進行深度的交流，是能夠提昇自身的國際競爭力與研究視野的一大契機。以下為本人此次參與該會議之留影：

會議入口處留影

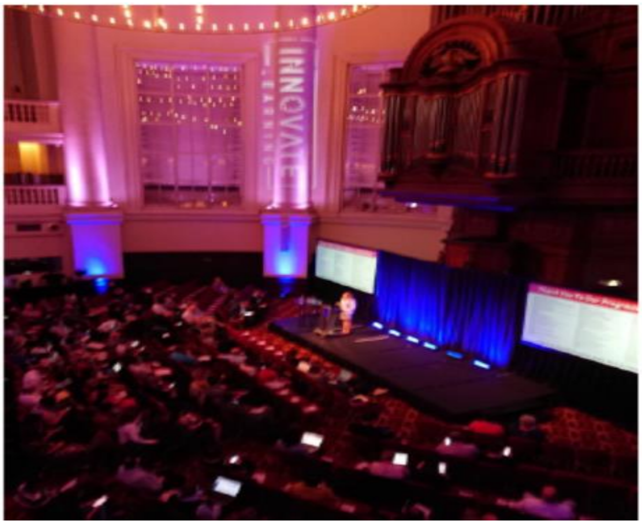


會議入口處留影

共同作者合影



博士班研究生報告



參與專題演講者之演講	參與專題演講者之演講

二、與會心得

透過這次出國發表的機會，除了可以將臺灣的教育研究成果與歐美的研究者分享外，也可以與國際學者進行學術交流，藉此機會建立良好的學術合作關係，未來將可以洽談國際合作或研究交流。相信若常參加此類研討會的國內學者，能夠與國際學者彼此交流對於相關理論、研究與應用等方面，進而激發出創新的研究方向或靈感。

三、建議

參與此類研討會能夠增加國際交流的經驗與增加研究合作的人脈，而參與會議的過程中可與其他國家的學者交流，建立跨國研究合作的契機。建議科技部能夠持續補助國內優秀學者參與此類國際重要之研討會，提昇臺灣教育相關研究的能見度，在國際社群中佔有一席之地，發揮其影響力。

四、攜回資料名稱及內容

論文會議手冊電子檔。

五、其他

附上本次發表論文 The role of elementary school students' scientific epistemic beliefs in a digital game-based learning environment 之摘要

The role of elementary school students' scientific epistemic beliefs in a digital game-based learning environment

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Abstract: This study attempted to understand the role of elementary school students' scientific epistemic beliefs in a digital game-based learning environment. A total of 107 elementary school students participated in this study. Two instruments were adopted to assess the participants' scientific epistemic beliefs and conceptual understanding with respect to the light and shadow concepts. The first finding indicated that the students' post-test scores were significantly higher than their pre-test scores, suggesting that the digital game-based learning environment is effective to promote their conceptual understanding performance. Second, the students with advanced scientific epistemic beliefs performed better than those in the less advanced scientific epistemic beliefs group in terms of their post-test scores. A further analysis suggests that the participants with advanced epistemic beliefs in the factor of "Justification" performed better than those with less advanced belief of the same factor in terms of post-test scores and gain scores. This result also echoed the correlational results, suggested that the "Justification" epistemic belief may be the most decisive factor in predicting the participants' conceptual performance.

107年度專題研究計畫成果彙整表

計畫主持人：林宗進			計畫編號：107-2511-S-003-004-MY2		
計畫名稱：臺灣高中生之科學學習投入研究：兼探科學知識觀信念與科學學習自我效能					
成果項目			量化	單位	質化 （說明：各成果項目請附佐證資料或細項說明，如期刊名稱、年份、卷期、起訖頁數、證號...等）
國內	學術性論文	期刊論文	0	篇	
		研討會論文	0		
		專書	0	本	
		專書論文	0	章	
		技術報告	0	篇	
		其他	0	篇	
國外	學術性論文	期刊論文	2	篇	Lin, T.-J. (under review). Multi-dimensional explorations into the relationships between Taiwanese high school students' science learning self-efficacy and engagement. International Journal of Science Education. Lin, T.-J. (under review). Taiwanese high school science learners' epistemic knowledge profiles and their multifaceted learning engagement. Research in Science Education.
		研討會論文	4		Chiu, Y.-J., Hsu, C.-Y., Liang, J.-C., Lin, T.-J., & Tsai, C.-C. (2018, June). The role of elementary school students' scientific epistemic beliefs in a digital game-based learning environment. Paper will be presented at the EdMedia + Innovate Learning International Conference (EdMedia 2018), Amsterdam, Nederland. Lin, T.-J. (2019, November). An exploratory study on the Taiwanese high school students' beliefs about knowing and learning engagement in science. Paper presented at the Third International Conference for "Personal Epistemology and Learning in Digital Age," Taipei, Taiwan. Kuo, T. M.-L., Lin, T.-J. & Wang,

					J.-C. (2019, December). Developing and validating the learning engagement with chatbot service scale (LECSS) for evaluating educational chatbot service. Paper presented at the 2nd International Conference of Innovative Technologies and Learning (ICITL 2019), Tromso, Norway. Lin, T.-J. (2020, June). Multifaceted effects of self-efficacy on Taiwanese high school students' learning engagement. Paper presented the 2020 annual meeting of Australasian Science Education Research Association (ASERA), Wollongong, NSW, Australia.
		專書	0	本	
		專書論文	0	章	
		技術報告	0	篇	
		其他	0	篇	
參與計畫人力	本國籍	大專生	3	人次	陳煒皓、張耀楚、范揚鑫
		碩士生	0		
		博士生	0		
		博士級研究人員	0		
		專任人員	0		
	非本國籍	大專生	0		
		碩士生	0		
		博士生	0		
		博士級研究人員	0		
		專任人員	0		
其他成果 （無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。）					

	成果項目	量化	名稱或內容性質簡述
科教國合司計畫加	測驗工具（含質性與量性）	2	Science Learning Engagement Instrument (SLEI)：高中生版與國小生版 Epistemic Knowledge of Science Instrument (EKSI)：高中生版
	課程/模組	0	
	電腦及網路系統或工具	0	

填項目	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	