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Developing instruments concerning scientific epistemic beliefs and goal orientations in learning science: a validation study

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ABSTRACT
The purpose of this study was to develop and validate two survey instruments to evaluate high school students' scientific epistemic beliefs and goal orientations in learning science. The initial relationships between the sampled students' scientific epistemic beliefs and goal orientations in learning science were also investigated. A final valid sample of 600 volunteer Taiwanese high school students participated in this survey by responding to the Scientific Epistemic Beliefs Instrument (SEBI) and the Goal Orientations in Learning Science Instrument (GOLSI). Through both exploratory and confirmatory factor analyses, the SEBI and GOLSI were proven to be valid and reliable for assessing the participants' scientific epistemic beliefs and goal orientations in learning science. The path analysis results indicated that, by and large, the students with more sophisticated epistemic beliefs in various dimensions such as *Development of Knowledge*, *Justification for Knowing*, and *Purpose of Knowing* tended to adopt both *Mastery-approach* and *Mastery-avoidance* goals. Some interesting results were also found. For example, the students tended to set a learning goal to outperform others or merely demonstrate competence (*Performance-approach*) if they had more informed epistemic beliefs in the dimensions of *Multiplicity of Knowledge, Uncertainty of Knowledge*, and *Purpose of Knowing*.

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Motivation; secondary/high school; learning environment

Introduction

The strand of personal epistemology research has been thriving in the field of educational psychology during the last few decades (Schraw, 2013). Personal epistemology researchers normally recognise that epistemic beliefs could be described as a multidimensional system composed of a number of mostly investigated dimensions such as certainty, simplicity, justification, or source of knowledge in the literature related to the nature of knowledge and knowledge acquisition (see Hofer & Pintrich, 1997). Numerous studies have investigated the influence of epistemic beliefs on students' learning orientations, processes, and outcomes. For instance, learners with more informed or advanced epistemic beliefs (i.e. knowledge as tentative, complex, or derived by reasoned justification) may be more

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likely to adopt deep learning strategies, possess stronger motivation for learning, and acquire better academic performance or outcomes (e.g. Cano, 2005; Phan, 2008; Tsai, Ho, Liang, & Lin, 2011).

Recently, a handful of researchers have challenged the issue of conceptualising and measuring personal epistemic beliefs about knowledge and knowing. One of the theoretical concerns pertains to the categories of epistemic beliefs. At present, those who have advocated a multidimensional perspective on epistemic beliefs have pointed out that the current dimensions may be insufficient to yield a reliable depiction of the nature of epistemic beliefs (e.g. DeBacker, Crowson, Beesley, Thoma, & Hestevold, 2008). Drawing on the philosophical discussions of knowledge, Chinn, Buckland, and Samarapungavan (2011) have also stressed the need to expand the dimensions of epistemic beliefs. However, very few empirical studies have explored this issue by means of a reliable instrument. Accordingly, this study attempted to broaden the current epistemic beliefs framework by adding several new dimensions.

Another aspect that has a long history but is often neglected by educators is learners' motivation. Many researchers (Alsop, 2005; Pintrich, 1999; Sinatra, 2005; Sinatra & Pintrich, 2003) have indicated that students' motivation plays a considerable role in shaping learning, and potentially interacts with cognitive constructs. Motivation depicts the individuals' desire to act or behave in a particular manner (Paulsen & Feldman, 1999). According to a body of studies, a common phenomenon in school science is that there seems to be a trend of falling motivation to learn science throughout the adolescent years, and a decline in willingness to take on challenging learning tasks in school or to consider future science-related careers (e.g. Lavigne, Vallerand, & Miquelon, 2007; Osborne, Simon, & Collins, 2003; Vedder-Weiss & Fortus, 2011). In light of the significance of students' motivation in science learning, it has been widely recognised as a crucial component of conceptual learning and conceptual change (Pintrich, Marx, & Boyle, 1993; Sinatra, 2005). However, in general, learners' motivational constructs have been less frequently investigated compared to other cognitive constructs, as contended by Koballa and Glynn (2007).

Among a variety of theories depicting learners' motivation, goal theory has received much attention within the educational psychology literature during the last two decades (Kaplan & Maehr, 2007). It is evident that learners' different goal orientations are associated with qualitatively different learning patterns and levels of academic engagement (e.g. Pintrich, 2000; Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2010). For instance, Pintrich (2000) pointed out that achievement goals considerably influence the nature of learning, as students with a mastery goal in an area are more likely to engage with material as they seek new information to further their understanding. It should be noted that, to date, this topic 'remains of particular urgency for those in the middle and high school grades' (Rolland, 2012, p. 397). Besides, motivation researchers (e.g. Buehl & Alexander, 2001; Dweck, 1999) have recommended that learners' goals may be rooted in and derived from their academic belief systems. Hence, it is likely that learners' epistemic beliefs are related to their goal orientations. A more detailed inspection may provide science educators with potential insights to better understand high school students' science learning characteristics.

Literature review

Situating epistemic beliefs

The educational psychology researchers have mainly focused on empirical observations of the epistemology of laypersons (Briell, Elen, Verschaffel, & Clarebout, 2011). After a scrupulous review of the personal epistemology research, Hofer and Pintrich (1997) proposed the 'epistemological theories' to conceptualise personal epistemology. They identified four dimensions, clustered into two core aspects, namely *nature of knowledge* (certainty of knowledge and simplicity of knowledge) and *nature of knowing* (source of knowledge and justification for knowing). The certainty of knowledge measures the degree to which an individual considers that knowledge is fixed or fluid, while the simplicity of knowledge regards knowledge as an accumulation of discrete facts or highly related concepts. On the other hand, the source of knowledge evaluates an individual's conception that knowledge comes from an external authority or originates from reasoning, while the justification for knowing refers to the approaches by which individuals justify knowledge claims, including the justification of experts and authority or evaluation via multiple sources. Due to the significance of this seminal work (Hofer & Pintrich, 1997), the epistemological theories have been widely employed to guide the following works in the line of personal epistemology research.

Since the last decade, investigations of students' scientific epistemic beliefs have received much attention (e.g. Conley, Pintrich, Vekiri, & Harrison, 2004; Tsai et al., 2011). For example, following on from the work of Hofer (2000) and Elder (2002), Conley and her colleagues (2004) focused on four dimensions of epistemic beliefs with respect to the nature of knowledge and knowing in science. These four dimensions, namely *Source of knowledge*, *Justification of knowing*, *Certainty of knowledge*, and *Development of knowledge*, are also aligned with the conceptual framework of Hofer and Pintrich (1997). The former two dimensions reflect beliefs about the nature of knowing, while the latter two represent beliefs about the nature of knowledge. They adapted existing questionnaire items (e.g. Elder, 2002; Schommer, 1990) and developed a quantitative measure to understand elementary school students' epistemic beliefs about science based on these four dimensions. Until now, this questionnaire is still one of the most frequently adopted quantitative measures when assessing students' scientific epistemic beliefs (e.g. Beghetto & Baxter, 2012; Kizilgunes, Tekkaya, & Sungar, 2009; Tsai et al., 2011).

The need to expand the dimensions of epistemic beliefs

As previously mentioned, a number of researchers have been striving to explore students' epistemic beliefs based on the four dimensions proposed by Hofer and Pintrich (1997). Although these four crucial dimensions have been widely explored, a handful of researchers have stressed the necessity of expanding or revising the framework to increase its predictive and explanatory power (Barzilai & Zohar, 2014; Chinn et al., 2011; Greene & Yu, 2014). For instance, Chinn et al. (2011) argued an expansion of the dimensions of epistemic beliefs to include components such as epistemic aims (i.e. people's goals for inquiry). Similarly, as explicated and claimed by Hofer and Pintrich (1997), additional dimensions of epistemic beliefs such as the *purpose* of knowledge or knowing have not been explicitly discussed in the personal epistemology research, and may warrant further investigation.

In science education research, some potential insights may contribute to the personal epistemology research. The development of an adequate understanding of epistemology of science has long been considered as one of the major goals of science education (AAAS, 1989; NRC, 1996). Understanding of epistemology of science involves beliefs about the nature of scientific knowledge, such as its purposes, its assumptions, and how it has developed over time (e.g. Kremer, Specht, Urhahne, & Mayer, 2014; Osborne et al., 2003; Urhahne, Kremer, & Mayer, 2011). For example, the purpose of science knowledge, as indicated by Driver, Leach, Millar, and Scott (1996), is an attempt to describe, explain, and predict natural phenomena. From the perspective of constructivism, the purpose of knowledge is not to represent reality, but to provide our interpretations and explanations, which allow us to picture the natural world (Alles, 2004; von Glasersfeld, 1998). In sum, as suggested by Chinn et al. (2011), how students view and adopt 'epistemic aims' in learning situations may have the potential to influence other epistemic beliefs and in turn affect the learning processes in which they engage.

Second, since the nature of knowing has been deemed as a core aspect of epistemic beliefs in the theory of Hofer and Pintrich (1997), the purpose of knowing in science may be of great importance to explore further. For constructivist learners, the purpose of knowing science should be regarded as an active process of knowledge construction, instead of a passive process of knowledge reproduction (Staver, 1998). Tsai (1998, 2000) has contrasted the purpose of knowing between empiricist and constructivist epistemology from the area of philosophy of science. He indicated that 'science does not represent the reality while scientists are producers of the reality, not the reproducers of the reality' (Tsai, 2000, p. 196). In other words, empiricist epistemology views science learning as an accumulation of facts, whereas constructivist epistemology regards learning as 'coping with experiences, relating to prior knowledge' (Tsai, 1998, p. 51). Therefore, constructivist learners (i.e. knowledge producers) may regard the purpose of knowing as an active process of knowledge construction by linking what they know about the physical world.

Conceptualising goal orientation

Achievement goal theory concerns the various purposes for engaging in achievement behaviour or tasks (Pintrich & Schunk, 2002). The key construct in achievement goal theory is goal orientation (Rolland, 2012; Vedder-Weiss & Fortus, 2011) which not only includes the purposes or reasons for achievement, but also establishes an internal standard by which learners judge their performance and success or failure in reaching that specific goal (Pintrich, 2000). In other words, goal orientation refers to why and how learners engage in academic activities in the context of academic behaviour (Vedder-Weiss & Fortus, 2011). Furthermore, it seems that goal orientation involves the nature of the reasons and purposes of approaching certain tasks, and the internal standards to evaluate task performance (Elliot & Thrash, 2001).

Several researchers have proposed a *multiple goals perspective* (e.g. Elliot, 1999; Elliot & McGregor, 2001; Elliot & Thrash, 2001). A 2-by-2 framework consisting of four distinct goal orientations has recently been advocated; those orientations are the mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance goals. The mastery-approach goal focuses on attaining task mastery or improvement.

The mastery-avoidance goal which has received relatively less theoretical and empirical attention in the literature (Kaplan & Maehr, 2007), represents striving not to fall short of task mastery (e.g. misunderstanding) or not to lose one's skills, abilities, or knowledge. As for the performance-approach goal, learners adopting this goal would be positively motivated to outperform others and to demonstrate their ability and superiority. In contrast, learners can be negatively motivated to strive to avoid failure or the demonstration of incompetence, which is labelled as the performance-avoidance goal.

Although the achievement goal orientation has received much attention in educational psychology, studies remain scarce in the field of science education. A handful of studies have been conducted in the domain of science (e.g. Chen, 2012; Chen & Pajares, 2010; Patrick & Yoon, 2004; Vedder-Weiss & Fortus, 2011, 2012). It is worth mentioning that, among the existing literature, very few studies have fully explored these four distinct achievement goals, suggesting that more efforts are required in this regard. In sum, based on the aforementioned considerations, this study explored Taiwanese high school students' goal orientations in terms of this 2-by-2 framework.

Learners' epistemic beliefs and goal orientations

In Hofer and Pintrich's (1997) review, they hypothesised that epistemic beliefs may function as a kind of implicit theory, which would give rise to particular achievement goal orientations. Later on, a number of studies examined the relations between epistemic beliefs and goal orientations (Braten & Stromso, 2004; Chen, 2012; Muis & Foy, 2010; Phan, 2008). Findings from these studies have typically shown that students who espouse more advanced beliefs are more likely to adopt mastery-approach goals. For instance, Chen (2012) investigated the relationships between the epistemic beliefs and achievement goal orientation of more than 1000 U.S. middle and high school students. The findings derived from zero-order correlation analysis indicated that the four dimensions proposed by Conley et al. (2004) had significant correlations to the mastery, performance-approach, and performance-avoidance goals. That is, for example, two dimensions of the scientific epistemic beliefs about knowing, namely Development (e.g. science knowledge is evolving and changing) and Justification (e.g. science knowledge should be based on evidence from different experiments), were positively correlated with the mastery goals as well as with the performance-approach goals, but negatively related to the performance-avoidance goals. The students' source epistemic belief had positive correlations with the mastery, performance-approach, and performance-avoidance goal orientations. In sum, these investigations only preliminarily undertook to unravel the underlying relationships between epistemic beliefs and goal orientations. More empirical evidence is needed to determine the nature of the relationships between students' epistemic beliefs and goal orientations in the domain of science. Thus, this study attempted to use a more rigorous method (i.e. the SEM technique) to understand the structural relationships between scientific epistemic beliefs and goal orientations in learning science.

Research purposes and questions

Based on the aforementioned, the main purpose of this study was to develop and validate two survey instruments in order to adequately evaluate Taiwanese high school students' scientific epistemic beliefs and goal orientation in learning science. After establishing the satisfactory validity and reliability of the two instruments, the initial relationships between the sampled high school students' scientific epistemic beliefs and goal orientations in learning science were unravelled. The concrete research questions are listed as follows.

1. Are the two survey instruments developed in this study (i.e. the SEBI and the GOLSI) valid and reliable based on the results of the exploratory and confirmatory factor analyses?
2. By using the SEM technique, what are the structural relationships between the Taiwanese high school students' scientific epistemic beliefs and goal orientations in learning science?

Methods

Participants

The initial sample included 623 senior high school students from 6 schools across the Northern, Central, Southern, and Eastern regions of Taiwan. Two to five classes were randomly chosen from each of these schools. All of the participants were invited to respond to the two instruments (described later) used in this study. Some of the returned surveys were regarded as invalid due to missing data or having the same repeated answer strings throughout the entire survey. After eliminating a number of invalid responses, a total of 600 senior high school students (i.e. 10th, 11th, and 12th graders) were regarded as the final sample. There were 309 male and 291 female students. The participants' ages ranged from 15 to 18, with an average age of 16.64.

The sampling process of this study was based on the following criteria. First, the selected students were roughly correspondent to the ratio of the actual distribution of Taiwanese high school students in terms of gender ratio and geographic location. Second, the sampled students were composed of those who had divergent academic achievements as well as socio-economic statuses from a number of public and private schools. It should be noted that, although these participants were not randomly chosen from the nation, the surveyed students from a variety of high schools in Taiwan might be said to represent many Taiwanese high school students and, to some degree, ensure the representativeness of the sampling.

Based on the abovementioned criteria, one of the researchers in this study first contacted collaborative school administrators and science teachers to obtain permission to carry out the survey. After receiving their consent, the school science teachers assisted in concurrently administering the two instruments to the participants. The purpose of this study and relevant instructions to the participants were briefly introduced before they were asked to complete the two instruments. The participants responded anonymously, and completed the two instruments within approximately 30 minutes.

Measuring students' epistemic beliefs in science

Since this study aims to expand the current understanding of the dimensions of scientific epistemic beliefs, the Scientific Epistemological Beliefs (SEB) questionnaire developed by

Conley et al. (2004) was adopted to serve as the basis for further revision in this study. The reasons for choosing this questionnaire are as follows. First, the dimensions of the SEB questionnaire encompassed the four dimensions of epistemological theories proposed by Hofer and Pintrich (1997). Second, this questionnaire was originally developed to assess students' epistemic beliefs in the domain of science. Third, it has been proven in many studies that the SEB questionnaire may be able to adequately capture Taiwanese students' scientific epistemic beliefs across different educational levels in terms of its high validity and internal consistency (e.g. Liang & Tsai, 2010; Tsai et al., 2011). Therefore, the SEB questionnaire would be more appropriate for further modification.

The SEB questionnaire originally developed by Conley et al. (2004) consisted of four dimensions, namely Source of Knowledge, Certainty of Knowledge, Development of Knowledge, and Justification for Knowing. Two additional dimensions (i.e. Purpose of Knowledge and Purpose of Knowing) were incorporated into the original SEB questionnaire. That is, based on the relevant works on Purpose of Knowledge (e.g. Alles, 2004; Driver et al., 1996; von Glasersfeld, 1998) and Purpose of Knowing (e.g. Staver, 1998; Tsai, 1998, 2000), the items were then designed to conform to the definitions of the two dimensions. In order to develop items for these two dimensions, a series of item generation procedures were followed. First, the relevant descriptions and items from the available literature (e.g. Driver et al., 1996; Tsai, 1998, 2000; Urhahne et al., 2011) were collected as the basis of item construction. Then, the researchers of this study collaboratively reviewed and discussed the clarity and relevance of each generated item. Further revisions were made if necessary. In turn, those finalised items formed the initial pool of items.

After establishing the initial pool of items, 5 experienced science education professors, 2 qualified senior high school science teachers, and 10 students were invited to review the adequacy (i.e. content validity) of the developed items. To be more specific, the science education professors commented on the proposed constructs and the overall comprehensiveness of each item to determine whether an item should be retained, revised, or removed. They also provided useful suggestions for improving the generated items such as clarifying the nature of specific constructs, or avoiding the ambiguity of statements. Then, the science teachers and students were mainly invited to clarify the wording of each statement. They were asked to review each statement and briefly explain their understanding with respect to the particular statement to ensure the readability of the items. The review results, in general, suggested some minor changes such as reducing the length of the item statements and clarifying ambiguous terms used within several sentences.

In turn, an adapted version named the SEBI with a total of 36 items presented with bipolar strongly agree/strongly disagree options on a 5-point Likert scale (i.e. *strongly agree, agree, somewhat agree and somewhat disagree, disagree, strongly disagree*) was developed to capture the students' scientific epistemic beliefs in this study. A detailed description of the six dimensions and corresponding sample items for each dimension are presented below:

(a) *Multiplicity of Knowledge* (five items): capturing students' beliefs about whether scientific knowledge is reliant on and transmitted from external authorities or is constructed by self-acquired knowledge from multiple sources. A sample item is 'Everybody has to believe what scientists say' (Reversed item).

(b) *Uncertainty of Knowledge* (six items): assessing students' beliefs about whether scientific knowledge is certain or whether it is uncertain and contextual. A sample item is 'All questions in science have one right answer' (Reversed item).
(c) *Development of Knowledge* (six items): evaluating students' beliefs about scientific knowledge as an evolving and changing subject. A sample item is 'Ideas in science sometimes change.'
(d) *Justification for Knowing* (nine items): examining students' views on the role of experiments and how an individual justifies scientific knowledge. A sample item is 'It is good to try experiments more than once to make sure of your findings.'
(e) *Purpose of Knowledge* (six items): capturing students' beliefs about whether the purpose of scientific knowledge is to reveal or to provide an explanation for reality. A sample item is 'The goal of scientific theories is to explain natural processes.'
(f) *Purpose of Knowing* (four items): assessing students' beliefs about whether the purpose of knowing is to accumulate a collection of facts or to cope with experiences, relating to prior knowledge. A sample item is 'The purpose of acquiring scientific knowledge is to construct a plausible way to understand one's surroundings.'

It should be noted that, in Conley et al.'s (2004) original SEB questionnaire, the two dimensions, Source of Knowledge and Certainty of Knowledge, were reverse-stated items. To avoid misinterpretation of the results of this study, these two dimensions were renamed as *Multiplicity* and *Uncertainty* for clarity in the SEBI. Also, those reverse-stated items were reversely scored. Accordingly, the students gaining higher scores in any dimension would show stronger agreement with the statements, suggesting a more sophisticated belief in that dimension. Due to the modifications to Conley et al.'s (2004) original SEB questionnaire, we performed a series of statistical processes such as exploratory and confirmatory factor analyses to carefully examine the reliability and validity of the SEBI based on the sampled students' responses (described later).

Evaluating students' goal orientations in learning science

Several instruments have been developed by science education researchers to assess students' goal orientations in learning science. For example, Pugh et al. (2010) adapted the Patterns of Adaptive Learning Survey (PALS, Midgley et al., 2000) to assess high school students' achievement goal orientations in biology courses in terms of a three-factor model (i.e. mastery, performance-approach, and performance-avoidance). Tuan, Chin, and Shieh (2005) developed the Students' Motivation toward Science Learning (SMTSL) questionnaire to understand Taiwanese junior high school students' motivation for learning science. Among the six scales of SMTSL, two were used to assess the students' goal orientations in learning science, that is the Performance goal and Achievement goal orientations. Nevertheless, very few studies have adopted the 2-by-2 achievement goal model to comprehensively understand learners' goal orientations in learning science. For this reason, in the current study, we adapted the Achievement Goal Questionnaire which originated from the study of Elliot and McGregor (2001).

As previously mentioned, the Achievement Goal Questionnaire (Elliot & McGregor, 2001) conforms to the 2-by-2 achievement goal model. In this study, a revised questionnaire for measuring students' goal orientations in learning science, namely the GOLSI, was developed. The original 12 items of Elliot and McGregor's questionnaire were firstly translated into Mandarin. After the translation process, 5 experienced science education professors, 2 qualified senior high school science teachers, and 10 students were invited to review the adequacy of the revised items to ensure the content validity of the GOLSI. Then, the back-translation items were also repeatedly compared with the original English statements until the discrepancies were resolved.

In turn, the GOLSI comprised three items for each dimension that 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. A description of each dimension with corresponding sample items is presented below.

(a) *Mastery-approach goal*: addressing students' goals in learning science as mastering tasks, understanding, and learning. A sample item is 'It is important for me to understand the content of the science course as thoroughly as possible.'
(b) *Mastery-avoidance goal*: measuring students' goals in learning science as avoiding misunderstanding, or avoiding not mastering tasks. A sample item is 'I worry that I may not learn all that I possibly could in science class.'
(c) *Performance-approach goal*: evaluating students' goals in learning science as outperforming others in science class. A sample item is 'It is important for me to do well compared to others in science class.'
(d) *Performance-avoidance goal*: capturing students' goals in learning science as avoiding inferiority in comparison to others. A sample item is 'My goal in science class is to avoid performing poorly.'

Accordingly, the students scoring higher on a certain dimension indicated stronger agreement with the statements. Furthermore, Elliot and McGregor (2001) conducted both exploratory and confirmatory factor analyses to ensure the structure, reliability, and validity of the questionnaire. The alpha reliability of the above four dimensions in the questionnaire used in their study were 0.87, 0.89, 0.92, and 0.83, respectively. It should be noted that, in the current study, the GOLSI items were devised from the original version of Elliot and McGregor (2001) and tailored for the context of science learning. As a result, a series of statistical procedures including exploratory and confirmatory factor analyses (presented later) were then employed in this study to carefully examine the reliability and validity of the GOLSI.

Data analysis

In order to answer the research questions raised in this study, the following data analysis procedures were undertaken. First, to ensure the factor structure and construct validity of each instrument, both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were utilised. This approach has been deemed to be a relatively rigorous way to establish the construct validity of an instrument (Hair, Black, Babin, & Anderson, 2010). It should be noted that the total sample of 600 students was evenly divided into two random sub-samples ($n = 300$) for the EFA and CFA, respectively. Second, the reliability of each instrument was then established in terms of the Cronbach's alpha reliability coefficient. In the rest of the analyses, the CFA sub-sample was used. Next, to initially explore the relationships between the students' scientific epistemic beliefs and goal orientations in learning science, a series of Pearson correlation analyses was performed based on the CFA sub-sample. The results of these analyses were then used to build the hypothesised paths. Finally, the SEM technique was employed to understand the structural relationships among the SEBI and GOLSI constructs in a hypothesised path model (Kelloway, 1998).

Results

Exploratory and confirmatory factor analyses of the SEBI

To initially validate the SEBI, an EFA with varimax rotation was conducted to clarify its structure. As shown in Table 1, the participants' responses were grouped into the six theorised factors, namely: *Multiplicity of Knowledge*, *Uncertainty of Knowledge*, *Development of Knowledge*, *Justification for Knowing*, *Purpose of Knowledge*, and *Purpose of Knowing*. The eigenvalues of the six factors from the principal component analysis were all larger than one. Items with a factor loading of less than 0.5 and with cross-loadings were excluded. Finally, a total of 30 items were retained, and total variance explained was 62.40%. The reliability coefficients in terms of Cronbach's alpha for the six factors were 0.80, 0.83, 0.88, 0.88, 0.85, 0.83, respectively, and the overall alpha was 0.88, indicating that these factors had satisfactory internal consistency for evaluating the students' scientific epistemic beliefs.

The CFA was used to further confirm the construct validity and the latent structure of the SEBI. The CFA factor loadings, the average variance extracted (AVE), composite reliability (CR), and the *t*-values of the items for each factor of the SEBI are shown in Table 2. As shown, all of the factor loadings and the *t*-values of the 30 items for the 6 factors of the SEBI show significance at the 0.05 level, specifying the relations of the observed measures (i.e. items) to their posited underlying constructs (i.e. factors). In addition, the AVE and CR values of all constructs are above the cut-off values of 0.50 and 0.70, respectively, ranging from 0.55 to 0.70 and from 0.83 to 0.92, respectively. Pertaining to the goodness-of-fit indices of the model, the ratio of chi-square to degrees of freedom = 1.69, goodness of fit index (GFI) = 0.96, normed fit index (NFI) = 0.95, non-normed fit index (NNFI) = 0.96, comparative fit index (CFI) = 0.97, and root mean square error of approximation (RMSEA) = 0.0046, suggesting a satisfactory model fit.

Besides, the 300 students' average item scores (i.e. mean scores) and the standard deviations of the six factors of the SEBI are shown in Table 2. That is, the students scored highly on the 'Development of Knowledge' factor (an average of 4.20 per item) and on the 'Justification for Knowledge' factor (an average of 4.10 per item). Their scores on

Table 1. The results of the exploratory factor analysis of the SEBI ($n = 300$).

Factor	Number of item	Factor loading	Cronbach's alpha
Multiplicity of Knowledge	4	0.70–0.82	.80
Uncertainty of Knowledge	5	0.52–0.78	.83
Development of Knowledge	5	0.69–0.83	.88
Justification for Knowing	7	0.59–0.74	.88
Purpose of Knowledge	5	0.68–0.77	.85
Purpose of Knowing	4	0.55–0.70	.83

Note: Total variance explained: 62.40%, overall alpha = 0.88.

Table 2. The results of the confirmatory factor analysis of the SEBI ($n = 300$).

Factor	Number of items	Factor loading	*t*-value	AVE	CR	Mean (S.D.)
Multiplicity of Knowledge	4	0.69–0.83	10.88*–15.34*	0.57	0.84	3.25 (0.75)
Uncertainty of Knowledge	5	0.67–0.77	11.35*–15.65*	0.67	0.83	3.81 (0.68)
Development of Knowledge	5	0.70–0.89	14.38*–19.11*	0.62	0.89	4.20 (0.61)
Justification for Knowing	7	0.70–0.83	12.32*–17.12*	0.61	0.92	4.10 (0.61)
Purpose of Knowledge	5	0.68–0.77	11.72*–14.95*	0.55	0.86	3.66 (0.68)
Purpose of Knowing	4	0.75–0.83	13.25*–16.54*	0.70	0.88	3.78 (0.69)

Notes: AVE: Average Variance Extracted; CR: Composite Reliability. Chi-square per degrees of freedom = 1.69, GFI = 0.96, NFI = 0.95, NNFI = 0.96, CFI = 0.97, RMSEA = 0.046.
*$p < .05$.

the 'Multiplicity of Knowledge' factor, an average of 3.25 per item, were the lowest compared to the other factors.

Exploratory and confirmatory factor analyses of the GOLSI

Following the same procedure, an EFA with varimax rotation was carried out to clarify the structure of the GOLSI. As shown in Table 3, the 300 students' responses were grouped into four factors, namely *Mastery-approach*, *Mastery-avoidance*, *Performance-approach*, and *Performance-avoidance*. The eigenvalues of the four factors from the principal component analysis were all larger than one. All of the 12 items were retained in the finalised version of the GOLSI, and the total variance explained was 78.05%. Furthermore, the reliability coefficients in terms of Cronbach's alpha for these four factors were 0.86, 0.88, 0.90, 0.83, respectively, and the overall alpha value was 0.88, suggesting that these factors had high internal consistency for evaluating the students' goal orientations in learning science.

The CFA was performed to further confirm the construct validity and the underlying structure of the GOLSI. The CFA factor loadings, the AVE, CR, and the *t*-values of the items for each factor of the GOLSI are shown in Table 4. That is, all of the factor loadings and the *t*-values of the 12 items on the four factors of the GOLSI show significance at the 0.05 level, specifying the relations of the observed measures to their posited underlying constructs. In addition, the AVE and CR values of all of the constructs are above the cut-off values of 0.50 and 0.70, respectively, ranging from 0.66 to 0.77 and from 0.85 to 0.91, respectively. Pertaining to the GFIs of the CFA model, the ratio of chi-square to degrees of freedom = 1.86, GFI = 0.95, NFI = 0.97, NNFI = 0.96, CFI = 0.98, and RMSEA = 0.039, suggesting a reasonable model fit.

Table 4 also illustrates the 300 students' average item scores and the standard deviations of the 4 GOLSI factors. That is, the students attained relatively high scores on the *Mastery-approach* (an average of 3.70 per item) and on the *Mastery-avoidance* (an average of 3.75)

Table 3. The results of the exploratory factor analysis of the GOLSI ($n = 300$).

Factor	Number of item	Factor loading	Cronbach's alpha
Mastery-approach	3	0.78–0.85	0.86
Mastery-avoidance	3	0.73–0.86	0.88
Performance-approach	3	0.82–0.90	0.90
Performance-avoidance	3	0.82–0.89	0.83

Note: Total variance explained: 78.05%, overall alpha = 0.88.

Table 4. The results of the confirmatory factor analysis of the GOLSI ($n = 300$).

Factor	Number of item	Factor loading	t-value	AVE	CR	Mean (S.D.)
Mastery-approach	3	0.81–0.92	15.75*–19.31*	0.76	0.90	3.70 (0.80)
Mastery-avoidance	3	0.86–0.90	17.10*–19.05*	0.77	0.91	3.75 (0.85)
Performance-approach	3	0.77–0.95	14.79*–20.61*	0.77	0.91	3.30 (1.01)
Performance-avoidance	3	0.76–0.85	13.77*–16.01*	0.66	0.85	3.12 (0.95)

*$p < .05$.

Notes: AVE: Average Variance Extracted; CR: Composite Reliability. Note: Chi-square per degrees of freedom = 1.86, GFI = 0.95, NFI = 0.97, NNFI = 0.96, CFI = 0.98, RMSEA = 0.039.

factors, while attaining the lowest score on the *Performance-avoidance* factor (an average of 3.12).

Relationships between students' epistemic beliefs and goal orientations in science

Pearson correlation analysis was also conducted to explore the relations between the students' responses on the SEBI and GOLSI. As shown in Table 5, the *Multiplicity of Knowledge*, *Development of Knowledge*, *Justification for Knowing*, *Purpose of Knowledge*, and *Purpose of Knowing* factors of the SEBI were positively related to the *Mastery-approach*, *Mastery-avoidance*, and *Performance-approach* factors of the GOLSI ($r = 0.15$~0.48, $p < .001$). The SEBI factor *Uncertainty of Knowledge* only positively associated with the GOLSI factor *Performance-approach* ($r = 0.24$, $p < .001$). However, no significant relations were found between the GOLSI factor *Performance-avoidance* and any of the SEBI factors in the current study.

As mentioned above, the correlation results were then adopted as hypothesised paths to conduct the path analysis through SEM analysis. In turn, a path model was proposed to further verify the structural relationships between Taiwanese students' scientific epistemic beliefs and goal orientations in learning science. As a result, the path analysis results indicated that the model could adequately explain the collected data. The fit indices were indicative of satisfactory model-to-data fit (i.e. Chi-square per degrees of freedom = 2.12, GFI = 0.92, NFI = 0.96, NNFI = 0.97, CFI = 0.98, RMSEA = 0.051). As shown in Figure 1, first, the SEBI factors, *Multiplicity of Knowledge*, *Development of Knowledge*, *Justification for Knowing*, and the two newly added dimensions *Purpose of Knowledge* and *Purpose of Knowing* have significantly positive contributions to the GOLSI factor *Mastery-approach*. Second, the SEBI factors, *Development of Knowledge*, *Justification for*

Table 5. The correlations between the students' responses on the SEBI and GOLSI ($n = 300$).

	SEBI					
GOLSI	Multiplicity of Knowledge	Uncertainty of Knowledge	Development of Knowledge	Justification for Knowing	Purpose of Knowledge	Purpose of Knowing
Mastery Approach	0.23***	0.06	0.39***	0.48***	0.38***	0.45***
Mastery Avoidance	0.15***	0.07	0.33***	0.37***	0.19***	0.28***
Performance Approach	0.17***	0.24***	0.16***	0.18***	0.16***	0.25***
Performance Avoidance	0.10	0.06	0.08	0.04	0.09	0.05

***$p < .001$.

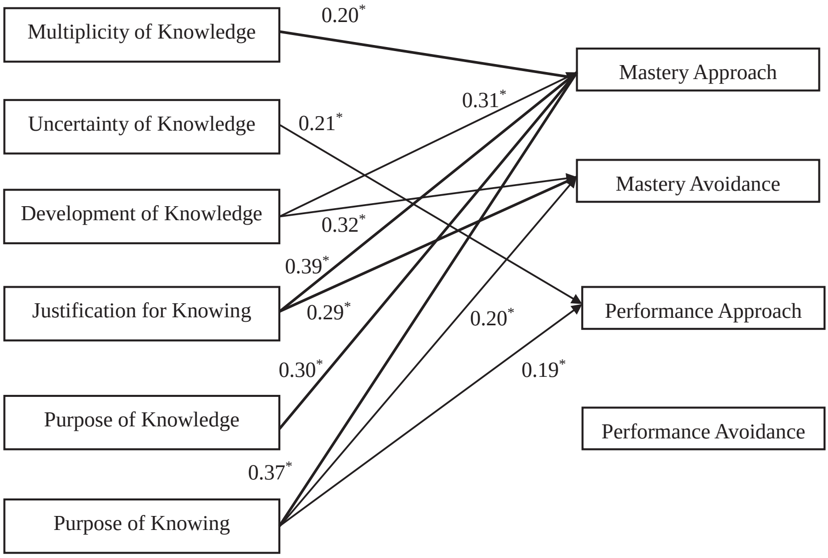

Figure 1. Path analysis and path coefficients of SEBI and GOLSI.
Note: $*p < .05$. Chi-square per degrees of freedom = 2.12, GFI = 0.92, NFI = 0.96, NNFI = 0.97, CFI = 0.98, RMSEA = 0.051.

Knowing, and *Purpose of Knowing*, could serve as positive predictors of the GOLSI factor *Mastery-avoidance*. The SEBI factors, *Uncertainty of Knowledge* as well as *Purpose of Knowing*, could positively contribute to the GOLSI factor *Performance-approach*. In sum, the path analysis results suggest that, by and large, it seems that the students with more sophisticated epistemic beliefs in terms of appreciating the developmental nature of science knowledge, the justification of knowledge claims, and the purpose of knowledge acquisition and construction, tended to adopt two types of mastery goals. Besides, those who appreciated that science knowledge could be acquired from multiple sources and that the purpose of science knowledge is to provide logical explanations of the natural world were more oriented to set learning goals of mastering science. Moreover, the students tended to set a learning goal to outperform others if they believed the nature and aim of science knowledge could be acquired from multiple sources and is an active process of knowledge construction.

Discussion

This study attempted to develop and validate the two instruments, the SEBI and GOLSI, by means of commonly adopted methods, including exploratory and confirmatory factor analyses. In particular, on the one hand, the SEBI incorporated four commonly investigated dimensions proposed by Conley et al. (2004), and expanded the notion of epistemic beliefs by adding two dimensions, *Purpose of Knowledge* and *Purpose of Knowing*, as suggested by Chinn et al. (2011). On the other hand, this study is one of the few to attempt to understand students' goal orientations in learning science according to the 2-by-2 goal model, as suggested by motivational researchers (Elliot & McGregor, 2001). Through both exploratory and confirmatory factor analyses, the two developed instruments were proven to be valid and reliable for assessing the participants' scientific epistemic beliefs and goal orientations in learning science. The two instruments used in this study could be useful and meaningful survey tools for science education researchers to conduct relevant studies in the future. For example, in this study, the two instruments were only validated with a Taiwanese high school student sample. Researchers interested in this line of research could adopt the two instruments as prototypes, with certain modifications if necessary, to conduct subsequent studies of other countries, different levels of learning, or different educational contexts.

After the statistical results were gathered from the exploratory and confirmatory factor analyses to evaluate the effectiveness of the SEBI and GOLSI, the structural relations between the Taiwanese high school students' scientific epistemic beliefs and goal orientations in learning science were investigated. In general, the students with more sophisticated epistemic beliefs in various dimensions tended to adopt mastery-oriented learning goals. Similar findings could be found in the previous investigations (e.g. Chen & Pajares, 2010; Kizilgunes et al., 2009). In fact, researchers (e.g. Mason, Boscolo, Tornatora, & Ronconi, 2013) have accounted for the relations between the epistemic beliefs and goal orientations. Students' epistemic beliefs are the internal standards to interpret a task, which then influence how they define their learning goals (Muis, 2007). It is very likely that students with more sophisticated epistemic beliefs may set up a goal to understand by engaging in meaningful and deep processing (Mason et al., 2013). They may express a strong innate desire to truly understand the scientific knowledge in the process of scientific inquiry, thus intrinsically motivating their science learning and adopting a mastery goal (Liang, Lee, & Tsai, 2010). It is worth noting that past studies (e.g. Liang & Tsai, 2010; Tsai et al., 2011) have also documented that Taiwanese students' beliefs about justification of knowledge play a relatively more influential role than other dimensions of their epistemic beliefs. Mason et al. (2013) also found that students' beliefs about justification of scientific knowledge are a strong and positive predictor of their mastery goal orientation. This study also corroborates relevant findings of previous studies.

This study further identified that the students with sophisticated epistemic beliefs were also prone to set a *Mastery-avoidance* goal to avoid misunderstanding the science learning materials. *Mastery-avoidance* goals, as suggested by Elliot and MacGregor (2001), oftentimes relate to anxiety during task engagement. In fact, Taiwanese students have been regarded as high test-anxiety learners because of the standardised tests and nationwide examinations (Lin, Deng, Chai, & Tsai, 2013). The students with sophisticated epistemic beliefs may be strongly influenced by the over-emphasised high-stakes standardised examinations at both the school and national levels in Taiwan. That is, when preparing for these tests and examinations, these students may suffer from more anxiety and pressure from themselves, teachers, and parents. Thus, they also tend to adopt *Mastery-avoidance* goals in their science learning. This speculation could be further investigated in the future.

As previously mentioned, although the past findings mostly indicate that sophisticated epistemic beliefs could positively predict mastery-oriented goals, this study found that the students who believed in science knowledge as uncertain (i.e. those with sophisticated epistemic beliefs) were more likely to adopt a learning goal of outperforming others to gain favourable judgments of their competence (i.e. *Performance-approach* goal). This particular phenomenon may be due to the sociocultural and educational environments of Taiwan. Traditionally, these sociocultural and educational contexts in Taiwan are rooted in Confucianism whereby students should respect senior authority figures such as parents and teachers (Tweed & Lehman, 2002). In fact, those believing that science knowledge is uncertain and contextual may think that there should be more than one fixed answer to scientific problems shown in standardised tests and examinations. Although Taiwanese students recognise the uncertainty of science knowledge, they still rely on teachers' opinions as the authoritative source of the *correct* answers. The quizzes, homework, and tests assigned by science teachers are also formatted as providing a certain answer to a question, similar to the national high-stakes examinations in Taiwan. At the same time, in order to enter prestigious universities, Taiwanese students may be under intensive pressure from their parents and teachers, and be judged by how well they outperform others in terms of classroom performance and test scores to determine their academic success or failure (Tsai et al., 2011). Ho and Liang (2015) also suggested that the more Taiwanese students believe in the uncertainty of science knowledge, the less they are motivated to seek deep and meaningful learning in science. Combining the two, those students with more sophisticated epistemic beliefs in the uncertainty of science knowledge may, in contrast, choose to adopt a *Performance-approach* goal orientation in learning science in such learning environments. Further research is definitely needed to verify this speculation.

It is also interesting to point out that a significantly positive relation between *Purpose of Knowing* and *Performance-approach* was also found. In other words, those Taiwanese students with a more informed belief in purpose of knowing tended to adopt not only both mastery-oriented goals but also *Performance-approach* goals in learning science. In fact, Hofer and Pintrich (1997) asserted that the process of knowing (e.g. purpose of knowing) may be closely associated with the process of learning (e.g. conceptions of learning). In the study of Lee, Johanson, and Tsai (2008), the findings suggested that Taiwanese high school students who believed that learning science is applying learned knowledge to real-life contexts and seeking in-depth understanding tended to possess not only deep motive but also surface motive toward science learning. This phenomenon may be due to the educational climate that strongly emphasises their performance on high-stakes examinations and school activities to enter prominent universities in Taiwan. Thus, the students with more informed epistemic beliefs about the purpose of knowing may tend to set normative standards in science learning (*Performance-approach* goals) such as test scores and grades, in addition to *Mastery-approach* goals.

Based on the above-mentioned findings, it is also possible that the students with more informed epistemic beliefs in *Purpose of Knowing* could adaptively set both mastery and performance goals in various learning situations. For example, Pintrich (2000) has suggested that secondary school learners with high-mastery and high-performance goals tended to have better strategy use and self-efficacy. In the study of van der Veen and Peetsma (2009), the Dutch first-year university students of the lowest level of secondary education achievements with both high mastery and performance goal orientations tended to be more self-regulated in their cognition in terms of metacognitive strategy use. Bromme, Pieschl, and Stahl (2010) also claimed that students with more sophisticated epistemic beliefs should be better at calibrating or adapting their learning process to set different goals for different learning tasks. This study may provide further evidence that developing a more informed epistemic belief in the dimension of *Purpose of Knowing* may be a crucial and viable way of cultivating students to become better self-regulated learners.

Implications

Some of the above-mentioned indications also reflect the limitations of this study. One is the fact that it only employed two self-reported instruments to understand Taiwanese students' epistemic beliefs and goal orientations. Although the relations have been quantitatively identified, the indications provided in this study could be further substantiated by means of diverse methods such as open-ended questionnaires, interviews, or reflective journals to better capture and understand the relationships and to interpret them through a sociocultural lens. Besides, although the sample of this study drew from a variety of high schools across different main regions in Taiwan and, as such, was fairly representative of the larger population of high school students, generalisation of the findings may be limited to a certain extent. Replicated studies with a national random sample may be meaningful in consolidating the findings of this study. Moreover, this study did not take relevant background variables such as gender or grade into consideration to explore the differences and similarities between the two main constructs, suggesting that further substantial work is needed.

Some implications are also provided here for practitioners and teacher educators. First, mastery-oriented learning goals are deemed to be, in general, related to positive outcomes such as the use of deep processing and learning strategies, task engagement, self-efficacy, and academic achievement (Mason et al., 2013). As Rolland (2012) indicated, students who perceived their classrooms to be higher in mastery goals had, on average, higher levels of personal mastery goals. In other words, learning and educational environments may have an impact on students' goal orientations in learning science. Thus, as mentioned above, the emphasis on high-stakes assessments and examinations in Taiwan would reduce students' intentions to adopt mastery goals. 'Supportive teacher-student classroom interactions, in addition to dyadic relationships, are related to students' perceived competence and academic achievement' (Rolland, 2012, p. 423), suggesting that science teachers should create a supportive science classroom environment that highlights developing personal competence and improvement instead of emphasising a reproductive-oriented assessment and learning framework.

Second, Hofer and Pintrich (1997) proposed that epistemic beliefs can generate particular types of goals for learning, and that these goals can serve as guides for self-regulatory cognition and behaviour. These goals, in turn, can influence the types of learning and metacognitive strategies learners use when learning and problem-solving. Promoting students' sophistication of scientific epistemic beliefs is imperative, and is the first priority in self-regulated learning (Muis, 2007). Science teachers should engage students in meaningful learning by providing them with a more authentic science learning context such as argumentation, informal reasoning, and reflective thinking about the aspects of scientific knowledge and knowing processes.

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