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RESEARCH REPORT

Development of an Instrument Designed to Investigate Elements of Science Students' Metacognition, Self-Efficacy and Learning Processes: The SEMLI-S

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The development and evaluation of science students' metacognition, learning processes and self-efficacy are important for improving science education. This paper reports on the development of an empirical self-report instrument for providing a measure of students' metacognition, self-efficacy and constructivist science learning processes. A review of the range of literature related to metacognition, self-regulation and constructivist learning processes resulted in the development of an initial bilingual (English and traditional Chinese) instrument composed of 72 items. This instrument was completed by 465 Hong Kong high school students. The data collected were subjected to exploratory factor analysis and Rasch analysis. The subsequent refinement process resulted in a final version of the Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S) consisting of 30 items that can be used for either analysing and focusing on any or all of its dimensions or for assigning scores to individuals that enable comparison between them in relation to their metacognitive science learning orientations.

Introduction

Metacognition is a construct that is often considered to confer attention on the improvement of students' learning processes and consequently their learning outcomes. Since Flavell's seminal work (Flavell, 1976, 1979) there has been continual interest in and research into how to develop, enhance, and measure students' metacognition. One reason for the constancy of this research agenda is the possibility

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that students' learning processes can be developed and improved. It is often argued that the importance of metacognition lies in its potential to explore, explain and ultimately to improve students' thinking and learning processes (White, 1988, Thomas and McRobbie, 2001). Such a possibility promotes optimism in education circles and provides an alternative to deficit models of cognition that so often view students' learning potentials as fixed, pre-determined, and beyond the salvation of any form of intervention.

However, while the continuing considerations of and research into metacognition have provided valuable insights for improving student learning, such activities have not been without their problems, many of which persist. Veenman, Hout-Wolters, and Afflerbach (2006) highlighted the ongoing concern raised by Wellman (1985) that metacognition is a fuzzy concept that lacks coherence and that means many things to many people. They note that, 'while there is consistent acknowledgement of the importance of metacognition, inconsistency marks the conceptualisation of the construct' (p. 4). This issue is evident within the science education literature where metacognition has been defined as, for example, knowledge, control and awareness of learning processes (Baird, 1990; Thomas & McRobbie, 2001) and the ability to think about one's thinking (Gilbert, 2005), with Blank (2000) positing additionally that students' consideration of the status of their science ideas also constitutes an aspect of metacognition. Veenman et al also suggested that terms such as self-regulation, metacognitive awareness and learning strategies are commonly associated with metacognition. Consequently, the relationship between metacognition and self-regulated learning and the actual learning processes that students employ should be acknowledged wherever possible because while it is often interesting and informative to look at metacognition as a 'stand-alone' concept, it does not influence learning outcomes in isolation but rather is related to other elements of learning theory. Schraw, Crippen and Hartley (2006), in summarising the literature related to this matter, contend that metacognition and the strategies and processes that students employ are subsets of self-regulation and that other elements of self-regulation such as self-efficacy, the extent to which individuals are confident in relation to performance of tasks or goal attainment, are also influential in determining learning outcomes.

Accordingly, while there is a need for practitioners to subscribe to theoretical frameworks and constructs upon which they can agree, and to have their foundations in research studies, there is also a need to recognise that understanding how students learn science is a complex matter and that no one construct—such as metacognition—can account for all variations in learning processes and outcomes. We view such an agglomeration of interacting and complementary constructs relevant to understanding a student's science learning processes as comprising their metacognitive science learning orientation. We choose to use the word 'orientation' to suggest that any assessment, evaluation or measurement of such a characteristic of any student or group of students is situation- and context-related and that any individual or group of individuals' responses may vary between subject areas and over time. Therefore, we suggest that constructs such as metacognition be considered wherever possible in concert with other relevant aspects of learning theory if they are to be operationalised for use in classroom and individual interventions and other research into such endeavours.

The assessment and evaluation of students' metacognition also presents a problem. This matter manifests itself in two ways. The first is evident because of the aforementioned variations in the definition of the construct and the relation of that construct with others that also help explain students' learning. Obviously, the nature of the framework that is operationalised for considering metacognition and its related areas will influence greatly the foci of any intervention or research studies. The second relates to the methodologies, research strategies and instruments that might be employed to seek empirical data for use in, for example, evaluating the nature and extent of students' metacognitive knowledge and metacognitive processing, and evaluating the effects of interventions designed to develop and/or enhance students' metacognition (Garner & Alexander, 1989; Schraw & Impara, 2000). In relation to these issues, Veenman et al. (2006) suggested that attention should be directed to considering metacognitive knowledge and skills that are both general across subject domains as well as those that are more domain related. We see this suggestion as reasonable, but propose however that teachers and students in science learning settings see themselves as teaching and learning science and that their teaching and learning activities at any given time will be closely related to the science material under consideration. We do not disagree with Veenman et al. (p. 7) that, 'general metacognition may be instructed concurrently in different learning situations and may be expected to transfer to new ones.' We mean simply to highlight the importance of the context within which teachers and students undertake their roles.

Most research into metacognition relies on self-report measures from students (Rowe, 1991; Royer, Cisero, & Carlo, 1993). Self-report measures are probes of students' metacognitive knowledge and their perceived use of metacognitive strategies that ask students to consider the nature and extent of their cognition and metacognition and rate their use of cognitive and metacognitive processes. Most existing empirical self-report instruments that explore students' learning and metacognition, such as the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich & Garcia, 1993; Pintrich, Smith, Garcia, & McKeachie, 1991), the Learning and Study Strategies Inventory (LASSI) (Weinstein, Schulte and Palmer, 1987), the Assessment of Cognitive Monitoring Effectiveness (ACME) (Osborne, 1998) and the Learning Processes Questionnaire (LPQ) (Biggs, 1987) , do not account for the classroom context or help students locate their self-report in relation to the learning of specific subjects such as science. Further, they are premised on general metacognitive and cognitive constructs (Schraw, 2000). Schraw also observes that many instruments developed to measure metacognition and related constructs often have unknown psychometric properties and were developed for use for specific studies.

We propose, therefore, that it would be valuable for empirical instruments to be used in science classrooms for studying metacognition and related constructs to acknowledge the interplay between the context of the subject being taught and learned and the metacognition and related learning processes associated with the learning of science material. Of relevance to this proposal are the suggestions of Gunstone (1994) and Thomas and McRobbie (2001) that there is a need to acknowledge the importance of the nature of science content and processes when investigating metacognition in science learning settings. This is also in accord with the need to recognise the close and sometimes inseparable distinction between cognitive and metacognitive processes. What this means for the construction of instruments for use in science classrooms is that it is reasonable to specify to students that any self-report that is being sought from them regarding the processes they use when they learn science should relate specifically to their science learning. There are precedents for such a perspective in science education in the area of learning environments research. Widely used instruments such as the Constructivist Learning Environment Scale (Taylor, Fraser & White, 1994) and the Metacognitive Orientation Learning Environment Scale—Science (Thomas, 2003, 2004) employ prefixes such as 'in this science classroom' and/or statements in the introduction of the instrument to help students locate their reflection and self-report specifically in relation to their science classroom learning environments, even though the items might be considered to be related to general parameters of any classroom environment. In other words, students might be asked to focus on general statements as they relate specifically to their science learning and this might be some way to ease the aforementioned tension to acknowledge domain general as well as more domain specific learning processes and metacognition.

This paper describes the development of an instrument designed to investigate broadly aspects of science students' metacognition, self-efficacy and learning processes. We aimed to develop a psychometrically sound and justifiable instrument that attended to a range of factors related to metacognition and learning processes that are relevant to students' science learning. This might be used as one of a range of indicators in the assessment and evaluation of metacognition and learning processes that are relevant to current perspectives of science education, and that might be easy for teachers and science educators to administer and interpret the data from.

Methodological Considerations and Field Testing

The aforementioned issue of how to deal with the various conceptions of and interactions between metacognition, self-regulated learning and cognition was important in the initial stages of writing items for an initial instrument. To acknowledge the various operational definitions of metacognition, we decided to write items that reflected the broad scope of metacognition as reflected in the literature, and to include items associated with self-regulated learning such as self-efficacy. Furthermore, given the relationship between metacognition and cognition, it was deemed appropriate to include items that reflected constructivist learning processes, especially those related to the conscious interrelation and association of concepts and ideas. These are highly relevant to the development of conceptual understanding in science education and have guided much of contemporary science education research (Tobin, 1993; Fraser & Tobin, 1998). We considered that the inclusion of such a broad range of items and dimensions might: (a) accommodate the aforementioned issues related to metacognition; and (b) enhance potentially the breadth of use of the final form of the instrument.

Following a review of the literature and other relevant instruments such as those previously mentioned an initial set of items was developed. Because the development of this instrument and initial field testing was conducted primarily in Hong Kong where Cantonese is the mother tongue and traditional Chinese is the major written script, linguistic issues were of importance. The items were written initially in English and then a series of translations and back translations as recommended by Brislin (1976, 1980) and Brislin, Lonner and Thorndike (1973) took place using experienced translators so that conceptually equivalent English and traditional Chinese versions of the instrument were developed. The items were reviewed by colleagues, including readers of both English and traditional Chinese, from Hong Kong, Canada, the USA and Australia, who had expertise in metacognition, science learning and scale construction. Such scrutiny of the items and their face validity led to the deletion, modification and inclusion of some items prior to field testing.

The resulting 72-item initial instrument utilised a five-point Likert scale (1 = never or almost never; 2 = sometimes; 3 = about half the time; 4 = frequently; 5 = always or almost always). It asked students to self-report on the frequency of their engagement in particular metacognitive, cognitive and behavioural processes and about their self-efficacy as science learners. The 72 items for this initial phase of instrument development fell within one of seven tentatively constructed dimensions that could be considered to best reflect our understanding of their orientation in terms of existing relevant theory. They were used for reasons of convenience only and to help us to relate items to what was already known from the literature. These dimensions, reflecting our *a priori* understanding of the literature, were Control/Regulation, Monitoring, Awareness, Evaluation, Planning, Behavioural Evidence of Metacognition, and Self-Efficacy. However, our intention was never to write and validate only items that fell neatly within these pre-determined dimensions as is the case with many psychometric surveys. From the outset we decided not to be bound by our *a priori* conceptions and the consequent dimensions within which each of the 72 items might have been located tentatively following the process of scale reduction and item deletion, no matter how convenient. Rather, we made the conscious decision to allow the analysis of the statistical data obtained from the participants to guide our final categorisation of the items and the dimensions in which they were located, even though we were aware that such action might result in conflict between our final proposal for item categories and dimensions and put us at odds with existing theory and theorists. In other words, the final dimensions of the Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S) reflect our analysis of participants' views as represented their item responses rather than our own *a priori* views. Such an approach can be justified as a reasonable alternative to commonly used content/construct based approaches that pre-determine dimensions and subscales exclusively according to existing theory (Aiken, 1982). Finally, prior to the large scale field testing of the instrument, advice from a sample of 40 students on the nature of the items and their comprehension of the items was sought (Nashon, Anderson, Thomas, Yagi, Neilsen, & Hisasaka, 2005; Anderson & Nashon, 2007). Students' advice was that the items were reasonable, unambiguous and comprehensible and that students were able to justify their responses to their self-reports on the items. This rigorous process of item development, review and revision gave us confidence to field test the instrument.

The initial instrument was administered to 465 students across 19 classes of forms two to seven (13–18 years of age) during their science classes. Of this sample 163 were from form two, 154 were from form four and 148 were from forms six and seven. In this way, we sought to ensure that responses from across the levels of secondary schooling were obtained. It was made very clear to students that their responses were required in relation to their science learning processes.

Analysis

The data were subjected to analysis which employed exploratory factor analysis and Rasch analysis in an iterative manner. Our purpose in employing such an approach was to explore factors that might be useful as dimensions or sub-scales in a final instrument, and also to look at the unidimensionality of the overall scale as an indicator of students' metacognitive science learning orientations. Factor analysis is a commonly used procedure for discerning dimensions and subscales in such instruments. Each factor provides information about an individual's self-perception of the extent to which they perform or otherwise in relation to the construct reflected in the dimension.

However, while the practice of adding scores from particular factors together to compute an overall score for individuals is common, such a practice is often inappropriate (Bond & Fox, 2001). To develop individual sum scores requires that the scale should measure some overall unidimensional construct. Rasch analysis aids and facilitates the process of item deletion so that the instrument can be calibrated and its unidimensionality can be established and examined. The consequence of this is that an overall measure of the individual's self-perceptions that reflects the guiding construct, in this case the metacognitive science learning orientation, for the whole instrument can be determined. In this way it is possible to ascertain and compare students' perceptions as a whole and also in relation to specific dimensions. Such a quality in instruments increases their potential use. In the end we sought a statistically robust, theoretically justifiable, and parsimonious instrument that could be used in field studies.

The factor analysis was undertaken using SPSS (SPSS, 1999) to establish and explore possible dimensions within which related items might be located. It employed principal components analysis followed by varimax rotation and estimation of the internal consistency. Throughout the refinement process only those items that loaded on to a single factor with loadings above 0.4 were retained. Such analysis quickly led us to conclude that our decision to assign only tentatively items to dimensions prior to field testing and to let the data and its analysis help to determine the final dimensions had been appropriate. This was because these tentative dimensions drawn from across metacognition, self-regulation and learning theory quickly disintegrated when the items that had been located within them were found to situate themselves with items from other dimensions that contradicted our *a priori* conceptualisation of their location.

The Rasch scale modelling (Wright & Masters, 1982) employed WINSTEPS (Linacre & Wright, 1999). The Rasch model specifies the form of the relations between person and item variables that are developed on a questionnaire to operationalise the overall construct measured by the scale, that is, the metacognitive science learning orientation. The likelihood of higher scores on the instrument would increase as students perceive that they have greater metacognitive learning orientation and decrease as they reported they had less. In the latter instance the items would be harder to endorse. Rasch analysis provides useful information for scale construction. Person and item separation and reliability of separation are indicators of the instruments' spread across the metacognitive learning orientation continuum. In traditional test theory, reliability analyses imply reliability as inherent to the scale. In Rasch analysis the Person Separation Indices are analogous to the reliability of traditional test theory. However, in Rasch analysis ability estimates are used instead of raw scores. Two facets are employed in Rasch analysis: the items of the instruments and the answers of respondents. Reliability is viewed as a 'property of the sample being measured by the scale, as well as a property of the scale being gauged by the sample' (Mok & Flynn, 2002, p. 23). The accepted cut-off for Person Separation Indices is 0.7 and values above this threshold suggest higher (Rasch) reliability (Smith, 1998). Item separation indices inform as to whether a scale's items are able to define a line of increasing intensity in relation to the degree to which they are separated along that line (Wright & Masters, 1982). Both item and person separation indices are reported in this study and values greater than 0.7 are accepted as suggesting reasonable separation. Further, as suggested by Wright and Maters (1982), H_1, i.e., $H_1 = (4G_1 + 1)/3$ is used to indicate the number of item strata defined by the scale. In this equation G_1 is the item separation index.

To facilitate visual inspection of the findings from the Rasch analysis Figure 1 is provided. Figure 1 presents items arranged according to their expectation and also in relation to the dimensions of the revised instrument. It provides a qualitative representation that is valuable for determining action for future development and enhancement of the SEMLI-S. Gaps in the distribution may be seen to indicate generally that the items are not adequately investigating metacognitive learning orientation construct. Ideally, terms on the SEMLI-S would cover a reasonable range of difficulties on the linear continuum of metacognitive learning orientation from very easy to very hard to endorse. Finally, the outweighted mean square (Outfit MNSQ) statistics are used as indicators of the extent to which each item fits a Rasch rating scale (Smith, 1999). It is generally accepted that Outfit MNSQ values between 0.5 and 1.5 are suggestive of items fitting reasonably a Rasch rating scale while items with values beyond that range do not fit the model.

Results

The iterative use of exploratory factor analysis and Rasch analyses resulted in substantial item deletion to ensure conferring parsimony on the instrument while maintaining concurrently an appropriate level of theoretical justifiability. The final version of what we have called the SEMLI-S (Appendix) has 30 items and five subscales. These five sub-scales, each reflecting a dimension of students' self-perceived metacognitive science learning orientation, were named:

(1) Constructivist Connectivity (CC)
(2) Monitoring, Evaluation & Planning (MEP)
(3) Science Learning Self-efficacy (SE)
(4) Learning Risks Awareness (AW); and
(5) Control of Concentration (CO).

These dimensions were conceived as a consequence of the data analysis and bear testimony to our willingness to set aside our *a priori* conceptualisations. We did not pre-judge which items should fall within dimensions or judge any item's value depending on whether it was consistent with the exiting views that informed the development of the initial instrument. Items were removed that (a) did not add to the psychometric properties of the instrument, and (b) that seemed to be conceptually at odds with other items found that clustered in the same factor.

The Constructivist Connectivity dimension contains items that explore students' perceptions of whether they construct connections between information and knowledge across various science learning locations. It reflects our interests and the interests of an increasing number of science educators on expanding the study of science learning beyond traditional classroom and laboratory settings and in viewing science learning more broadly and holistically. The Monitoring, Evaluation and Planning dimension contains items that might be seen as traditionally related to metacognition. We see them as valuable items because they reflect important strategies for the learning of sciences even if they might be also relevant to the learning of other subjects. The Self-Efficacy dimension explores students' perceptions of their orientation to organise and execute actions that are needed to attain science learning goals. The Learning Risks Awareness dimension probes students' perceptions of their levels of their awareness in relation to situations that may prove detrimental to their learning. In some ways the items in this dimension and those in the Control of Concentration dimension might also be considered to relate to monitoring and evaluation of learning. However, in light of the strong statistical support for their belonging to different factors, we decided to allow them to remain separate from each other. In the end, the items from both of these dimensions, as will be reported below, were amongst the easiest for the students in this Hong Kong sample to endorse. We propose that this reflects these students' familiarity with ideas such as concentration and risk awareness and this notion is discussed later in the paper.

Therefore, to maintain a range of items for students to attend to that reflects a wide range of learning-related issues that they may or may not be familiar with and that could be effectively related to important variables that influence students' learning and cognitive processes, we decided to include these two factors to remain as dimensions in the final instrument. The final 30 items form an instrument that is psychometrically sound and that explores students' perceptions of a range of processes and views that are known to influence science students' learning.

Factor Analysis

Statistical information in the form of internal consistency (Cronbach's alpha), sub-scale means, discriminant validity and standard deviations is provided in Table 1 and the correlations between dimension sub-scales are shown in Table 2. The Cronbach alphas suggest there is an acceptable level of internal consistency among the items for each of the sub-scales. The discriminant validity (using the mean correlation of a sub-scale with the other five sub-scales as a convenient index) for each of the sub-scales indicated that, while there is some overlap between the dimensions, they each measure distinct aspects of metacognitive learning orientation. Further, as indicated in Table 2 there is a high level of correlation between the scales. This might be expected because of the aforementioned integrated nature of learning and other cognitive processes. What is of particular interest to us in Table 2 are the relatively high levels of correlation between CC and MEP and between MEP and SE. These correlations are what might be expected in relation to science students' metacognitive science learning orientations. We could reasonably expect that students' reporting high levels of CC might report engaging in high levels of MEP and in so doing be more successful science learners. Consequently, they would have higher SE. Conversely, students who report engaging low levels of CC might also report low levels of MEP, be less successful science learners, and therefore report lower SE. These data coalesce with what contemporary science learning theory (e.g., Baird & Northfield, 1992; Tobin, 1993; Mintzes, Wandersee, & Novak, 1998) suggests: That students who actively construct science knowledge and who engage in monitoring, evaluation and planning may be more successful science learners and therefore have

Table 1. Descriptive statistics and Cronbach's Alpha coefficient of dimension subscales

Instrument dimension (sub-scale)	No of items	Cronbach's α	Sub-Scale Mean	Std deviation	Discriminant validity
Constructivist Connectivity (CC)	7	0.84	19.61	6.62	0.42
Monitoring, Evaluation & Planning (MEP)	9	0.84	25.72	6.18	0.50
Science Learning Self-efficacy (SE)	6	0.85	18.0	4.85	0.47
Learning Risks Awareness (AW)	5	0.77	16.96	3.74	0.40
Control of Concentration (CO)	3	0.68	9.43	2.89	0.36

Table 2. Correlations between dimension subscales

	Monitoring, Evaluation & Planning (MEP)	Science Learning Self-efficacy (SE)	Learning Risks Awareness (AW)	Control of Concentration (CO)
Constructivist Connectivity (CC)	0.529**	0.542**	0.322**	0.289**
Monitoring, Evaluation & Planning (MEP)		0.577**	0.457**	0.470**
Science Learning Self-efficacy (SE)			0.452**	0.338**
Learning Risks Awareness (AW)				0.374**

**. Correlation is significant at the 0.01 level

higher levels of science learning self-efficacy, and visa versa. While further research and analysis would be needed to confirm this speculation, it does lend some further level of support for the validity of the SEMLI-S.

The analyses of data in relation to students' responses to the items for each dimension also coalesce with what is known about Confucian Heritage Culture (CHC) science learners in Hong Kong. It is known that CHC learning environments in Hong Kong are not particularly metacognitively oriented (Thomas, 2006) although as Thomas points out this is not to suggest that learning environments that reflect non-CHC traditions are necessarily any more metacognitively oriented. Table 3 shows variations between the different populations comprising form (year) levels of students for each of the dimensions. Statistically significant differences at the 0.5 level were found between populations for both the CC and MEP dimensions and at the 0.001 level for the AW dimension. No statistically significant differences were found between the form populations for the SE and CO dimensions.

These findings might be expected in the Hong Kong context. The Hong Kong education system is a highly selective system in which only approximately twenty percent of students progress to tertiary education. Students are selectively screened from further science schooling by highly competitive examinations at form three and form five. Therefore, it might be expected that science students at more advanced

Table 3. Variations in students' response across Form levels in the refined version of the SEMLI-S

Population	CC	MEP	SE	AW	CO
Overall (n = 465)	2.80	2.83	2.99	3.39	3.14
Form 2 (n = 163)	2.65	2.72	3.01	3.15	3.17
Form 4 (n = 154)	2.86	2.93	3.01	3.50	3.16
Form 6 & 7 (n = 148)	2.89	2.84	2.96	3.53	3.09

levels of schooling would report higher levels of CC, MEP and AW as these might be expected to be characteristics of successful learners of science and therefore higher science achievers. The lack of statistically significant difference for the SE dimension suggests that students do not feel any more confident about their self-efficacy as they pass through school, despite their success. Such a finding is in concert with the lack of a meta-curriculum (Perkins, 1992) in Hong Kong schools that would facilitate students' increased understanding of the reasons for their success or otherwise as science learners. The lack of statistically significant difference for the CO dimension suggests that students' attention to concentration remains reasonably stable over time and this might be expected in CHC learners in Hong Kong who are told from a young age that effort, repeated practice and concentration on the task at hand are key elements in determining learning success (see, e.g., Hau & Salili, 1991; Watkins & Biggs, 1996) and where students' propensity to concentrate hits 'ceilings' that can be raised no further as is reportedly the case in the Hong Kong CHC context.

Finally, while correlations exist between the sub-scales, support for the relative independence of each of them is found in the results of the factor analysis on the items. Each of the 30 items has a factor loading of greater than 0.40 with its own sub-scale and less than 0.40 with other sub-scales, therefore providing support for the factorial validity of the refined instrument. Table 4 shows the factor loadings of the items identified by their number on the original 72-item version of the instrument and also identified according to their coding on the final version of the SEMLI-S.

Rasch Analysis

Table 5 presents summary information regarding the whether the data showed acceptable fit to the Rasch model. Ideally, the mean infit and outfit for Person and Item mean squares should be close to 1. For the Person mean squares the outfit and infit are 1.00 and 1.01 respectively. The values for the Item mean squares were 1.00 and 1.00. Ideally, the mean standardised infit and outfit should be 0.00. In this case they were –0.4 for Persons and –0.2 and –0.1 respectively for Items. Therefore, in summary, the items overfit, suggesting that the data fit the model better than expected. Such overfit may suggest that some items might be redundant and might be able to be removed from this instrument without decreasing its diagnostic value. This possibility is discussed below. An indication of the extent of overall misfit for Persons is the standard deviation of the standardised infit (Bode & Wright, 1999). Using 2.0 as an acceptable cut-off criterion, the standardised infit standard deviation for persons (0.67) and Items (0.17) show little overall misfit. The results suggest that overall the scale is quite reliable in Rasch terms. The Real Item Reliability is 0.97, suggesting high internal consistency, and the Real Person Rasch reliability is 0.92. The Person Separation Index is 3.33, well above the 0.7 threshold criterion. The point biserial correlations are generally high and this suggests that all of the SEMLI-S items are good indicators of a unified construct. The student mean

Table 4. Factor loadings* of items in the refined version of the SEMLI-S

Original item No (Code in SEMLI-S)	Constructivist Connectivity (CC)	Monitoring, Evaluation & Planning (MEP)	Science Learning Self-efficacy (SE)	Learning Risks Awareness (AW)	Control of Concentration (CO)
5 (CC1)	0.69				
11 (CC2)	0.80				
12 (CC3)	0.77				
22 (CC4)	0.68				
26 (CC5)	0.73				
35 (CC6)	0.53				
39 (CC7)	0.74				
8 (MEP4)		0.67			
21 (MEP1)		0.65			
23 (MEP5)		0.61			
24 (MEP2)		0.76			
32 (MEP3)		0.68			
50 (MEP6)		0.56			
55 (MEP7)		0.60			
57 (MEP8)		0.47			
64 (MEP9)		0.51			
15 (SE1)			0.63		
27 (SE2)			0.65		
33 (SE3)			0.71		
53 (SE5)			0.75		
62 (SE6)			0.63		
69 (SE4)			0.67		
16 (AW1)				0.71	
20 (AW2)				0.73	
36 (AW3)				0.71	
65 (AW4)				0.63	
71 (AW5)				0.60	
41 (CO1)					0.68
61 (CO2)					0.76
68 (CO3)					0.74

*. All loadings smaller than 0.4 have been omitted

measure is around –0.1 logits suggesting that the items were well matched to the perceptions of the students in the sample. Values of differences between item and person means of greater than one would suggest that that items may be potentially too difficult or too easy, respectively, for students to endorse. If that was the case then a major revision of items might be required.

Figure 1 shows the spread of scale items over the expectation continuum. Items are also located in relation to their dimension affiliation. The spread of the item difficulty estimates is from –0.69 (Item 16) to +0.61 (Item 8), which might be

Table 5. Overall model fit information, separation and mean logit: practice mirroring

Summary of 465 Measured Persons (Students)								
					INFIT		OUTFIT	
	RAW SCORE	COUNT	Measure	MODEL ERROR	MNSQ	ZSTD	MNSQ	ZSTD
Mean	89.2	29.9	–0.05	0.21	1.01	–0.4	1.00	–0.4
S.D.	18.5	0.2	0.83	0.02	0.67	2.5	0.66	2.5
Max.	136.0	30.0	2.38	0.37	4.65	8.5	4.64	8.5
Min.	38.0	29.0	–2.98	0.20	0.09	–6.9	0.09	–6.8
REAL RMSE	0.24	ADJ.SD	0.80	Separation	3.33	Person Reliability		0.92
MODEL RMSE	0.21	ADJ.SD	0.80	Separation	3.76	Person Reliability		0.93
S.E. of Person Mean =		0.02						
Summary of 30 Measured Items								
Mean	1382.7	464.0	0.00	0.05	1.00	–0.2	1.00	–0.1
S.D.	116.5	1.2	0.33	0.00	0.17	2.6	0.17	2.7
Max.	1621.0	465.0	0.61	0.06	1.53	7.3	1.52	7.3
Min.	1169.0	461.0	–0.69	0.05	0.77	–4.0	0.78	–3.9
REAL RMSE	0.06	ADJ.SD	0.33	Separation	5.94	Item Reliability		0.97
MODEL RMSE	0.05	ADJ.SD	0.33	Separation	6.14	Item Reliability		0.97
S.E. of Item Mean =		0.06						

considered to be a narrow spread. However, the Item Separation Index is 5.93, and according to the formula of Wright and Masters (1982) there are approximately 8.24 item strata. Both of these indices are more than acceptable in terms of item separation. Inspection of Figure 1 reveals some interesting locations of individual items and groups along that continuum. Of concern is the clumping of some items of some dimensions, e.g. AW and CC. While there is a reasonable spread of items across the continuum, it might be preferable to have less clustering and a wider range of difficulties for the items of the dimensions, and increased overlap between the items of some dimensions. Any revision of the instrument could consider adding and deleting items as appropriate that result in this objective being met. However, such an inclination would need to be balanced against the possibility that an increased difficulty range for items of any sub-scale might lead to lower factor loadings.

Table 6 presents further results of the Rasch analysis including the item difficulties and point biserial correlations for the SEMLI-S items. Even though the 30 items were subject to a single analysis, they are shown in their expectation dimensions and in ascending order of difficulty to endorse to assist readers' interpretations. Using the aforementioned criterion of Outfit MNSQ values being between 0.5 and 1.5 for evaluating the reasonableness of fit of items to a Rasch scale model, it can be seen that the items have reasonable mean square fit values ranging from 0.78 (Item 27) and 1.52 (Item 71). Item 71 is the only item that has a mean square fit value outside

Item Difficulty	Cognitive Connectivity (CC)	Monitoring, Evaluation, Planning(MEP)	Self-Efficacy (SE)	Learning Risks Awareness (AW)	Control of Concentration (CO)
1.0					
0.9					
0.8					
0.7					
0.6		8(4)			
0.5					
0.4	11(2)				
	39(7)				
0.3		23(5), 24(2)			
	35(6)	32(3)	15(1)		
0.2	12(3), 26(5), 5(1)	57(8)			
		21(1)			
0.1			53(5)		
			33(3)		
0		55(7)			
	22(4)	50(6)			
–0.1			27(2)		
					68(3)
–0.2		69(9)	64(4)		61(2)
–0.3					41(1)
–0.4			62(6)	20(2)	
–0.5				36(3)	
				65(4)	
–0.6				71(5), 16(1)	
–0.7					
–0.8					
–0.9					
–1					

Figure 1. Map of items (original item number (final item code in that dimension)) according to expectation dimension and item difficulty

Table 6. Rasch rating scale analysis of SEMLI-S subscales

Subscales and Items	Item Difficulty	Outfit MNSQ	Infit MNSQ	PTBIS Corr.
Constructivist Connectivity				
CC4: I seek to connect the information in science class with what I already know	−0.02	0.92	0.92	0.64
CC1: I seek to connect what I learn from what happens in the science classroom with out of class science activities (e.g. field trips or science visits)	0.21	1.24	1.23	0.54
CC5: I seek to connect what I learn from out-of-class science activities (e.g. field trips, science museum visits) with what happens in the science class.	0.21	0.94	0.93	0.64
CC3: I seek to connect what I learn in my life outside of class with science class.	0.22	0.91	0.91	0.65
CC6: I seek to connect what I learn in other subject areas with science class	0.29	0.96	0.95	0.69
CC7: I seek to connect what I learn from what happens in the science classroom with out-of-school science activities	0.39	0.97	0.98	0.65
CC2: I seek to connect what I learn from out-of-school science activities with what happens in the science classroom	0.44	0.94	0.95	0.65
Monitoring, Evaluation & Planning				
MEP9: I try to predict possible problems that might occur with my learning.	−0.18	0.93	0.87	0.51
MEP6: I assess how much I am learning during a learning task	−0.04	0.83	0.84	0.62
MEP7: I evaluate my learning processes with the aim of improving them.	0.02	0.81	0.82	0.64
MEP1: I adjust my plan for a learning task if I am not making the progress that I think I should.	0.19	0.90	0.88	0.56
MEP8: I try to understand clearly the aim of a task before I begin it.	0.25	0.82	0.82	0.64
MEP3: I stop from time to time to check my progress on a learning task.	0.28	0.91	0.92	0.58
MEP5: I consider what type of thinking is best to use before I begin a learning task.	0.30	0.84	0.84	0.65
MEP2: I plan to check my learning progress during a learning task.	0.32	0.82	0.83	0.63
MEP4: I consider whether or not a plan is necessary for a learning task before I begin that task.	0.61	1.19	1.21	0.51
Self-efficacy				
SE6: I am confident of understanding the basic concepts taught in this course.	−0.37	0.89	0.90	0.62
SE4: I believe I will get an excellent grade in this course.	−0.17	0.93	0.93	0.63
SE2: I know I can master the skills being taught in this course.	−0.08	0.78	0.77	0.59
SE3:I am confident I can do a good job on the assignments and tests in this science class.	0.05	1.02	1.03	0.60

Table 6. *(continued)*

Subscales and Items	Item Difficulty	Outfit MNSQ	Infit MNSQ	PTBIS Corr.
SE5: I am confident of understanding the most complex material presented by the teacher in this course.	0.13	0.89	0.90	0.65
SE1: I know I can understand the most difficult materials presented in the readings of this course.	0.28	1.06	1.08	0.56
Learning Risks Awareness				
AW1: I am aware of when I am about to have a learning challenge.	−0.69	1.12	1.10	0.48
AW5: I am aware of when I am not concentrating.	−0.68	1.52	1.53	0.42
AW4: I am aware of when I have learning difficulties	−0.54	0.99	0.97	0.54
AW3: I am aware of when I don't understand an idea	−0.48	0.96	0.97	0.54
AW2: I am aware of when I am about to lose track of a learning task	−0.36	1.23	1.24	0.42
Control of Concentration				
CO1: I adjust my level of concentration depending on the learning situation.	−0.29	1.30	1.29	0.50
CO2: I adjust my level of concentration depending on the difficulty of the task.	−0.17	1.19	1.18	0.53
CO3: I adjust my level of concentration to suit different science subjects.	−0.13	1.22	1.20	0.50

the acceptable range and this further confirms the fit of the items to a Rasch scale model.

A general interpretation is that items on the AW and CO dimensions and some on the SE dimension were easy to endorse, and items on the CC and MEP dimensions and some on the SE dimension were difficult to endorse. This observation is consistent with what is known from the literature; that students' understanding of their learning processes and management of those processes is often rudimentary and that science teachers are more often interested in covering content then developing students' monitoring, planning and evaluation strategies or their constructivist learning processes. As previously mentioned, such an observation is also consistent with what is known about the learning styles of CHC learners, the sample in this study, the types of learning environments within which their learning strategies are shaped, and the consequent approaches to learning they adopt. Students are often asked to focus on their concentration and they do develop an awareness of their exposure to learning risks as they progress through school. Consequently they find elements of the SEMLI-S that are related to these more familiar issues easier to endorse.

In summary, the SEMLI-S fits the Rasch model well and can be regarded as unidimensional. It has adequate separation so that there are sufficient strata, has items that are reasonably calibrated and not too far apart, and has individual items that all contribute to and reflect the underlying construct of metacognitive learning orientation.

Concluding Comments

The SEMLI-S is an instrument developed for exploring science students' self-perceptions of elements of their metacognition, self-efficacy and science learning processes. We have termed these student characteristics their metacognitive science learning orientations. Students' completion of the SEMLI-S will provide snapshots of such self-perceptions. Its possible uses include collecting pre- and post data from students in relation to innovations that aim to enhance metacognition and learning processes and for providing feedback for students in relation to their development of metacognitive knowledge and related learning constructivist cognitive processes. However, we stress in concert with Schraw (2000), Thomas and McRobbie (2001) and Veenman et al. (2006) that it is our contention that a multi-methods approach is most appropriate for exploring students' learning processes and metacognition and that even though the SEMLI-S is a statistically robust instrument, it does not attend to all aspects of science students' learning processes and metacognition. Therefore, it should be used with other methods to give credible and trustworthy assessments in relation to the nature and extent of students' metacognitive science learning orientations.

The SEMLI-S was developed following an extensive review of the literature on metacognition, self-regulation and constructivist science learning processes and the incorporation of items reflecting that literature into an initial 72-item instrument. This initial instrument was reduced to thirty items following an iterative process of factor analysis and Rasch analysis. This study provides one of the first examples of the combined use of use of factor and Rasch analysis in the development of such a psychometric instrument in science education. The five dimensions and the items that constitute them reflect this analysis and are justifiable in terms of:

(a) their salience in relation what is known from the literature to be important for science learning;
(b) their usefulness in contributing to understanding students' perceptions of their learning processes; and
(c) their confirmatory insights, however minor, in relation to what is already known about the learning context and learning processes of the sample that aided in the development of this instrument.

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Appendix. Final Version of the SEMLI-S

DIRECTIONS 指引

1. **Purpose of the Questionnaire 這問卷的目的**
This questionnaire asks you to describe HOW OFTEN you do each of the following practices when 這問卷的目的science. There are no right or wrong answers. This is not a test and your answers will not affect your assessment. ***Your opinion is what is wanted.*** Your answers will enable us to improve future science classes.

這問卷需要你形容以下每一重要習慣在上科學課時出現的次數多少。這些問題是沒有正確的答案。它不是一個測驗，你的答案是不會影響你的成績/評核。你的意見是最主要的。你的答案能 讓我們改善將來的科學課。

2. **How to Answer each Question 怎樣回答每條問題**
On the next few pages you will find 30 sentences. For each sentence, circle only one number corresponding to your answer. For example:

在後幾頁，你會看到 30 句句子。每一句只能圈上一個數字作為你的答案。例如:

		Never or Almost Never	Sometimes	1/2 of the time	Frequently	Always or Almost Always
1.	I ask the teacher or others why I went wrong on a question or problem 我問老師或其他人為何我遇到問題/困難。	1	2	3	4	5

- If you think you *always* or *almost always* ask the teacher or others why you went wrong on a question or problem, circle the 5. 如你覺得你*經常*或*差不多經常*問老師或其他人你為何遇到問 題/困難，圈 5。
- If you think you *never* or *almost never* ask the teacher or others why you went wrong on a question or problem, circle the 1. 如你覺得你*從未*或*差不多從未*問老師或其他人你為何遇到問題/困難，圈 1。
- Or you can choose the number 2, 3, or 4 if one of these seems like a more accurate answer. 如你覺得它是更貼切的答案，你能選擇 2，3，或 4。

3. How to Change Your Answer 如何更改你的答案

If you want to change your answer, cross it out and circle a new number. For example:

如你想要更改你的答案，删除它，然後圈上一個新的數字。例如：

4.	I ask the teacher or others why I went wrong on a question or problem 我問老師或其他人為何我遇到問題/困難。	1	2	3	④

4. Course Information 班別資料

Please provide information in the box below. Please be assured that your answers to this questionnaire will be treated confidentially.

請在格內填寫以下資料。你在這問卷的答案將會被保密處理。

Grade/Year-level:	Age:	M F

5. Completing the Questionnaire 作答問卷

Now turn the page and please give an answer for every question. 現在請翻到下一頁，作答所有問題

SCALE等級:: 1 = Never or only Rarely 從不或很少 2 = Sometimes 有時; 3 = Half of the time 半數時間; 4 = Frequently 經常地; 5 = Always or Almost Always 一直或幾乎一直.

#	Questions 問題	Scale 等級 Circle one number *只圈一個數字*
CC1	I seek to connect what I learn from what happens in the science classroom with out-of-class science activities (e.g. field trips or science visits). 我試圖把我在科學堂上所學到的與課外的科學活動(如實地考察或科學探訪)連結在一起。	1 2 3 4 5
MEP1	I adjust my plan for a learning task if I am not making the progress I think I should. 如果我在學習課業得不到預期的進展時，我會調整學習計劃。	1 2 3 4 5
SE1	I know I can understand the most difficult material presented in the readings for this course. 我知道我能夠瞭解本課程的讀物中最艱深的資料。	1 2 3 4 5
AW1	I am aware of when I am about to have a learning challenge. 當我遇到學習上的考驗時，我會覺察得到。	1 2 3 4 5
CC2	I seek to connect what I learn from out-of-school science activities with what happens in the science classroom. 我試圖把校外科學活動所學到的與科學堂連結在一起。	1 2 3 4 5
MEP2	I plan to check my progress during a learning task. 我計劃檢查自己在學習課業中的進度。	1 2 3 4 5
CO1	I adjust my level of concentration, depending on the learning situation. 我會根據學習的情況而調整專心程度。	1 2 3 4 5
MEP8	I try to understand clearly the aim of a task before I begin it. 當我開始一項課業前我先會了解清楚其目的。	1 2 3 4 5
SE2	I know I can master the skills being taught in this course. 我知道自己能夠掌握本課程所授的技能。	1 2 3 4 5
MEP7	I evaluate my learning processes with the aim of improving them. 我評估自己的學習過程，籍此加以改進。	1 2 3 4 5
CC3	I seek to connect what I learn in my life outside of class with science class. 我試圖把校外生活上學到的與科學堂連結在一起。	1 2 3 4 5
AW2	I am aware of when I am about to loose track of a learning task. 當我進行某項學習課業，並失去方向時，我會覺察得到。	1 2 3 4 5
MEP5	I consider what type of thinking is best to use before I begin a learning task. 在展開一項學習課業前，我會先考慮哪一種想法才是最合適。	1 2 3 4 5

#	Questions 問題	Scale 等級 Circle one number *只圈一個數字*				
SE3	I'm confident I can do a good job on the assignments and tests in this science class. 我有信心能夠把這科學堂的習作和測驗做得很好。	1	2	3	4	5
CC4	I seek to connect the information in science class with what I already know. 我試圖把科學堂的資料與我已知的連結在一起。	1	2	3	4	5
AW3	I am aware of when I don't understand an idea. 當我不明白一些意念時，我會覺察得到。	1	2	3	4	5
MEP4	I consider whether or not a plan is necessary for a learning task before I begin that task. 在展開一項學習課業前，我會考慮是否需要訂立一個計劃。	1	2	3	4	5
CO2	I adjust my level of concentration depending on the difficulty of the task. 我會視乎課業的難度而調整專心程度。	1	2	3	4	5
SE4	I believe I will receive an excellent grade in this course. 我相信我會在本課程取得很好的成績。	1	2	3	4	5
CC5	I seek to connect what I learn from out-of-class science activities (e.g. field trips or science museum visits) with what happens in the science class. 我會嘗試把與科學有關的課外活動(如實地考察或參觀科學館)及科學堂所發生的連結在一起。	1	2	3	4	5
MEP3	I stop from time to time to check my progress on a learning task. 我不時停下來檢查自己在學習課業上的進展。	1	2	3	4	5
AW4	I am aware of when I have learning difficulties. 當我在學習上遇到困難，我會覺察得到。	1	2	3	4	5
SE5	I'm confident of understanding the most complex material presented by the teacher in this course. 我有信心明白本課程老師提供的最複雜資料。	1	2	3	4	5
MEP9	I try to predict possible problems that might occur with my learning. 我嘗試估計自己在學習上可能出現的問題。	1	2	3	4	5
CC7	I seek to connect what I learn from what happens in the science classroom with out-of-school science activities. 我試圖把在科學堂所學的與校外科學活動連結在一起。	1	2	3	4	5
AW5	I am aware of when I am not concentrating. 當我精神不集中時，我會覺察得到。	1	2	3	4	5
MEP6	I assess how much I am learning during a learning task. 進行學習課業時我會評估自己學會多少。	1	2	3	4	5
SE6	I'm confident of understanding the basic concepts taught in this course. 我有信心明白本課程所授的基本概念。	1	2	3	4	5
CO3	I adjust my level of concentration to suit different science subjects. 我會視乎不同的科學科目而調整專心程度。	1	2	3	4	5
CC6	I seek to connect what I learn in other subject areas with science class. 我試圖把其他科目所學的與科學科連結在一起。	1	2	3	4	5