The Role of Student Learning Processes in Enhancing Physics Conceptual Understanding

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Abstract

The overarching goal of this research programme was to investigate the role of student learning processes in enhancing physics conceptual understanding. Over 2000 Year 11 students from a large secondary school in Singapore were involved in the research. Five journal papers have been prepared and submitted for publication based on the results. Papers 1 through 3 report upon the validity of three instruments used in the research programme: the *Motivated Strategies for Learning Questionnaire* (MSLQ); the *Two-Factor Revised Learning Process Questionnaire* (R-LPQ-2F); and a researcher-developed *Physics Task Value Scale* (PTVS). Paper 4 reports results of a study on the relationships between self-regulated learning, learning approaches and physics conceptual understanding, while Paper 5 reports on the effects of assessment expectations on students' approaches to learning, conceptual understanding, and task value in physics.

Results reported in Papers 1-3 indicated that the MSLQ, the R-LPQ-2F and the PTVS demonstrated sound psychometric properties within the Singapore secondary school context. Results reported in Paper 4 indicated that while significant relationships were observed between students' performance on a measure of conceptual understanding in physics (the *Force Concept Inventory*, or FCI) and several MSLQ and R-LPQ-2F variables, most of these relationships were not apparent when gains in FCI scores were used as the criterion variable, instead of concurrent FCI scores. These results suggest that, contrary to the assumed direction of the relationships posed in previous studies, a more complex pattern of directionality in these relationships could be present. Results presented in Paper 5 suggest that students' learning approaches can be altered significantly through the use of different assessment approaches. Specifically, results of this study indicated that students who expected to confront a short structured question format assessment at the end of a physics unit tended to use more deep strategies and/or less surface strategies, and had developed a higher level of task value in the subject matter, than those who expected a multiple choice question format assessment. Implications of these findings are discussed, and ecommendations for teachers and education policy-makers are proposed.

To my wife Susan, for her enduring love and support, and to my baby Lucas, for bringing tremendous joy to the family.

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No amount of words can fully express my deep gratitude for my parents, who have been most caring and supportive throughout my life. This dissertation is indeed a realization of their dream.

During the years that I worked on my dissertation, I married my beautiful and intelligent wife and she gave birth to my adorable son. My second son will soon be born. I would like to take this opportunity to express my gratitude for her love, understanding and encouragement in this challenging journey, and for taking good care of the family while I was busy with my research.

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Introduction

The thesis is presented as a series of papers[1], all of which have been submitted for review at this stage. This first chapter was designed to provide a context for the five papers presented. The chapter begins with a personal statement indicating my own motivations for conducting the research and an overview of the Singapore's education system. A broad overview of each of the underpinning constructs in the research programme as a whole is then presented, followed by brief introduction to all of the studies reported in the thesis.

Personal Statement

As a professional doctorate, the research reported here was designed primarily to enhance professional practice in the area of physics education. The online *Oxford Advanced Learner's Dictionary* defines physics as "the scientific study of matter and energy and the relationships between them, including the study of forces, heat, light, sound, electricity and the structure of atoms" (Physics, n.d.). Young and Freeman (2014, p.1), in the opening chapter of their physics textbook for university students, highlighted the importance of physics as a discipline:

> Physics is one of the most fundamental of the sciences. Scientists of all disciplines use the ideas of physics, including chemists who study the structure of molecules, paleontologists who try to reconstruct how dinosaurs walked, and climatologists who study how human activities affect the atmosphere and oceans. Physics is also the foundation of all engineering and technology. No engineer could design a flat-screen TV, an interplanetary spacecraft, or even a

[1] http://www.postgraduate.uwa.edu.au/students/thesis/series

> better mousetrap without first understanding the basic laws of physics. (...) You will come to see physics as a towering achievement of the human intellect in its quest to understand our world and ourselves.

The inspiration for this research programme derived from my own experience as a physics educator for the past 18 years. In this role, I have been passionate about finding ways to improve the teaching and learning of physics at the secondary school level. In my career, I have encountered countless numbers of students who have struggled in learning physics concepts, including those who invest a tremendous amount of time and effort into their learning. Despite these investments, many continue to have difficulties in mastering physics concepts, and retain deep-rooted misconceptions. It was these observations that spurred me on to investigate ways to enhance students' understanding of physics concepts, by increasing my own understanding of their learning processes.

Singapore's Education System

Singapore is a small country with no natural resources and hinterland. The pioneer leaders and their successors believed that education was the key for Singapore to survive and prosper. The importance of education was highlighted by Singapore's current Prime Minister Mr Lee Hsien Long in his Teachers' Day Rally in 2006 (Lee, 2006):

> …. education is one of our top national priorities… This is one of the key things which we have to focus on. Why? Firstly, because it's the most precious gift we can give our children. Secondly, because it's the most critical investment in our future. And thirdly, because it's the most effective strategy which will enable us to survive and to thrive in a changing world. Since the beginning of nation building, the political leaders understand the importance of education in charting.

Within one generation, Singapore transformed from a poor third world country to a first world metropolis (Lee, 2015, August 23). Singapore's education system is also regarded as one of the best in the world, consistently outperforming other systems in the world in international benching tests such as the Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) (Davie, 2016, December 6; Organisation for Economic Co-operation and Development, 2011; Teng, 2016, November 29).

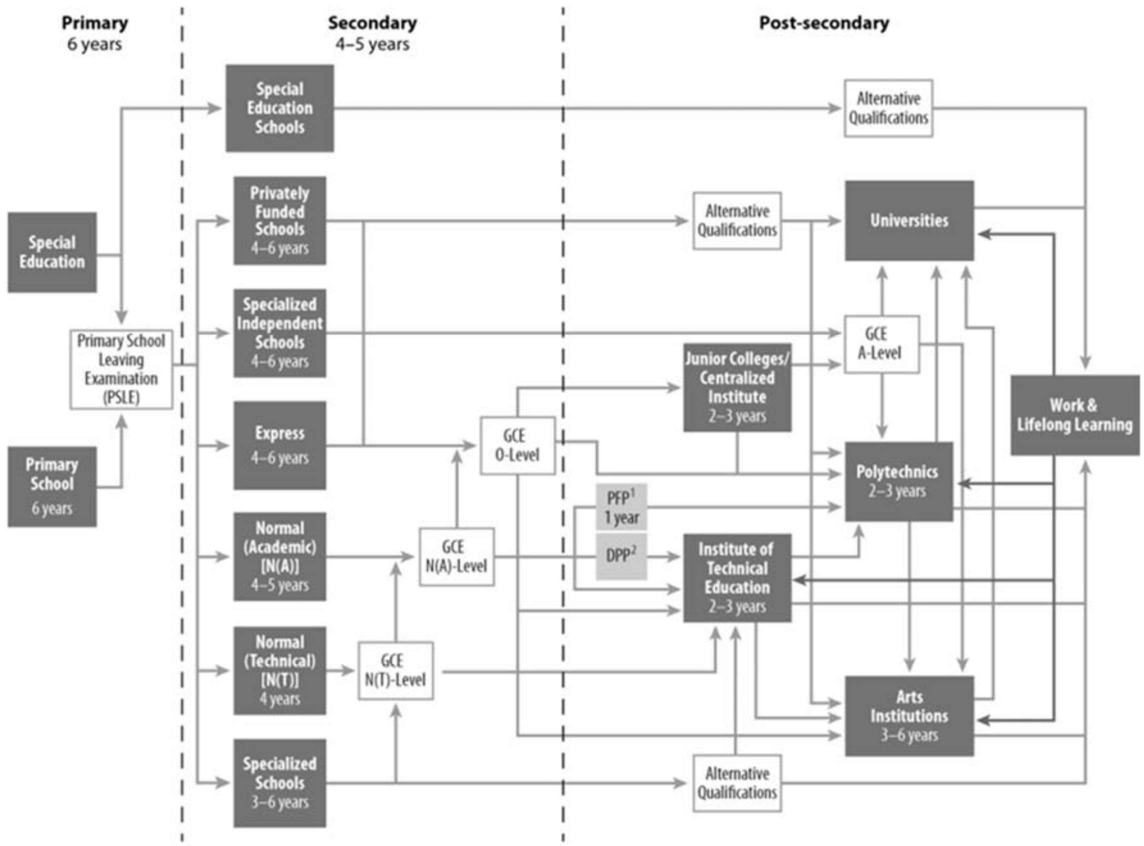
Meritocracy is a fundamental principle in Singapore's education system. Singapore's former Prime Minister and current Emeritus Senior Minister Mr Goh Chok Tong spoke about meritocracy and its value in Singapore (Goh, 2013, July 27):

> At its core, meritocracy is a value system by which advancement in society is based on an individual's ability, performance and achievement, and not on the basis of connections, wealth or family background. For Singapore in particular, a meritocratic system…. is the best means to maximise the potential and harness the talents of our people to society's advantage.

Bilingualism is also the cornerstone of Singapore's education system (Channel News Asia, 2015). All students study the English language and their mother-tongue language (Chinese, Malay or Tamil). Former Acting Minister for Education and current Deputy Prime Minister Mr Tharman Shanmugaratnam justified the policy of bilingualism in Singapore:

> Bilingualism gives us an edge, a special advantage as an economy and as a people. It allows us to take advantage of the strengths of both the western and eastern economies. It also allows us to reach into our own cultures, and be confident of ourselves as a society.

An overview of Singapore's education pathways is provided in Figure 1 (Ministry of Education, Singapore, 2016). In summary, all Singapore students attend six years of compulsory primary education, and almost all will proceed on to complete either four or five years of optional secondary education. National examinations are conducted at the end of primary and secondary education. Typically about 25-30% of students in each cohort progress to tertiary education (TIMSS 2015 Encyclopedia, 2015).



[1] The Polytechnic Foundation Programme (PFP) is a diploma-specific foundation program conducted by the polytechnics over two academic semesters for students who have completed Secondary 4N(A). Students who successfully complete the PFP may progress directly into the first year of their respective polytechnic diploma courses.
[2] The Direct-Entry-Scheme to Polytechnic Programme (DPP) is a through-train pathway to polytechnics for students who have completed Secondary 4N(A). DPP students who successfully complete a two-year Higher Nitec program at ITE and attain the required qualifying Grade Point Average (GPA) scores are guaranteed a place in a polytechnic diploma course mapped to their Higher Nitec course.

Figure 1. Singapore's education pathways.

Reprinted from *Education System,* Ministry of Education, Singapore, 2016. Retrieved from https://www.moe.gov.sg/education/education-system

The Importance of Conceptual Understanding in Physics

Throughout my research, I have focused on enhancing students' conceptual understanding in physics. According to the *National Assessment of Educational Progress in the United States* (NAEP, 2003, p.10), students demonstrate conceptual understanding when they:

> … provide evidence that they can recognize, label, and generate examples of concepts; use and interrelate models, diagrams, manipulatives, and varied representations of concepts; identify and apply principles; know and apply facts and definitions; compare, contrast, and integrate related concepts and principles; recognize, interpret, and apply the signs, symbols, and terms used to represent concepts… Conceptual understanding reflects a student's ability to reason in settings involving the careful application of concept definitions, relations, or representations of either.

Physics educators have long advocated a focus on conceptual understanding in approaches to teaching and learning in the classroom. Concurrently, there has been an increasing move away from the emphasis on having students produce the 'right answers' in standardized assessments (McDermott, 1991; Hewitt, 1983). McDermott (1991) observed that students who were able to arrive at the right answers in solving physics problems might still not have understood the concepts that underpinned those answers. Hewitt (1983) went so far as to say that that students who solved physics problems in the absence of conceptual understanding are "akin to a deaf person writing music or a blind person painting" (p. 305).

Various studies have indicated that many physics students at both the secondary and tertiary levels do not have a good understanding of physics concepts, even if they have performed adequately in standard assessments. For example, in a study of physics and engineering students at the Harvard University, Mazur (1997) reported that many students were able to excel in examinations, even if they had little understanding of the physics concepts involved. These students were able to adopt strategies based on memorizing algorithms to solve physics problems and, hence, perform well in relevant examinations. Yet, in the absence of conceptual understanding, it is unlikely that these students would be equipped to deal with new problems they encountered post-graduation.

Similar results were reported by Hestenes (1998), who found that first year tertiary students performed poorly in the Force Concept Inventory (FCI: Hestenes, 1992), regarded as a ‘gold standard’ in assessing students’ conceptual understanding in the areas of Newtonian mechanics. This was so even after they completed and passed an introductory physics course. Specifically, Hestenes found that fewer than 15% of the students had actually understood Newton’s Third Law (which is one of the fundamental law in Newtonian mechanics), even though about 80% of them had no problem stating the law. Other researchers have reported similar results (Hake, 1998; Halloun & Hestenes, 1985; McDermott, 1991). In light of these results, it appeared to me that my own observations and concerns had already been expressed by several others within the field.

Importance of Learning Processes in Developing Conceptual Understanding

To address the issues highlighted above, I have tried a variety of pedagogies in my own professional practices. These have included blended learning, team-based learning, flipped learning and inquiry-based learning. I have experienced varying degrees of success in using these pedagogies, but have also noticed that different pedagogies appealed to different students. While these are useful tools with which teachers should be equipped, unfortunately, they are not a panacea in resolving learning issues in physics.

During the past decade, I have had the opportunity to teach a few classes of very capable and high-achieving students, and observed some common characteristics amongst them. All were highly self-regulated in their learning; all appeared very passionate about their learning; and all appeared to be seeking a deep understanding of the subject matter, because they appeared to recognize the inherent value of studying the subject matter. I realized that in these situations, it was not necessary for me to 'disseminate' knowledge. Rather, I played the role of facilitator in the students' constructions of their own knowledge. I also found that these students learned better when they were given the opportunity to play a more active role in their learning, such as when they were working collaboratively on projects, critiquing each other's work, and researching areas in which they already had a deep intrinsic interest.

Focus Learning Process Variables in the Present Research Programme

Based on the experiences described above, I was inspired to gain a better understanding of the learning processes I had seen in these classes, and to find ways to foster these in other students. My observations of the students in high-achieving classes led me to focus primarily on the value that students assigned to their learning tasks in physics; on how well the students were able to monitor and guide their own learning processes (i.e., self-regulated learning processes); and on the approaches they took when confronting new and unfamiliar concepts in physics classes. This section provides an overview of each of these constructs, and describes the instruments that were used in the present research programme to assess them.

Task Value

The notion of task value has attracted an increasing amount of attention in the research literature in recent years. The term refers to students' perceptions of the interest, usefulness, importance and cost of a task (Eccles, 1983; Eccles, Adler, & Meece, 1984; Eccles & Wigfield, 1995, 2002; Parsons & Goff, 1980; Wigfield, 1994; Wigfield & Eccles, 1992, 2000, 2002). According to Eccles and Wigfield (2002), task values are subjective motivational constructs that are inextricably linked to achievement behaviours. In particular, the level of value that students assign to given academic tasks has been proposed by several researchers as a key factor in determining the level of investment that they will subsequently make to master those tasks.

Researchers have found that various components of task value are academically significant motivational constructs, as they predict achievement behaviours such as course enrollment, self-regulated learning, effort, and persistence (Eccles & Wigfield, 1995; Ormrod, 2006; Schunk, Pintrich & Meece, 2008; Shell, Colvin, & Bruning, 1995; Wigfield, 1994; Zimmerman, 2000). Eccles and her colleagues have also shown that the value of a particular task is situational and powerfully impacts the types of academic choices students make (see Wigfield et al., 1997, for a brief review). Metallidou and Vlachou (2010) and Pintrich (2000, 2003) also suggest that task value will relate positively to students' self-regulation strategies (see next section), while Pintrich (1999) asserted that students who value learning tasks will tend to exhibit better learning performance than those who do not.

The above findings aligned well with the observations that I had made in my own teaching practice. As noted previously, I had observed that high performing students differed from lower performing students in a few significant ways. One of these differences related to the apparent value that the former students assigned to their academic tasks. On speaking with these students, it became clear to me that they saw a point in studying physics – that they perceived it to be important either for their further study, for their future careers, or for their own personal interest. As a result, I decided to incorporate task value as a key variable in my research into enhancing conceptual understanding in physics classrooms.

Despite its perceived importance in academic motivation, few instruments exist presently which focus specifically on this construct in education contexts. Whilst various instruments, such as the Motivated Strategies for Learning Questionnaire (MSLQ - Pintrich et al., 1991), incorporate subscales that focus on elements of task value, as noted by some researchers in the field (e.g., Eccles, 2002), apparently subtle differences in the operationalisations of the construct across these instruments have significant conceptual implications. Furthermore, none lend themselves well to assessing task value in a specific classroom or subject area. As a result, practitioners who wish to assess levels of task value in their students must often use their own, locally developed instruments, which have not been evaluated in terms of their validity. In light of this, one of the studies reported in this thesis was conducted to evaluate the construct validity of a new instrument that I developed, for assessing levels of task value in the area of secondary school physics.

Self-Regulated Learning

Research on self-regulated learning (SRL) in education has spanned over many decades. In the 1970s and 1980s, however, research in this area tended to focus on highly restrictive self-regulatory processes such as the use of specific strategies for learning (Zimmerman, 2008). In 1986, a symposium was held at the American Educational Research Association annual meeting, and attended by a number of foremost SRL researchers, such as Steve Graham, Paul Pintrich, Dale Schunk, and Barry Zimmerman. The gathering was regarded as a defining moment in the history of SRL research. At the symposium, a more inclusive definition of the SRL was adopted, which was stated as “the degree to which students are metacognitively, motivationally, and behaviorally active participants in their own learning processes” (Zimmerman, 1986, p.31). According to Zimmerman (2008, p. 166), SRL can now be viewed as “proactive processes that students use to acquire academic skills, such as setting goals, selecting and deploying strategies, and self-monitoring one’s effectiveness”.

Consistent with this definition, Zimmerman and Moylan (2009) proposed an integrated model of SRL, which depicted the process of self-regulation as proceeding through three cyclic phases: the *Forethought* phase, the *Performance* phase, and the *Self-reflection* phase, as depicted in Figure 2. In the forethought phase, highly self-regulated students assess their academic situations realistically, and decide upon strategies that will allow them to address a given learning challenge. In the performance phase, self-regulated learners will implement their selected strategies, monitoring their own progress, and adjusting their plans in response to feedback and their own evaluations. In the self-reflection phase, self-regulated students will reflect upon the efficacy of the strategies they have used, and apply the products of these reflections in confronting their next learning tasks.

Given that the model of SRL proposed above aligned well with my own observations in high-performing classrooms, I decided to incorporate a focus on self-regulation in my own research work. As a result, one of my preliminary tasks in conducting the research reported here was to identify a suitable instrument for measuring SRL levels in the context of secondary physics classes.

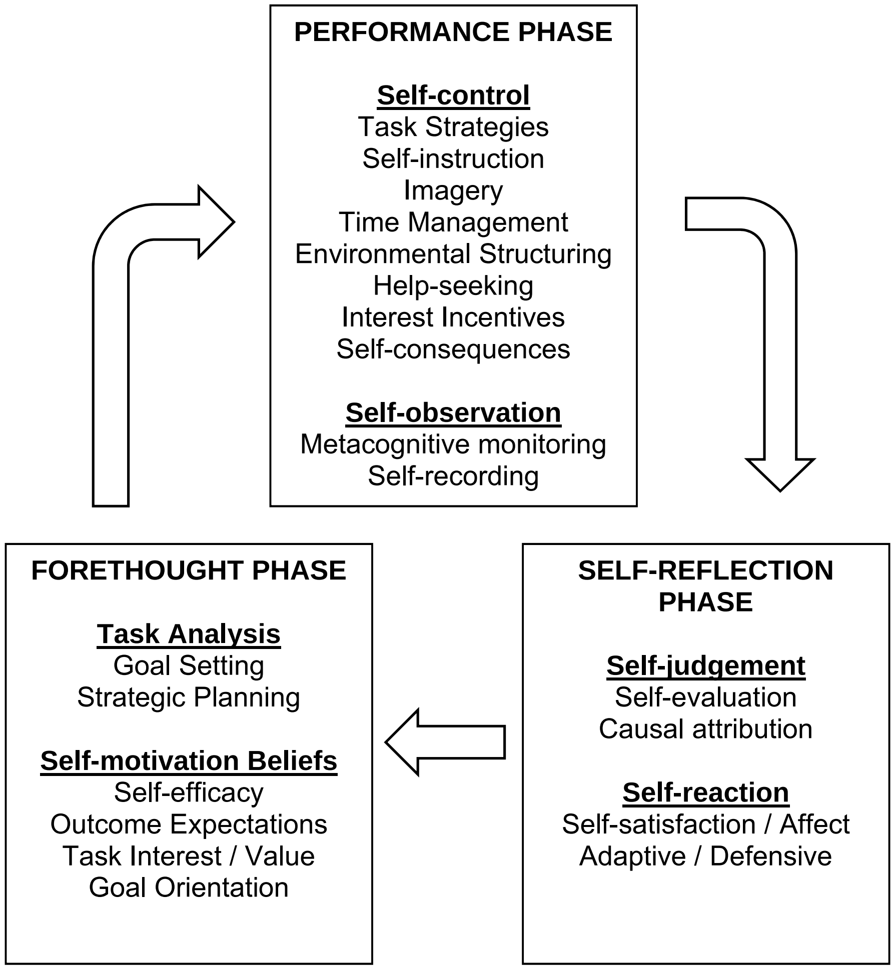


Figure 2. A model of self-regulated learning
proposed by Zimmerman and Moylan (2009)

In the late 1980s and 1990s, several instruments were developed to assess SRL, based on its conceptual definition as a metacognitive, motivational, and behavioral construct. Some of the more popular instruments include the *Learning and Study Strategies Inventory* (LASSI: Weinstein, Schulte & Palmer, 1987), the *Motivated Strategies for Learning Questionnaire* (MSLQ: Pintrich, Smith, Garcia, & McKeachie, 1991) and the *Self-Regulated Learning Interview Scale* (SRLIS: Zimmerman & Martinez-Pons, 1986). Research using these instruments has established that students who are more self-regulated in their learning are likely to achieve better learning outcomes than less self-regulated students (see Pintrich et al., 1993; Zimmerman & Martinez-Pons, 1986).

In the current research programme MSLQ (Pintrich et al., 1991) was chosen to assess students' SRL processes. The MSLQ was chosen not only because it was one of the most widely used self-report instruments to assess SRL, but also because it is the most comprehensive instrument published to date. This instrument comprises two sections (motivation and learning strategies) with a total of 15 scales and 81 items. Table 1 presents the structure of the MSLQ together with a sample question for each scale.

The motivation section of the MSLQ assesses three main constructs: *Value* (students' perceptions of the importance and interest of tasks), *Expectancy* (students' beliefs about their task competency), and *Affect* (students' emotional reactions to learning tasks). The *Value* construct is assessed by the scales Intrinsic Goal Orientation, Extrinsic Goal Orientation and Task Value. The *Expectancy* construct is assessed by the scales Control of Learning Beliefs, Self-efficacy for Learning and Performance. The *Affect* construct is assessed through the Test Anxiety scale.

The learning strategies section of the MSLQ also assesses three main constructs: *Cognitive Strategies* (students' ways of processing information from reading materials and lessons), *Metacognitive Strategies* (students' control and regulation of their own thinking processes), and *Resource Management Strategies* (students' control and usage of learning resources). *Cognitive Strategies* are assessed through the scales Rehearsal, Elaboration, Organization and Critical Thinking. *Metacognitive Strategies* are assessed through the Self-regulation subscale. *Resource Management* is assessed though the scales of Time and Study Environment, Effort Regulation, Peer Learning, and Help Seeking. The summary presented in Table 2 provides a brief description for each of the scales, summarized from Pintrich et al.'s (1991) MSLQ manual.

Table 1. Structure and sample item statements of the MSLQ

Scale	Construct	Subscale	No. of Items	Sample Item Statement
Motivation	Value	Intrinsic Goal Orientation	4	The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.
		Extrinsic Goal Orientation	4	Getting a good grade in this class is the most satisfying thing for me right now.
		Task Value	6	I think the course material in this class is useful for me to learn.
	Expectancy	Control of Learning Beliefs	4	If I don't understand the course material, it is because I didn't try hard enough.
		Self-efficacy of Learning and Performance	8	I'm confident I can understand the most complex material presented by the instructor in this course.
	Affect	Test Anxiety	5	I feel my heart beating fast when I take an exam.
Learning Strategies	Cognitive Strategies	Rehearsal	4	When studying for this class, I read my class notes and the course readings over and over again.
		Elaboration	6	When I study for this course, I write brief summaries of the main ideas from the readings and the concepts from the lectures.
		Organization	4	I make simple charts, diagrams, or tables to help me organize course material.
		Critical Thinking	5	I often find myself questioning things I hear or read in this course to decide if I find them convincing.
	Metacognitive Strategies	Self-regulation	12	When I study for this class, I set goals for myself in order to direct my activities in each study period.
	Resource Management Strategies	Time and Study Environment	8	I make good use of my study time for this course.
		Effort Regulation	4	Even when course materials are dull and uninteresting, I manage to keep working until I finish.
		Peer Learning	3	When studying for this course, I often try to explain the material to a classmate or a friend.
		Help Seeking	4	When I can't understand the material in this course, I ask another student in this class for help.

Table 2. Description of scales assessed in the MSLQ

Section	Scale	Description
Motivation	Intrinsic Goal Orientation	The extent to which a student perceives him/herself to be participating in a task for reasons such as challenge, curiosity and mastery.
	Extrinsic Goal Orientation	The extent to which the student perceives him/herself to be participating in a task for reasons such as grades, rewards, performance, evaluation by others and competition.
	Task Value	Students' perceptions of the task in terms of interest, utility and importance.
	Control of Learning Beliefs	A student's beliefs that him/herself efforts will result in positive outcomes.
	Self-efficacy for Learning and Performance	A student's expectation of his/her own task performance, and his/her self-evaluation of his/her ability to perform a task.
	Test Anxiety	Students' negative thoughts, which disrupt performance, and affective and physiological arousal aspects of anxiety.
Learning Strategies	Rehearsal	Reciting or naming items from a list to be learned.
	Elaboration	Paraphrasing, summarizing, creating analogies, and generative note-taking.
	Organization	Activities that help students to make sense of information presented to them, such as clustering, outlining, and identifying key ideas.
	Critical Thinking	Applying previous knowledge to new situations in order to solve problems.
	Self-regulation	The awareness, knowledge, and control of cognition, which involves the process of planning, monitoring, and regulating.
	Time and Study Environment	The extent to which a student is capable of managing his/her time effectively, and selecting a conducive environment for learning.
	Effort Regulation	The extent to which a student is willing to work hard and remain committed to pursue his/her learning goals, even if the task is uninteresting or difficult.
	Peer Learning	The extent to which a student will collaborate with his/her peers to complete his learning task.
	Help Seeking	The extent to which a student will seek help from his/her peers and instructors to complete given learning tasks.

Approaches to Learning

In 1976, Ference Marton and Roger Säljö published an influential paper that reported their observations on how students approached their learning tasks (Marton & Salijio, 1976). In their study, the students were requested to read a 1500 word article, after which they were asked questions relating to the article. From their responses, the researchers proposed that there were two distinct approaches used by the students - a deep approach, which focused on understanding, and a surface approach, which focused on content reproduction, without making a conscious effort to understand the content.

Since the publication of Marton and Säljö’s (1976) seminal study, other researchers have observed that different learning approaches are linked to the level of commitment shown by learners in confronting learning tasks (Biggs, 1987a; Entwistle, 1981; Ramsden, 2003; Tagg, 2003). For example, various researchers have found that students who adopt a deep learning approach (as described above) tend to use a variety of effective learning strategies to help them understand the materials more thoroughly, such as checking references from different sources, seeking help from their peers and teachers, reflecting on how different pieces of information are connected, and applying knowledge they acquire to new situations (Biggs, 1989). On the other hand, students who use surface learning strategies are generally inclined to rely on rote learning techniques, such as reciting the content repeatedly (Biggs, 1989; Tagg, 2003).

Compared with students who adopt a surface approach to learning, studies have indicated that students who adopt a deep approach tend to achieve better academic outcomes (e.g., Biggs, 1989; Prosser & Millar, 1989). They have also been reported to retain acquired knowledge for a longer period of time, and be more effective in academic problem-solving (e.g., Ramsden, 2003; Whelan, 1988). In a recent large-scale study involving 22,000 students across 30 secondary schools in the United States, it was found that students who adopted a deep learning approach consistently demonstrated higher levels of content mastery and problem-solving skills, than those who adopted more surface-oriented approaches (O’Day & Garet, 2014). Other studies have also indicated that students who adopt a deep approach report higher levels of enjoyment and fulfilment in the process of learning, than do those who adopt a surface approach (e.g., Biggs & Tang, 2011; Ramsden, 2003).

Based on these findings, I decided that students' learning approaches should form another key focus of my research programme. Given in particular the proposed links between deep learning approaches and superior conceptual understanding, I believed that the variable could provide a key mechanism for enhancing students' understanding of new physics concepts at the secondary school level. In my search for relevant instruments to assess students' approaches to learning, I found that the most widely used instruments were the Study Process Questionnaire (SPQ: Biggs, 1987b), the Learning Process Questionnaire (LPQ: Biggs, 1987c) and the Approaches to Study Inventory (ASI: Entwistle & Ramsden, 1983). The SPQ and ASI were designed to assess students' learning approaches at the tertiary levels, while the LPQ was designed for use at the secondary school level.

As the target population for the research was secondary school students, I chose the LPQ for use within this research programme. Each of the scales in the R-LPQ-2F comprises a motive and a strategy subscale, producing four subscales in all (Deep Motive, Deep Strategy, Surface Motive and Surface Strategy). Within each subscale, there are two further components, as indicated in Table 3. There are a total of 22 item statements within the R-LPQ-2F, to which students respond on a five-point scale (*'never or only rarely true of me'* to *'always or almost always true of me'*). The score for each scale, subscale and component are typically computed by taking the average of their corresponding item scores. Thus, the scores range from 1 ('*never or only rarely true of me'*) to 5 ('*always or almost always true of me'*).

The Research Programme

The research reported in this thesis was conducted as a series of studies, with over 2000 Year 11 students from a secondary school in Singapore. The first three studies evaluated the validity of the instruments chosen or developed for use in the research to assess students' learning processes. As noted, these were the Motivated Strategies for Learning Questionnaire; the Revised Learning Process Questionnaire; and a researcher-developed Physics Task Value Scale. These three studies were essentially conducted to confirm that the use of these instruments was tenable in the Singapore secondary school context.

The third and fourth studies focused on two substantive questions that motivated this research endeavour. The first substantive question was, is there a relationship between learning process variables and the development of physics conceptual understanding, and if so, what is the nature of this relationship? The second question was, can students' learning processes be altered in a manner that enhances physics conceptual understanding? Given these overarching questions, Study 4 investigated the relationships between self-regulated learning, physics conceptual understanding and students' learning approaches, while Study 5 examined how one factor in the teaching and learning process (assessment expectations) affected students' approaches to learning, conceptual understanding and task value in physics.

The next chapters of this thesis present each of the papers that have been submitted to journals for review at this point. The final chapter of the thesis presents a brief concluding statement, which summarises the findings of the studies, and discusses the key implications of the research for practice.

Table 3. Structure and items in the R-LPQ-2F

Scale	Subscale	Component	Item Statement
Deep Approach	Deep Motive	Intrinsic Interest	(1) I find that at times studying makes me feel really happy and satisfied.
			(5) I feel that nearly any topic can be highly interesting once I get into it.
			(9) I work hard at my studies because I find the material interesting.
		Commitment to Work	(13) I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes.
			(17) I come to most classes with questions in mind that I want answering.
			(19) I find I am continually going over my school work in my mind at times like when I am on the bus, walking, or lying in bed, and so on.
			(21) I like to do enough work on a topic so that I can form my own conclusions before I am satisfied.
	Deep Strategy	Relating Ideas	(2) I try to relate what I have learned in one subject to what I learn in other subjects.
			(6) I like constructing theories to fit odd things together.
		Understanding	(10) I try to relate new material, as I am reading it, to what I already know on that topic.
			(14) When I read a textbook, I try to understand what the author means.
Surface Approach	Surface Motive	Fear of Failure	(3) I am discouraged by a poor mark on a test and worry about how I will do on the next test.
			(7) Even when I have studied hard for a test, I worry that I may not be able to do well in it.
		Aim for Qualification	(11) Whether I like it or not, I can see that doing well in school is a good way to get a well-paid job.
			(15) I intend to get my A Levels because I feel that I will then be able to get a better job.
	Surface Strategy	Minimizing Scope of Study	(4) I see no point in learning material which is not likely to be in the examination.
			(8) As long as I feel I am doing enough to pass, I devote as little time to studying as I can. There are many more interesting things to do.
			(12) I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra.
			(16) I find it is not helpful to study topics in depth. You don't really need to know much in order to get by in most topics.
		Memorization	(18) I learn some things by rote, going over and over them until I know them by heart.
			(20) I find the best way to pass examinations is to try to remember answers to likely questions.
			(22) I find I can get by in most assessment by memorizing key sections rather than trying to understand them.

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Paper 1 – Construct Validation of the Motivated Strategies for Learning Questionnaire in a Singapore Secondary School

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This first paper was designed to confirm the construct validity of the MSLQ for use in the Singapore school context. This was conducted to ensure that the instrument was suitable for use in subsequent studies within the research programme. Bibilographic Details: Chow, C.W. & Chapman, E. (Submitted). Construct Validation of the Motivated Strategies for Learning Questionnaire in a Singapore Secondary School Sample. Journal of Psychoeducational Assessment, Print ISSN 07342829, Online ISSN 15575144, Impact Factor 0.922.

Abstract

In this study, the construct validity of the Motivated Strategies for Learning Questionnaire (MSLQ) was assessed. Participants were 441 Year 11 students in Singapore. Three separate confirmatory factor analyses were conducted for each section of the MSLQ (motivation and learning strategies). Results indicated that the original factor structures proposed by the instrument developers produced the best model fit. Cronbach α coefficients were also acceptable for all but one of the individual scales. Correlations with the Revised Learning Process Questionnaire – Two Factor and physics achievement test scores also aligned with the theoretical basis of the MSLQ. These results confirmed the potential utility of this instrument for assessing the motivation and learning strategies of secondary students in Singapore.

Keywords: Motivated Strategies for Learning Questionnaire (MSLQ), secondary students, construct validity, Singapore

Introduction

The 21st Century Competency Framework developed by the Singapore Ministry of Education in 2010 places central importance on the development of students' self-regulatory skills (Ministry of Education Singapore, 2010). The term self-regulation, when applied to learning, refers to the proactive process whereby learners set goals for their learning, actively monitor their progress, and regulate their cognition, motivation and behaviour in order to achieve their learning goals (Pintrich, 2000). Research has indicated that individuals with higher levels of self-regulation are not only more successful in schools, but also in other aspects of their lives. In addition to performing better academically, these students tend also to achieve greater success in their careers, and enjoy better health, than those with lower levels of self-regulation (Bandura, 1982; Baumeister, Heatherton, & Tice, 1994; Boekaertz, Pintrich, & Zeidner, 2005, Locke & Latham, 2002; Mischel, Shoda, & Rodriguez, 1989).

The Ministry of Education's 2010 initiative points to the need for a validated instrument that can be used to assess the self-regulation levels of secondary level students in Singapore. One of the most widely used instruments for assessing students' self-regulated learning is the *Motivated Strategies for Learning Questionnaire* (MSLQ: Pintrich, Smith, García & McKeachie, 1991, 1993). Duncan and McKeachie (2005) identified 55 empirical studies that had employed either the entire MSLQ or part of it within just a five-year period (2000-2004). At the college level, the instrument has been applied in studies across Western countries (e.g., Campbell, 2001; McKenzie & Gow, 2004; Suárez, González, & Valle, 2001) and other contexts (e.g., Cheung, Rudowicz, Lang, Yue & Kwan, 2001; Ostovar & Khayyer, 2004). In 2011, a meta-analysis by Credé and Phillips (2011) identified 67 studies that had used the MSLQ with 19,900 college students. The MSLQ has also been used at the secondary level in several countries, including America (e.g., Liu, 2003), Germany (e.g., Neber & Heller, 2002), Hong Kong (e.g., Sachs, Law & Chan, 2002), Israel (e.g., Eshel & Kohavi, 2003), Korea (e.g., Bong, 2001) and Turkey (e.g., Andreou, 2004).

The MSLQ is divided into two distinct sections: motivation and learning strategies. The motivation section comprises six subscales and the learning strategies section comprises nine subscales. In all, the MSLQ includes 81 items, to which students respond on a seven-point scale (‘*not at all true of me*’ to ‘very true of me’). Table 1 presents the overall structure of the MSLQ, along with sample item statements.

The six subscales of the motivation section comprises: Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-efficacy for Learning and Performance, and Test Anxiety. These motivation subscales are used to assess three main constructs (García & Pintrich, 1995): values (i.e., students’ perceptions of the importance and interest of tasks), expectancy beliefs (i.e., students’ beliefs about their task competency), and affect (i.e., students’ emotional reactions to learning tasks). Amongst the six motivation subscales, Intrinsic Goal Orientation, Task Value, Control of Learning Beliefs and Self-efficacy for Learning and Performance are often regarded as ‘positive’ motivations, as these have been linked to desirable education outcomes. Conversely, Extrinsic Goal Orientation and Test Anxiety are often linked to less desirable education outcomes, and hence are regarded as ‘negative’ motivations.

Table 1. Structure and sample item statements of the MSLQ

Scale	Construct	Subscale	# Items	Sample Item Statement
Motivation	Value	Intrinsic Goal Orientation	4	The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.
		Extrinsic Goal Orientation	4	Getting a good grade in this class is the most satisfying thing for me right now.
		Task Value	6	I think the course material in this class is useful for me to learn.
	Expectancy	Control of Learning Beliefs	4	If I don't understand the course material, it is because I didn't try hard enough.
		Self-efficacy of Learning and Performance	8	I'm confident I can understand the most complex material presented by the instructor in this course.
	Affect	Test Anxiety	5	I feel my heart beating fast when I take an exam.
Learning Strategies	Cognitive Strategies	Rehearsal	4	When studying for this class, I read my class notes and the course readings over and over again.
		Elaboration	6	When I study for this course, I write brief summaries of the main ideas from the readings and the concepts from the lectures.
		Organization	4	I make simple charts, diagrams, or tables to help me organize course material.
		Critical Thinking	5	I often find myself questioning things I hear or read in this course to decide if I find them convincing.
	Metacognitive Strategies	Self-regulation	12	When I study for this class, I set goals for myself in order to direct my activities in each study period.
	Resource Management Strategies	Time and Study Environment	8	I make good use of my study time for this course.
		Effort Regulation	4	Even when course materials are dull and uninteresting, I manage to keep working until I finish.
		Peer Learning	3	When studying for this course, I often try to explain the material to a classmate or a friend.
		Help Seeking	4	When I can't understand the material in this course, I ask another student in this class for help.

The nine scales of the learning strategy section comprises: Rehearsal, Elaboration, Meta-cognitive Self-regulation, Critical Thinking, Time and Study Environment, Effort Regulation, Peer Learning, and Help Seeking. The nine learning strategies subscales are used to assess three main constructs (García & Pintrich, 1995): cognitive strategies (i.e., students' ways of processing information from reading materials and lessons), metacognitive strategies (i.e., students' control and regulation of their own thinking processes), and resource management (i.e., students' control and usage of learning resources). Rehearsal is generally regarded as a 'negative' strategy, as this has been linked to the approach of learning by rote. All other strategies are generally regarded as 'positive' strategies, as these are generally linked to higher order thinking.

The first validation study on the MSLQ was conducted by the instrument developers (Pintrich et al., 1991) with a sample of college students in the United States. Confirmatory factor analyses (CFAs) performed in this study indicated a five-factor structure for the motivation section, and a nine-factor structure for the learning strategies section. High levels of internal consistency were found for most scales. These findings have since been supported by studies conducted with other samples of college students in the United States (Cho & Summers, 2012), Oman (Alkharusi et al., 2012) and Singapore (Rotgans & Schmidt, 2010).

In comparison to the supporting evidence that has accumulated with regard to college students, little evidence has been published on the validity of the MSLQ at the secondary level. At the time of writing, only two published studies involving secondary students could be located. Erturan Ilker, Arslan and Demirhan (2014) and Karadeniz et al. (2008) both investigated the factor structure of a Turkish version of the MSLQ. The Karadeniz et al.'s study involved 1114 Turkish students from three primary schools and three secondary schools, while the Erturan Ilker et al.'s study involved 1605 Turkish students from one secondary school. Both studies indicated that the instrument exhibited a similar factor structure to that found in earlier studies with college students.

Given the comprehensive nature of the MSLQ, this instrument has potential for monitoring the self-regulation levels of secondary school students in Singapore. To date, however, no validation studies in this context could be located. Thus, in the present study, the validity of the MSLQ was examined using a Singapore secondary school sample. Two key aspects of validity were examined within the study, based on the guidelines of the 2014 Standards for Educational and Psychological Testing (AERA, APA & NCME, 2014). The internal structure of the MSLQ was first investigated by replicating the CFAs published in previous validations, and by assessing the internal consistencies of, and inter-correlations between, the MSLQ subscales. Correlations with external variables which measure theoretically related constructs were then examined to further evaluate the construct validity of the instrument within this sample.

Method

Sample

Participants were 441 Year 11 students (267 male, 174 female) within the Singapore secondary school system (age *M* = 16.7 years, *SD* = 0.82). Participants were enrolled in a two-year physics course taught in the English language, which would prepare them for the General Certificate of Education Advanced Level (GCE ‘A’ Level) physics examination, at the time of the study. As such, the MSLQ was administered in this study with specific reference to physics classes, as recommended by Pintrich et al. (1991).

Validation Instruments

In addition to the Motivated Strategies for Learning Questionnaire (MSLQ), two further instruments were used for validation purposes: the Two-factor Revised Learning Process Questionnaire (R-LPQ-2F; Kember et al., 2004), and a physics achievement test. The R-LPQ-2F includes two main scales (Deep Approach and Surface Approach), each of which includes a motive and strategy subscale (i.e., four subscales in all: Deep Motive, Deep Strategy, Surface Motive and Surface Strategy). Studies on the R-LPQ-2F have indicated that it demonstrates sound psychometric properties (e.g., Phan & Deo, 2007; Socha & Sigler, 2012). Drawing upon the theoretical bases of the two instruments (e.g., Biggs & Tang, 2007; Curran & Bowie, 1998), deep motive scores would be expected to correlate positively with the positive motivation subscales in the MSLQ, while deep strategy scores should correlate positively with the positive MSLQ learning strategy scales. Surface motives would be expected to correlate negatively with the positive MSLQ motivation subscales, and positively with the two negative MSLQ motivation subscales, while surface strategies should correlate positively with the negative MSLQ strategy scale of Rehearsal. Expected correlations between the MSLQ and R-LPQ-2F are summarized in Tables 2 and 3.

Table 2. Expected correlations between MSLQ motivation subscales R-LPQ-2F motive subscales

Subscale	Deep Motive	Surface Motive
1. Intrinsic Goal Orientation	Positive	Negative
2. Extrinsic Goal Orientation	Negative	Positive
3. Task Value	Positive	Negative
4. Control of Learning Beliefs	Positive	Negative
5. Self-efficacy for Learning and Performance	Positive	Negative
6. Test Anxiety	Negative	Positive

Table 3. Expected correlations between MSLQ learning strategy scales and R-LPQ-2F strategy subscales

Subscale	Deep Strategy	Surface Strategy
1. Rehearsal	Negative	Positive
2. Elaboration	Positive	Negative
3. Organization	Positive	Negative
4. Critical Thinking	Positive	Negative
5. Metacognitive Self-regulation	Positive	Negative
6. Time and Study Environment	Positive	Negative
7. Effort Regulation	Positive	Negative
8. Peer Learning	Positive	Negative
9. Help Seeking	Positive	Negative

Given that both motivation and learning strategies are presumed to relate in some way to student achievement, a physics achievement test used within the school was used to provide further information on the validity of the MSLQ. This test is a two-hour pen-and-paper assessment comprising 15 multiple-choice questions and 3 short response questions, that are adapted directly from past year GCE ‘A’ level examinations. The test questions, including the marking scheme, were vetted by the subject coordinator and the head of the physics department, who each had more than ten years of teaching experience, to ensure close alignment to the assessment objectives of the GCE ‘A’ level physics examination (Singapore-Cambridge GCE ‘A’ level physics syllabus 9646, 2014). Scores on the physics achievement test were computed by summing the scores for the multiple-choice questions and the structured questions. The multiple-choice and structured questions were each worth a maximum score of 15 and 65 points, respectively, giving a total maximum score of 80. Expected correlations between the MSLQ subscales and physics achievement, based on the underlying theory of the MSLQ, are shown in Table 4 and 5.

Table 4. Expected correlations between MSLQ motivation subscales and physics achievement test scores

Subscale	Physics Achievement Test
1. Intrinsic Goal Orientation	Positive
2. Extrinsic Goal Orientation	Negative
3. Task Value	Positive
4. Control of Learning Beliefs	Positive
5. Self-efficacy for Learning and Performance	Positive
6. Test Anxiety	Negative

Table 5. Expected correlations between MSLQ learning strategy scales and physics achievement test scores

Subscale	Physics Achievement Test
1. Rehearsal	Negative
2. Elaboration	Positive
3. Organization	Positive
4. Critical Thinking	Positive
5. Metacognitive Self-regulation	Positive
6. Time and Study Environment	Positive
7. Effort Regulation	Positive
8. Peer Learning	Positive
9. Help Seeking	Positive

Procedures

Approval to conduct the research was first obtained from the Human Research Ethics Committee of the University of Western Australia. All procedures used within the study were conducted in compliance with the National Health and Medical Research Council's (2007) Australian Code for the Responsible Conduct of Research. Permission was also granted by the Principal of the participating school. All participating students took the R-LPQ-2F, the MSLQ and the physics achievement test in a single session. They were provided with hardcopies of the questionnaires and optical mark sheets to shade their responses.

Results and Discussion

SPSS Version 19 (IBM Corporation, 2010) was used to compute all descriptive statistics, Cronbach's α coefficients, and bivariate correlations. LISREL 8.8 (Jöreskog & Sörbom, 2006) was used to conduct all CFAs based on the maximum likelihood estimation method. Prior to the analysis, the scores of all negatively worded items were first reversed. Screening tests for conformity to underlying CFA assumptions were then conducted. These tests generally produced satisfactory results. Inspections of z-scores and Mahalanobis distances indicated no significant univariate or multivariate outliers at the .001 level, and there was no evidence of multicollinearity between variables within the set. Skewness and kurtosis coefficients indicated no significant deviations from normality in the item distributions in terms of kurtosis, though moderate levels of skew across several items were observed. Given this, the PRELIS Normal Scores module in LISREL 8.8 was used to transform the scores prior to conducting the CFAs. Item descriptive statistics for the MSLQ motivation and learning strategies subscales appear in Tables 6 and 7, respectively.

Table 6. Item descriptive statistics for the MSLQ

Motivation Subscale	Item	*M*	*SD*
1. Intrinsic Goal Orientation	1	5.01	1.25
	16	5.52	1.19
	22	5.65	1.06
	24	4.75	1.24
2. Extrinsic Goal Orientation	7	5.23	1.34
	11	5.11	1.27
	13	5.91	1.11
	30	4.73	1.50
3. Task Value	4	5.00	1.20
	10	6.12	0.89
	17	5.13	1.17
	23	5.53	1.01
	26	5.29	1.12
	27	5.69	0.99
4. Control of Learning Beliefs	2	5.99	0.83
	9	5.66	1.15
	18	5.78	.99
	25	5.07	1.24
5. Self-Efficacy for Learning and Performance	5	5.02	1.33
	6	4.38	1.46
	12	5.71	1.03
	15	4.48	1.42
	20	4.94	1.17
	21	5.27	1.22
	29	5.12	1.11
	31	5.04	1.19
6. Test Anxiety	3	3.90	1.70
	8	4.48	1.63
	14	4.31	1.67
	19	3.80	1.49
	28	4.21	1.64

Table 7. Item descriptive statistics for the MSLQ learning strategies scale

Learning Strategies Subscale	Item	*M*	*SD*
1. Rehearsal	39	3.98	1.55
	46	4.78	1.34
	59	5.12	1.25
	72	4.29	1.51
2. Elaboration	53	5.25	1.11
	62	4.77	1.29
	64	5.41	1.03
	67	4.53	1.51
	69	5.45	0.98
	81	4.76	1.21
3. Organisation	32	4.69	1.38
	42	5.60	0.98
	49	4.36	1.50
	63	4.95	1.27
4. Critical Thinking	38	4.94	1.32
	47	5.01	1.21
	51	4.57	1.25
	66	4.82	1.21
	71	4.97	1.22
5. Metacognitive Self-Regulation	33	4.58	1.42
	36	4.14	1.48
	41	5.72	0.92
	44	4.67	1.24
	54	5.01	1.38
	55	4.90	1.34
	56	4.49	1.31
	57	4.62	1.37
	61	4.77	1.27
	76	5.66	0.99
	78	4.74	1.30
	79	5.34	1.20
6. Time and Study Environment	35	5.51	1.17
	43	5.05	1.08
	52	3.68	1.68
	65	4.95	1.60
	70	5.48	1.09
	73	6.19	0.92
	77	3.95	1.38
	80	4.83	1.56
7. Effort Regulation	37	4.94	1.52
	48	5.13	1.30
	60	5.35	1.30
	74	5.23	1.20
8. Peer Learning	34	4.50	1.18
	45	4.95	1.15
	50	4.16	1.36
9. Help Seeking	40	3.94	1.56
	58	5.14	1.31
	68	5.48	1.20
	75	5.62	1.14

Validity evidence from investigating internal structure

(a) ***Confirmatory factor analyses.*** The internal structure of the MSLQ was first investigated by examining its factor structure. CFAs were performed separately for motivation and learning strategies subscales, given that the two MSLQ sections are theoretically distinct. For the motivation section, three competing nested models were tested, as presented in Table 8. Model M1 included all item statements from all motivation subscales as one factor, given that these all assess facets of learning motivation. Model M2 tested a three-factor model, with items grouped into the three broad theoretical constructs (value, expectancy and affect) stipulated by Pintrich et al. (1991, 1993). Model M3 tested a six-factor model based on the scales proposed by Pintrich et al. (Intrinsic Goal Orientation; Extrinsic Goal Orientation; Task Value; Control of Learning Beliefs; Self-Efficacy for Learning and Performance; Test Anxiety).

Table 8. Models tested for the motivation subscales of the MSLQ

Model	Number of Factor(s)	Subscales included in factor(s)
M1	One	All motivation items
M2	Three	Factor 1: Expectancy construct subscales-- Intrinsic Goal Orientation, Extrinsic Goal Orientation and Task Value Factor 2: Value construct subscales-- Control of Learning Beliefs, Self-efficacy of Learning and Performance Factor 3: Affect construct subscale—Test Anxiety
M3	Six	Factor 1: Intrinsic Goal Orientation Factor 2: Extrinsic Goal Orientation Factor 3: Task Value Factor 4: Control of Learning Beliefs Factor 5: Self-efficacy of Learning and Performance Factor 6: Test Anxiety

Another three models were tested for the MSLQ learning strategies section, as presented in Table 9. Model LS1 included the item statements for all the learning strategy subscales as one factor. Model LS2 tested a three-factor model, with items grouped into the three broad theoretical sub-constructs (cognitive, metacognitive and resource management) proposed by Pintrich et al. (1991, 1993). Model LS3 tested a nine-factor model, again based on the subscales of the MSLQ proposed by Pintrich et al. (Rehearsal; Elaboration; Organisation; Critical Thinking; Metacognitive Self-Regulation; Time and Study Environment; Effort Regulation; Peer Learning; and Help Seeking).

Table 9. Models tested for the learning strategies subscales of the MSLQ

LS1	One	All learning strategy items
LS2	Three	Factor 1: Cognitive strategies subscales—Rehearsal, Elaboration, Organization, Critical Thinking
		Factor 2: Meta-cognitive strategies subscale— Self-regulation
		Factor 3: Resource management— Time and Study Environment, Effort Regulation, Peer Learning and Help Seeking
LS3	Nine	Factor 1: Rehearsal
		Factor 2: Elaboration
		Factor 3: Organization
		Factor 4: Critical Thinking
		Factor 5: Self-Regulation
		Factor 6: Time and Study Environment
		Factor 7: Effort Regulation
		Factor 8: Peer Learning
		Factor 9: Help Seeking

Two absolute fit indices (the Standardized Root Mean Square Residual, or SRMR, and the relative chi-square value, or χ^2/df) and two relative fit indices (the Comparative Fit Index, or CFI, and the Non-Normed Fit Index, NNFI) were used to assess the fit of each model tested. Accepted cut-offs suggest that in CFAs, good model fit is indicated by a χ^2/df < 5 and SRMR < 0.08, with values greater than 0.90 for the CFI and NNFI (e.g., Browne & Cudeck, 1993; Byrne, 1989; Schumacker & Lomax, 2004). The Goodness of Fit Index (GFI) was not used in this study, based on current recommendations within the field (Sharma, Mukherjee, Kumar & Dillon, 2005). Differences between nested models within each of the MSLQ sections were evaluated using the chi square difference test (i.e., $\Delta\ \chi^2$).

The fit indices obtained for each model of the MSLQ in this study are presented in Table 10. As indicated, for the motivation section, the one factor model did not fit the data well. Both the three-factor and the six-factor models met accepted cut-offs for the CFI and NNFI, though the SRMR for the three-factor fell above the recommended cut-off value. All three models differed significantly from one another based on the $\Delta\chi^2$ test. Given these results, it was concluded that the six-factor model provided the best fit to the data.

For the learning strategies subscales, again, the one factor model did not fit the data well, though both the CFI and the NNFI fell only marginally below the accepted cut-values. Indeed, the χ^2/df value for the one-factor learning strategies model fell within acceptable parameters. The three-factor model represented a significant improvement on the one-factor based on the $\Delta\chi^2$ test, but this model still fell short of accepted cut-offs based on the SRMR and the NNFI. The nine-factor model was clearly the best-fitting, meeting accepted fit levels for the χ^2/df, CFI, and NNFI, though the SRMR for this model was still somewhat high. Based on these results, the nine-factor was deemed to represent the best-fitting model. These results are comparable to those obtained in previous studies (e.g., Alkharusi et al., 2012; Pintrich et al., 1991; Karadenzi et al., 2008). The path diagrams (with standardized coefficients) for models M3 and LS3 are presented in Figures 1 and 2, respectively.

Table 10. Fit indices alternative models of motivation and learning strategy subscales

Model	χ^2	df	χ^2/df	SRMR	CFI	NNFI	$\Delta\chi^2$ Statistics
M1: One-factor (motivation)	2801.19*	434	6.45	.110	.89	.88	M1 & M2: $\Delta\chi^2$ (3) = 854.90, $p < .05$
M2: Three-factor (motivation)	1946.29*	431	4.52	.092	.93	.92	M2 & M3: $\Delta\chi^2$ (12) = 557.18, $p < .05$
M3: Six-factor (motivation)	1389.11*	419	3.35	.076	.95	.95	M1 & M3: $\Delta\chi^2$ (15) = 1412.08, $p < 0.05$
LS1: One-factor (learning strategies)	5065.30*	1175	4.31	.092	.89	.89	LS1 & LS2: $\Delta\chi^2$ (3) = 166.85, $p < .05$
LS2: Three-factor (learning strategies)	4898.45*	1172	4.18	.093	.90	.89	LS2 & LS3: $\Delta\chi^2$ (33) = 1093.71, $p < .05$
LS3: Nine-factor (learning strategies)	3804.74*	1139	3.34	.087	.93	.92	LS1 & LS3: $\Delta\chi^2$ (36) = 1260.56, $p < .05$

*Significant at α = .001 level

(b) ***Internal consistencies.*** Cronbach's alphas for each of the MSLQ subscales are presented in Table 11. Kline (2000) suggested that an alpha coefficient of above .60 represents an acceptable level of internal consistency, with alpha coefficients of above .70 indicating a good level of consistency for low-stakes tests. As indicated, eight of the MSLQ subscales had a good level of internal consistency, with six others achieving an acceptable level. Only one scale (Help Seeking) was observed not to meet the acceptable level of 0.6. These results are similar to those obtained by Pintrich et al. (1991). The poor result obtained for the Help Seeking scale is also consistent with previous studies. García and Pintrich (1995) attributed the low internal consistency of Help Seeking to the fact that it relates both to seeking assistance from peers and from teachers. García and Pintrich argued that students might be inclined to seek help from only one of the sources, which would contribute to the lower internal consistency of this scale.

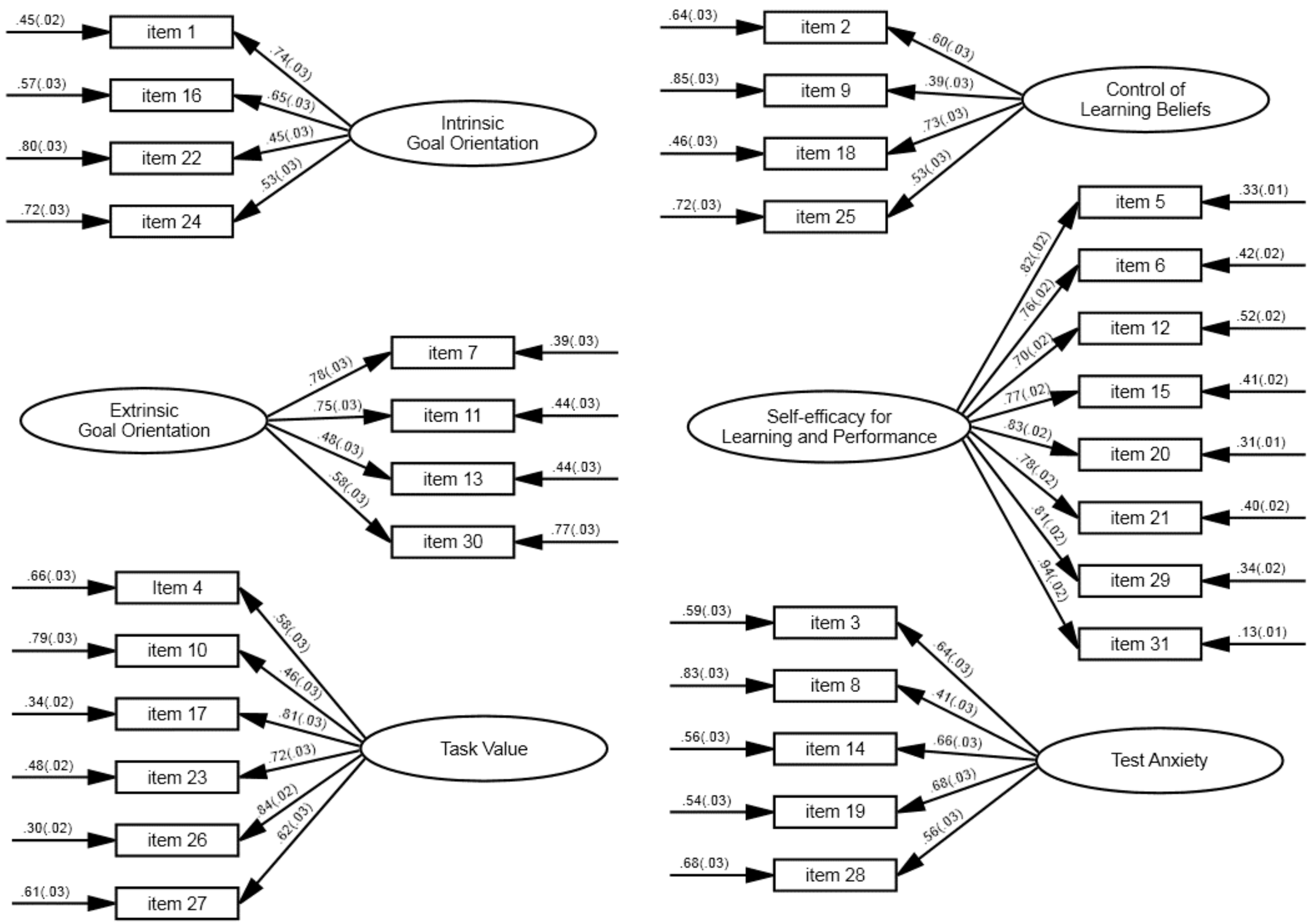

Figure 1. Original six-factor model of the MSLQ motivation subscales

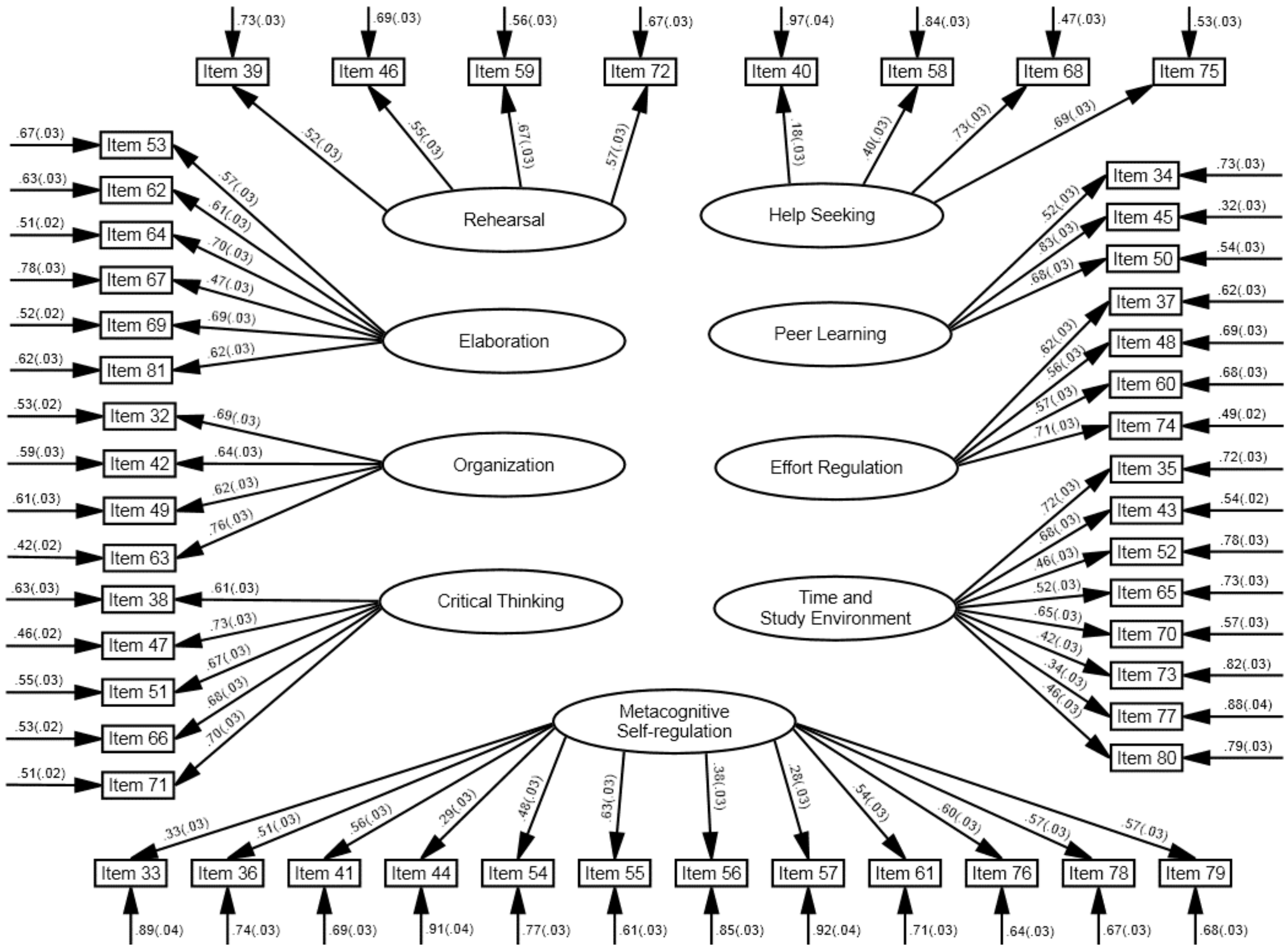

Figure 2. Original nine-factor model of the MSLQ learning strategies subscales

Table 11. Internal consistency of the MSLQ subscales

Section	Subscale	Cronbach Alpha	
		Current Study	Pintrich et al.'s (1991) Study
Motivation	a) Value Components		
	• Intrinsic Goal Orientation	.76	.74
	• Extrinsic Goal Orientation	.68	.62
	• Task Value	.84	.90
	b) Expectancy Components		
	• Control of Learning Beliefs	.68	.68
	• Self-efficacy for Learning and Performance	.94	.93
	c) Affective Component		
	• Test Anxiety	.69	.80
Learning Strategies	a) Cognitive and metacognitive Strategies		
	• Rehearsal	.69	.69
	• Elaboration	.75	.76
	• Organization	.76	.64
	• Critical Thinking	.80	.80
	• Metacognitive Self-regulation	.79	.79
	b) Resource Management Strategies		
	• Time and Study Environment	.72	.76
	• Effort Regulation	.66	.69
	• Peer Learning	.65	.76
	• Help Seeking	.51	.52

(c) ***Inter-correlations between subscales.*** The internal structure of the MSLQ was further assessed by examining correlations between the individual subscales. Results are presented in Tables 12 and 13, respectively. The pattern of correlations obtained aligned well with the theoretical basis of the instrument. Scores on Intrinsic Goal Orientation, Task Value, Control of Learning Beliefs and Self-efficacy were positively and highly correlated with one other, and the scores for all the self-regulated learning strategies subscales were also positively correlated with one other. The one subscale that exhibited some unexpected characteristics was the Extrinsic Goal Orientation component. First, the scores for this subscale did not correlate negatively with the scores of Intrinsic Goal Orientation. This is not aligned with the views of many researchers (e.g., Harter, 1981), who propose the two constructs to be opposing ends of a single continuum. Furthermore, significant positive correlations were found between Extrinsic Goal Orientation and Task Value, Control of Learning Beliefs, and Self-efficacy for Learning and Performance. This might be deemed counter-intuitive, as many studies conducted in the West have found extrinsic rewards to undermine intrinsic motivation (e.g. Deci, 1971; Kruglanski, Friedman, & Zeevi, 1971; Lepper, Greene, & Nisbett, 1973). The findings of this study are, however, consistent with other studies involving East Asian students. For example, Lin et al. (2003) found that the highest performing Korean students exhibited high levels of intrinsic motivation *as well as* moderate levels of extrinsic motivation. Similar results were also found in a study by Kember, Wong and Leung (1999) on Hong Kong students. Such observations may reflect the Confucian Heritage cultures of these countries, which places great emphasis on hard work and academic success, and in which education is viewed as important not only for the individual, but also, for the family and society (e.g., Biggs, 1998; Salili, 1996).

Table 12. Inter-correlations of the MSLQ motivation subscales

Subscale	1	2	3	4	5	6
1. Intrinsic Goal Orientation	–	.05	.67**	.50**	.59**	- .12*
2. Extrinsic Goal Orientation		–	.24**	.25**	.25**	.27**
3. Task Value			–	.60**	.58**	.01
4. Control of Learning Beliefs				–	.48**	- .03
5. Self-efficacy for Learning and Performance					–	- .24**
6. Test Anxiety						–

**p*< .05, ***p*< .01

Table 13. Inter-correlations of the MSLQ learning strategies subscales

Subscale	1	2	3	4	5	6	7	8	9
1. Rehearsal	–	.40**	.58**	.11*	.35**	.26**	.15**	.34**	.25**
2. Elaboration		–	.59**	.64**	.73**	.44**	.44**	.62**	.34**
3. Organisation			–	.27**	.57**	.48**	.36**	.47**	.21**
4. Critical Thinking				–	.64**	.29**	.29**	.45**	.14**
5. Metacognitive Self-regulation					–	.58**	.56**	.69**	.29**
6. Time and Study Environment						–	.83**	.61**	.23**
7. Effort Regulation							–	.78**	.27**
8. Peer Learning								–	.43**
9. Help Seeking									–

*$p < .05$, **$p < .01$

Validity evidence based on relationships with external variables

Correlations between the scores of the MSLQ and R-LPQ-2F motive subscales are presented in Table 14. With the exception of extrinsic motivation, all obtained correlations aligned well with expectations. The pattern of correlations for Extrinsic Goal Orientation departed somewhat from previous results obtained in Western cultures. Extrinsic Goal Orientation correlated positively (though weakly) with Deep Motive and not with Surface Motive. Again, this may reflect the Confucian Heritage culture of Singapore. Specifically, it may be that even students who adopt extrinsic goal orientations will be motivated to use deep learning strategies, because these strategies are often needed for a high success level.

Table 14. Correlations between MSLQ motivation and R-LPQ-2F motive subscales

Subscale	Deep Motive	Surface Motive
1. Intrinsic Goal Orientation	.38**	-.29**
2. Extrinsic Goal Orientation	.12*	.09
3. Task Value	.42**	-.29**
4. Control of Learning Beliefs	.33**	-.16**
5. Self-efficacy for Learning and Performance	.43**	-.21**
6. Test Anxiety	-.06	.16**

*$p< .05$, **$p< .01$

Table 15 presents correlations between MSLQ learning strategies and R-LPQ-2F strategy subscales scores. As expected, the scores for most of the MSLQ learning strategies subscales were positively correlated with Deep Strategy, and negatively or not significantly correlated with Surface Strategy. Help Seeking was an exception, but there were no theoretical grounds for the scores of this subscale to exhibit specific correlation patterns with those for deep or surface learning strategies. Interestingly, it was found that the scores for Rehearsal, which is a basic cognitive strategy, was positively correlated *both* with the scores for surface *and* with deep learning strategies. While its positive correlation with the scores of deep strategies is not aligned with previous studies conducted in Western cultures, this is again consistent with previous studies involving students from Confucian Heritage cultures. Strategies including repetition and memorizing are commonly used by Asian students who engage in deep learning, as a precursor to other strategies (Biggs, 1998).

Table 15. Correlations of the MSLQ learning strategy with R-LPQ-2F learning subscales

Scale	Deep Strategy	Surface Strategy
1. Rehearsal	.11*	.21**
2. Elaboration	.55**	-.08
3. Organization	.24**	.05
4. Critical Thinking	.65**	-.08
5. Metacognitive Self-regulation	.55**	-.16**
6. Time and Study Environment	.28**	-.18**
7. Effort Regulation	.27**	-.26**
8. Peer Learning	.43**	-.15**
9. Help Seeking	.06	.06

*$p < .05$, **$p < .01$

Correlations between the MSLQ subscales and physics achievement test scores are shown in Table 16. As indicated, again, most of the motivation subscales related as expected to achievement, with positive correlations obtained between the scores for achievement and Intrinsic Goal Orientation, Task Value, Control of Learning Beliefs, and Self-efficacy for Learning and Performance, and a negative correlation obtained between the scores on achievement and Test Anxiety. Extrinsic goal orientation, however, did not correlate significantly with achievement test scores. Relationships between the MSLQ learning strategies subscales and achievement (see Table 17) similarly aligned with expectations, though the scores for Rehearsal, Organisation, and Help Seeking were not significantly correlated with achievement test scores. Overall, however, these results suggest that the MSLQ scores related to achievement in alignment with the theoretical basis of the instrument.

Table 16. Correlations of the MSLQ motivation subscales and physics achievement test

Subscale	Physics Achievement Test
1. Intrinsic Goal Orientation	.26**
2. Extrinsic Goal Orientation	- .07
3. Task Value	.20**
4. Control of Learning Beliefs	.10*
5. Self-efficacy for Learning and Performance	.27**
6. Test Anxiety	-.10*

**p*< .05, ***p*< .01

Table 17. Correlations of the MSLQ learning strategy scales physics achievement test

Subscale	Physics Achievement Test
1. Rehearsal	- .05
2. Elaboration	.13**
3. Organization	.05
4. Critical Thinking	.19**
5. Metacognitive Self-regulation	.25**
6. Time and Study Environment	.19**
7. Effort Regulation	.21**
8. Peer Learning	.20**
9. Help Seeking	- .01

**p*< .05, ***p*< .01

Conclusion

Results of this study indicate that the internal structure of the MSLQ in Singapore secondary school students is similar to the original factor structure proposed by Pintrich et al. (1991). In this study, a structure comprising six motivation subscales and nine learning strategies subscales fit the data well. The internal consistencies of the subscales were also generally within acceptable ranges. While the Help Seeking subscale did exhibit a relatively low α coefficient, this aligns with the results obtained in the original validation of the scale. The latter result may signal the need for further refinements of this particular scale. Results of the inter-factor correlations within the MSLQ and correlations with external variables also generally supported the construct validity of the instrument. Overall, these findings suggest that the MSLQ is an appropriate measure of students' learning motivations and strategies in the Singapore secondary school context. Future research is needed to determine whether the instrument is suitable for use in other grade levels within this system.

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Paper 2 – Construct Validation of the Two-factor Revised Learning Process Questionnaire in a Singapore Secondary School

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This second paper was designed to confirm the construct validity of the R-LPQ-2F for use in the Singapore secondary school context. This was conducted to ensure that the instrument was suitable for use in subsequent studies within the research programme. Bibilographic Details: Chow, C.W. & Chapman, E. (Submitted). Construct Validity of the Two-factor Revised Learning Process Questionnaire in a Singapore Secondary School. Assessment for Effective Intervention, Print ISSN 1534-5084, Online ISSN 1938-7458, Impact Factor 0.483.

Abstract

The Revised Two-factor Learning Process Questionnaire (R-LPQ-2F) is an instrument for assessing students' learning approaches at the secondary school level. The instrument has significant potential for use in Singapore schools, but as yet, has not been validated in this context. This study evaluated the validity attributes of the R-LPQ-2F in a sample of Singapore senior secondary school students. The sample comprised 455 Year 11 students (266 male, 189 female) from Singapore. The internal structure of the R-LPQ-2F was evaluated by replicating the confirmatory factor analyses published in previous validations of the instrument, and assessing its internal consistencies and inter-scale correlations. Relationships between the R-LPQ-2F subscales and external variables were also evaluated. Results indicated that for the Deep Approach scale, a one-factor model fits the data well. For the Surface Approach scale, a four-factor model (Fear of Failure; Aim for Qualification; Minimizing Scope of Study; and Memorization) was found to fit the data best. Correlations between scores on the R-LPQ-2F subscales, on the Motivated Strategies for Learning Questionnaire, and a physics achievement test demonstrated expected patterns of correlation. Overall, results obtained in this study supported the construct validity of the R-LPQ-2F for use with Singapore secondary school students.

Keywords: Revised Learning Process Questionnaire (R-LPQ-2F), secondary students, construct validity, Singapore

Introduction

Recent decades have witnessed a growing interest in the approaches that students adopt when undertaking their learning tasks (Biggs, 1999; Marton, Hounsell & Entwistle, 1997; Marton & Säljö, 1976). In general, research in this field has focused on two distinct types of learning approach: deep and surface (Biggs & Tang, 2007; Entwistle, 1988; Marton & Säljö, 1976). Students who adopt a deep approach to learning are depicted as those who focus on internalizing new information, connecting new understandings with existing knowledge, and analyzing how new concepts can be applied across different situations. In contrast, students who adopt a surface approach to learning are depicted as those who focus on memorizing and reproducing information, paying less attention to understanding or applying what they have learned.

Previous studies have indicated a positive relationship between deep approaches to learning and cognitive development (e.g., Nelson Laird et al., 2007; Phan, 2007, 2011). In a recent large-scale study involving 22,000 students across 30 secondary schools in the United States, it was found that students who adopted a deep approach to learning demonstrated higher levels of content mastery and problem-solving skills than those who adopted more surface-based approaches (O'Day & Garet, 2014). Other research has also indicated that students who adopt a deep approach to learning tend to report higher levels of enjoyment and fulfilment in the process of learning than those who adopt a surface approach (e.g., Biggs & Tang, 201; Ramsden, 2003).

Traditionally, Asian learners have been perceived to rely heavily on surface approaches to learning (Pratt & Wong, 1999; Samuelowicz, 1987). While this viewpoint has been contested (Biggs, 1987; Kember & Gow, 1991; Watkins & Biggs, 1996), various government agencies in Asia have responded to such concerns through initiatives to discourage the use of surface learning methods by students. For example, in 1997, the Singapore Ministry of Education (MOE) reviewed its curriculum and assessment systems and proposed that schools should adopt methods that promote deep learning approaches, and, in so doing, develop students' critical and inventive thinking skills (Goh, 1997). This remained an emphasis in the Singapore MOE's (2006) *Teach Less Learn More* initiative, as well its more recent (2010) *21st Century Competency Framework* (Rajah, 2013).

In order to monitor the efficacy of such initiatives, valid and reliable measures of students' learning approaches are needed. At the secondary school level, the *Learning Process Questionnaire* (LPQ: Biggs, 1987) has been used for such a purpose (e.g., Campbell et al., 2001; Cano, 2005). The original LPQ comprised three main learning approach scales: deep, surface, and achieving. The term 'achieving approach' was used to refer to strategies adopted by students to maximize academic performance (Biggs, 1987). In a subsequent revision of the LPQ (Kember, Biggs & Leung, 2004), the achieving scale was removed due to its significant overlap with the deep and surface approach scales. This revision, labelled the *Revised Two-Factor Learning Process Questionnaire* (R-LPQ-2F), also included a reduced number of items to make the instrument more practical to administer in the classrooms.

Each of the two main R-LPQ-2F scales (Deep Approach and Surface Approach) comprises a motive and a strategy subscale, producing four subscales in all (Deep Motive, Deep Strategy, Surface Motive and Surface Strategy). Within each subscale, there are two further components, as indicated in Table 1. In total, the R-LPQ-2F comprises 22 item statements, to which students respond on a five-point scale ('never or only rarely true of me' to 'always or almost always true of me'). The score for each scale, subscale and component are typically computed by taking the average of their corresponding item scores. Thus, the scores range from 1 (never or only rarely true of me) to 5 (always or almost always true of me).

Table 1. Structure and items in the R-LPQ-2F

Scale	Subscale	Component	Item Statement
Deep Approach	Deep Motive	Intrinsic Interest	(1) I find that at times studying makes me feel really happy and satisfied.
			(5) I feel that nearly any topic can be highly interesting once I get into it.
			(9) I work hard at my studies because I find the material interesting.
		Commitment to Work	(13) I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes.
			(17) I come to most classes with questions in mind that I want answering.
			(19) I find I am continually going over my school work in my mind at times like when I am on the bus, walking, or lying in bed, and so on.
			(21) I like to do enough work on a topic so that I can form my own conclusions before I am satisfied.
	Deep Strategy	Relating Ideas	(2) I try to relate what I have learned in one subject to what I learn in other subjects.
			(6) I like constructing theories to fit odd things together.
		Understanding	(10) I try to relate new material, as I am reading it, to what I already know on that topic.
			(14) When I read a textbook, I try to understand what the author means.

Table 1. Structure and items in the R-LPQ-2F (Continued)

Scale	Subscale	Component	Item Statement
Surface Approach	Surface Motive	Fear of Failure	(3) I am discouraged by a poor mark on a test and worry about how I will do on the next test.
			(7) Even when I have studied hard for a test, I worry that I may not be able to do well in it.
		Aim for Qualification	(11) Whether I like it or not, I can see that doing well in school is a good way to get a well-paid job.
			(15) I intend to get my A Levels because I feel that I will then be able to get a better job.
	Surface Strategy	Minimizing Scope of Study	(4) I see no point in learning material which is not likely to be in the examination.
			(8) As long as I feel I am doing enough to pass, I devote as little time to studying as I can. There are many more interesting things to do.
			(12) I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra.
			(16) I find it is not helpful to study topics in depth. You don't really need to know much in order to get by in most topics.
		Memorization	(18) I learn some things by rote, going over and over them until I know them by heart.
			(20) I find the best way to pass examinations is to try to remember answers to likely questions.
			(22) I find I can get by in most assessment by memorising key sections rather than trying to understand them.

Despite the potential utility of the R-LPQ-2F for assessing students' learning approaches, only two studies have been published to date on its psychometric properties at the secondary school level. The first was published by the authors of the revised version (Kember et al., 2004), and was based on a sample of 841 Hong Kong senior secondary school students. Results of the first-order confirmatory factor analyses performed in this study are presented in Table 2. Only models using item scores as observed variables are included here, as those using component scores as observed variables can produce very different results (e.g., Bandalos & Finney, 2001). As indicated, fit indices for the two-factor model (i.e., Model I: Deep Approach and Surface Approach) were adequate. Separate CFAs were also conducted for the four components of the Deep Approach and for the four components of the Surface Approach (i.e., Models IIa and IIb in Table 2, respectively), and both produced excellent fit indices. While the Cronbach's αs for the overall Deep and Surface Approach scales were acceptable (0.82 and 0.71 respectively), values for the individual components within these scales were low, ranging from 0.48 to 0.70. Five of the eight components fell below the commonly accepted 0.60 level (Kline, 2000). The internal consistencies of the four subscales, however, ranged from 0.58 to 0.75, with only one (i.e., Surface Motive) falling just below the 0.60 level. The latter result was attributed to the multidimensionality of this particular subscale (Biggs, 1993).

Table 2. Fit indices reported by Kember et al. (2004) and Phan and Deo (2007)

Model	Latent Factors	Fit Indices	
		Kember et al. (2004)	Phan & Deo (2007)
(I) Two-factor	First-order factors: • Deep Approach • Surface Approach	CFI=0.804 SRMR=0.049	CFI=0.80 NNFI=0.78 RMSEA=0.06
(IIa) Four-factor (Deep)	First-order factors: • Intrinsic Interest • Commitment to Work • Relating Ideas • Understanding	CFI=0.969 SRMR=0.027	CFI=0.95 NNFI=0.93 RMSEA=0.05
(IIb) Four-factor (Surface)	First-order factors: • Fear of Failure • Aim for Qualification • Minimizing Scope of Study • Memorization	CFI=0.965 SRMR=0.024	CFI=0.85 NNFI=0.84 RMSEA=0.06

The only other validity study of the R-LPQ-2F that could be located which involved a secondary school sample was conducted by Phan and Deo (2007). They replicated Kember et al.'s (2004) analysis using a sample of 2295 students from 35 secondary schools in the Fiji islands. Results for this study are also summarized in Table 2. As indicated, the fit indices of the two-factor model (i.e., Model I: Deep Approach and Surface Approach) were again adequate, though the NNFI was somewhat low. The separate CFAs conducted for the four components of the Deep and Surface Approach scales (i.e., Models IIa and IIb in Table 2, respectively) produced better fits to the data, similar to the results obtained by Kember et al. (2004). However, Cronbach's α values were somewhat lower than those obtained in Kember et al.'s study. While the αs for the

Deep and Surface Approach scales as a whole were acceptable (0.70 and 0.62, respectively), the αs for all four of the subscales (i.e., Deep Motive, Deep Strategy, Surface Motive, and Surface Strategy) fell below 0.60. Internal consistencies were not reported for the eight individual subscale components in this study.

With only two validity studies conducted on the R-LPQ-2F using secondary school samples, it is clear that more research is needed to evaluate its psychometric properties. The R-LPQ-2F has also not yet been validated in the Singapore context. Though Kember et al.'s (2004) study was conducted in Hong Kong, where ethnic Chinese make up a majority of the population (similar to the Singapore context), Hong Kong and Singapore have very different educational systems and cultures (Yang & Lin, 2009). It is thus possible that different results would be obtained across the two settings. The goal of the present study, therefore, was to examine the construct validity of the R-LPQ-2F in a sample of Singapore secondary school level students.

Based on the 2014 Standards for Educational and Psychological Testing (AERA, APA & NCME, 2014), two types of validity evidence were examined in this study. First, the internal structure of the R-LPQ-2F was evaluated through CFAs which replicated those conducted by Kember et al. (2004) and Phan and Deo (2007). Internal consistencies and inter-correlations between the scales, subscales and components were also examined. Second, relationships between the R-LPQ-2F and two external variables: scores from the Motivation section of the Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia & McKeachie, 1991, 1993) and academic performance, were investigated. Expected patterns of relationships between these variables are discussed in more detail in the Method section.

Method

Participants

Participants were 455 Year 11 students (266 male and 189 female) from a secondary school in Singapore. The average age of the participants was 16.7 years (*SD* = 0.39). The participants were enrolled in a two-year physics course taught in the English language, which would prepare them for the General Certificate of Education Advanced Level (GCE 'A' Level) physics examination. The latter examination is administered jointly by the Cambridge International Examinations, Singapore Ministry of Education and the Singapore Examinations and Assessment Board.

Validation Instruments

In addition to the R-LPQ-2F, two further instruments were used in the validation study. First, the Motivation section of the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1991, 1993) was used. The MSLQ is a well-established instrument in the area of self-regulated learning (Duncan & McKeachie, 2005). Studies of the psychometric properties of the MSLQ have generally produced favourable results. For example, Garcia and Pintrich (1995) demonstrated the sound psychometric properties of the MSLQ using data gathered from 380 students across 14 different subject domains. The Motivation section of the MSLQ includes six scales: Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-efficacy for Learning and Performance, and Test Anxiety. There are a total of 31 item statements, to which students respond on a seven-point scale, ranging from 'not at all true of me' to 'very true of me'.

Table 3 summarizes the expected pattern of correlations between the R-LPQ-2F scales, subscales and components and the MSLQ motivation subscales. Variables relating to deep learning are generally expected to show positive correlations with the 'positive' motivation constructs measured by the MSLQ (i.e., Intrinsic Goal Orientation, Control of Learning Beliefs and Self-efficacy for Learning and Performance) (e.g., Biggs & Tang, 2011). Conversely, variables related to surface learning are expected to show negative correlations with the 'positive' motivation constructs in the MSLQ, and positive correlations with the 'negative' motivation constructs in the MSLQ (e.g., Curran & Bowie, 1998).

Table 3. Expected pattern of correlations between the R-LPQ-2F, MSLQ, and physics achievement test scores

R-LPQ-2F Variables	MSLQ 'Positive' Motivation Variables				MSLQ 'Negative' Motivation Variables		Achieve-ment
	1	3	4	5	2	6	7
Deep Approach	+	+	+	+	–	–	+
Deep Motive	+	+	+	+	–	–	+
Deep Strategy	+	+	+	+	–	–	+
Intrinsic Interest (Deep)	+	+	+	+	–	–	+
Commitment to Work (Deep)	+	+	+	+	–	–	+
Relating Ideas (Deep)	+	+	+	+	–	–	+
Understanding (Deep)	+	+	+	+	–	–	+
Surface Approach	–	–	–	–	+	+	–
Surface Motive	–	–	–	–	+	+	–
Surface Strategy	–	–	–	–	+	+	–
Fear of Failure (Surface)	–	–	–	–	+	+	–
Aim for Qualification (Surface)	–	–	–	–	+	+	–
Minimizing Scope of Study (Surface)	–	–	–	–	+	+	–
Memorization (Surface)	–	–	–	–	+	+	–

Note: 1. Intrinsic Goal Orientation; 2. Extrinsic Goal Orientation; 3. Task Value; 4. Control of Learning Beliefs; 5. Self-efficacy for Learning and Performance; 6. Test Anxiety; 7. Physics Achievement Test.

Scores on the R-LPQ-2F were also correlated with physics achievement test scores. The physics achievement test used in this study was a two-hour pen-and-paper assessment comprising 15 multiple-choice questions and 3 short response questions, adapted directly from past year GCE ‘A’ level examinations. The test questions, including the marking scheme, were vetted by the subject coordinator and the head of the physics department, who each had more than ten years of teaching experience, to ensure close alignment to the assessment objectives of the GCE ‘A’ level physics examination (Singapore Examinations and Assessment Board, 2014). The test scores were computed by summing the scores for the multiple-choice questions and the open-ended questions, with a maximum scores of 15 and 65 respectively, giving a total maximum score of 80. As indicated previously, deep learning is generally found to correlate positively with achievement scores, while surface learning has been found to correlate negatively with achievement. The expected pattern of correlations between the R-LPQ-2F and achievement is presented in Table 4.

Procedure

Approval to conduct the research was first obtained from the Human Research Ethics Committee of the authors’ research institution. Permission was also granted by the Principal of the participating school. At the end of a three-month physics course unit on Newtonian mechanics, all participating students completed the R-LPQ-2F and the motivation section of the MSLQ in a single session. They were provided with hardcopies of the questionnaires and optical mark sheets to shade their responses. Prior to completing the R-LPQ-2F and MSLQ, students were told that their individual responses would not have any bearing on their course grades. In a separate session, they also completed the pen-and-paper closed book physics achievement test. They were given unique codes to use for the questionnaires as well as for the physics achievement test answer scripts, so that their responses could be matched.

Table 4. Descriptive Statistics for main scale, subscale and components of R-LPQ-2F

		Item Number	*M*	*SD*
Main Scale	Deep Approach	1, 2, 5, 6, 9, 10, 13, 14, 17, 19, 21	3.26	0.59
	Surface Approach	3, 4, 7, 8, 11, 12, 15, 16, 18, 20, 22	2.86	0.48
Subscale	Deep Motive	1, 5, 9, 13, 17, 19, 21	3.12	0.61
	Deep Strategy	2, 6, 10, 14	3.50	0.73
	Surface Motive	3, 7, 11, 15	3.70	0.68
	Surface Strategy	4, 8, 12, 16, 18, 20, 22	2.38	0.57
Deep Motive Component	Intrinsic Interest	1, 5, 9	3.41	0.74
	Commitment to Work	13, 17, 19, 21	2.91	0.67
Deep Strategy Component	Relating Ideas	2, 6	3.32	0.90
	Understanding	10, 14	3.68	0.76
Surface Motive Component	Fear of Failure	3, 7	3.41	0.97
	Aim for Qualification	11, 15	3.99	0.76
Surface Strategy Component	Minimizing Scope of Study	4, 8, 12, 16	2.50	0.63
	Memorization	18, 20, 22	2.21	0.73

Results and Discussion

SPSS version 19 (IBM Corp, 2010) was used to generate all descriptive statistics, Cronbach α coefficients, and bivariate correlations, while LISREL 8.8 (Jöreskog & Sörbom, 2006) was used to perform all CFAs within the study. Prior to conducting these analyses, screening tests for conformity to underlying CFA assumptions were conducted. These tests generally produced satisfactory results. Inspections of z-scores and Mahalanobis distances indicated no univariate or multivariate outliners within the set, at the .001 level. There was also no evidence of multicollinearity within the variable set, and no evidence of significant deviations from normality based on skewness or kurtosis coefficients.

Table 5 presents descriptive statistics for items in the R-LPQ-2F. As indicated, the average scores for the Deep Approach scale were higher than for the Surface Approach scale. Interestingly, average scores for Surface Motive were the highest amongst all of the subscales. The latter result was due primarily to the high average scores observed for the two Surface Motive components, Fear of Failure and Aim for Qualification.

Table 5. Item descriptives for the R-LPQ-2F

Scale	Subscale	Component	Item	*M*	*SD*
Deep Approach	Deep Motive	Intrinsic Interest	1	3.39	0.96
			5	3.58	0.94
			9	3.25	0.89
		Commitment to Work	13	2.59	1.02
			17	2.86	0.90
			19	2.73	1.08
			21	3.47	0.92
	Deep Strategy	Relating Ideas	2	3.46	0.95
			6	3.19	1.14
		Understanding	10	3.62	0.92
			14	3.74	0.90
Surface Approach	Surface Motive	Fear of Failure	3	3.32	1.11
			7	3.50	1.10
		Aim for Qualification	11	3.96	0.90
			15	4.02	0.86
	Surface Strategy	Minimizing Scope of Study	4	2.57	0.95
			8	2.32	1.05
			12	2.92	0.89
			16	2.21	0.92
		Memorization	18	2.35	1.00
			20	2.20	0.97
			22	2.08	0.87

Evidence Based on Investigations of Internal Structure

(a) ***Confirmatory Factor Analyses.*** Confirmatory Factor Analyses (CFAs) were performed on two first-order models, replicating the analyses performed by Kember et al. (2004) and Phan and Deo (2007). Only first-order models were tested in this study. Three absolute fit indices (the Standardized Root Mean Square Residual, or SRMR; the relative chi-square value, or χ^2/df; and the Root Mean Square Error of Approximation, or RMSEA) and two relative fit indices (the Comparative Fit Index, or CFI, and the Non-Normed Fit Index, NNFI) were used to assess the fit of each model tested. Accepted cut-offs suggest that in CFAs, good model fit is indicated by a χ^2/df < 5, SRMR < 0.08, values greater than 0.90 for the CFI and NNFI (e.g., Browne & Cudeck, 1993; Byrne, 1989; MacCallum, Browne & Sugawara, 1996; Schumacker & Lomax, 2004), and RMSEAs of between 0.01 (excellent fit) to 0.08 (adequate fit). The Goodness of Fit Index (GFI) was not used in this study, based on current recommendations within the field (Sharma, Mukherjee, Kumar & Dillon, 2005). Differences between nested models within each of the MSLQ sections were evaluated using the chi square difference test (i.e., $\Delta\ \chi^2$). Three sets of models were tested:

- Models (a) and (b) were performed with all items within the instrument. Model (a) was a two-factor model, in which all items were grouped into their respective Surface and Deep Approach scales. Model (b) grouped items into the four subscales within the instrument (i.e., Surface Motive, Surface Strategy, Deep Motive, and Deep Strategy).
- Models (c), (d) and (e) were performed within the Deep Approach scale. Model (c) was a one-factor model for all Deep Approach scale items. Model (d) was a two-factor, with items grouped into their respective Deep Motive and Deep Strategy subscales. Model (e) was a four-factor model, with items grouped into

their respective Deep Approach components: Intrinsic Interest, Commitment to Work, Relating Ideas, and Understanding.

- Models (f), (g) and (h) were performed within the Surface Approach scale. Model (f) was a one-factor model for all Surface Approach scale items. Model (g) was a two-factor model, with items grouped into their respective Surface Motive and Surface Strategy subscales. Model (h) was a four-factor, with items grouped into their respective Surface Approach components: Fear of Failure, Aim for Qualification, Minimizing Scope of Study, and Memorization.

The fit indices for the models are presented in Table 6. As indicated, the fit indices for both of the overall scale models (i.e., Models (a) and (b)) approached, but did not meet, suggested criteria. These results contrast with the findings of Kember et al. (2004) and Phan and Deo (2007), who found adequate fit to their data for the overall two-factor model.

As indicated in Table 6, Models (c), (d) and (e) for the Deep Approach scale all indicated good fit to the data. Given that the fit indices for the more parsimonious one-factor model were adequate, a one-factor model was deemed most appropriate for the Deep Approach Scale. In contrast, Models (f), (g) and (h) for the Surface Approach Scale indicate that neither the one- nor the two-factor model fit the data well. The four-factor model fit significantly better than the two-factor model, and only this four-factor model meet the fit cut-offs on most criteria (i.e., χ^2/df, SRMR, RMSEA and CFI). Similar to the results of the Phan and Deo (2007) study, however, the NNFI for the latter model still fell slightly below the accepted cut-off of .90.

Table 6. Fit indices of first-order models

Model	χ^2	df	χ^2/df	SRMR	RMSEA	CFI	NNFI	$\Delta\chi^2$ statistics
(a) Two-factor (Deep and Surface Approach Scales)	1032.95*	208	4.97	.096	.10	.81	.79	(a) & (b): $\Delta\chi^2(5) = 200.01$, $p < 0.05$
(b) Four-factor (Deep and Surface Approach Subscales)	832.94*	203	4.10	.085	.09	.86	.84	
(c) One-factor (Deep Approach Scale)	176.42*	44	4.00	.050	.08	.95	.94	(c) & (d): $\Delta\chi^2(1) = 43.94$, $p < 0.05$
(d) Two-factor (Deep Approach Subscales)	132.48*	43	3.08	.044	.07	.97	.96	(d) & (e): $\Delta\chi^2(5) = 39.03$, $p < 0.05$
(e) Four-factor (Deep Approach Components)	93.45*	38	2.46	.036	.05	.98	.97	(e) & (c): $\Delta\chi^2(6) = 82.97$, $p < 0.05$
(f) One-factor (Surface Approach Scale)	480.08*	44	10.91	.110	.16	.66	.58	(f) & (g): $\Delta\chi^2(1) = 143.87$, $p < 0.05$
(g) Two-factor (Surface Approach Subscales)	336.21*	43	7.81	.098	.13	.77	.71	(g) & (h): $\Delta\chi^2(5) = 181.24$, $p < 0.05$
(h) Four-factor (Surface Approach Components)	154.97*	38	4.08	.075	.09	.91	.87	(h) & (f): $\Delta\chi^2(6) = 325.11$, $p < 0.05$

* Significant at $\alpha = .05$ level

Taken together, the most parsimonious model of the R-LPQ-2F that provided adequate data fit in the current study was the one-factor model for the deep learning scale, and the four-factor model for the surface learning scale (Fear of Failure, Aim for

Qualification, Minimizing Scope of Study, and Memorization). The final factor models of the Deep Approach and Surface Approach scales are presented in Figures 1 and 2 (respectively). These results suggest that, in the Singapore secondary school sample, while the Deep Approach scale could be considered unidimensional, the Surface Approach scale could not.

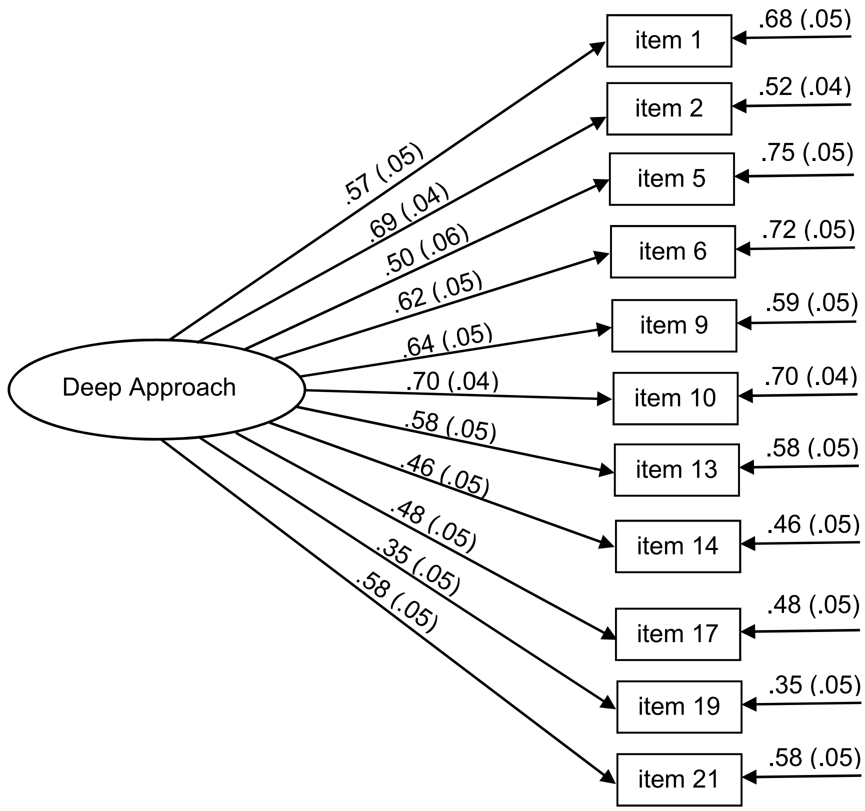

Figure 1. Final one-factor model for the Deep Approach Scale

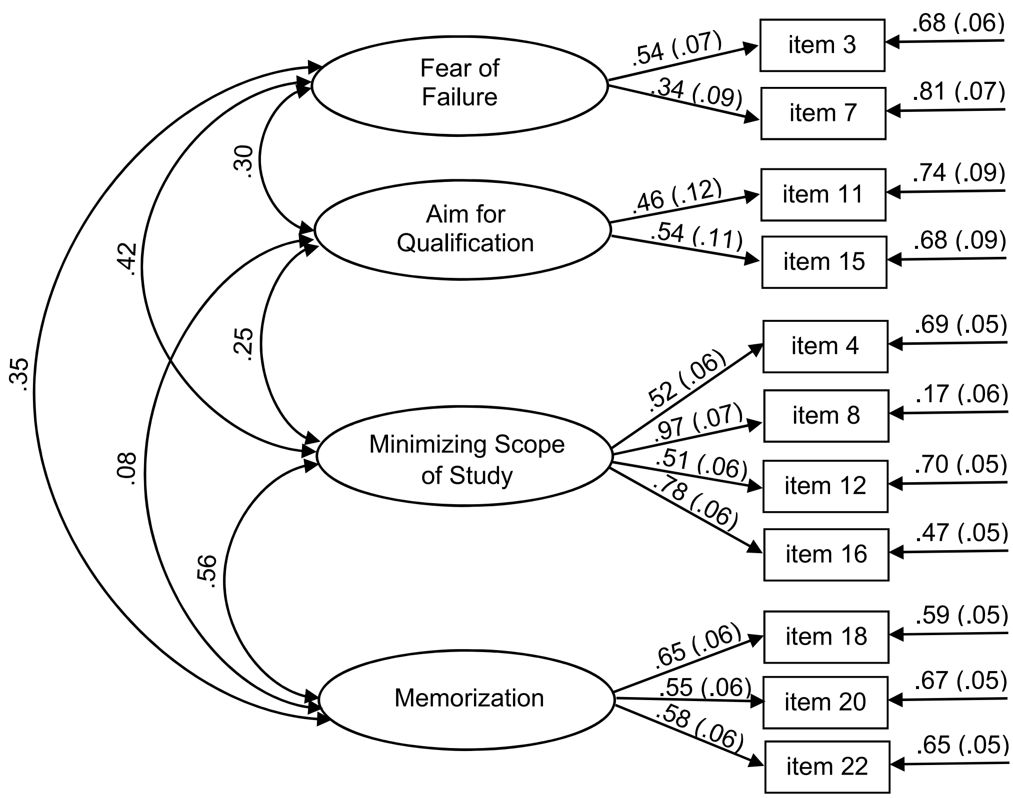

Figure 2. Final four-factor model for the Surface Approach Scale

(b) Internal Consistencies. Cronbach α coefficients (Cronbach, 1970) for the main scales, subscales and components of the R-LPQ-2F are presented in Table 7, together with the findings by Kember et al. (2004) and Phan and Deo (2007). As indicated, the two main scales and most of the subscales achieved sound internal consistencies, and even the components had reasonable coefficients, despite having a small number of items. The α coefficients in the current study were also observed to be generally higher than those in the other two studies conducted by Kember et al. and Phan and Deo.

Table 7. Cronbach α coefficients for the R-LPQ-2F

		No. of Items	Current Study	Kember et al.'s (2004) study	Phan and Deo's (2007) study
Main Scale	Deep Approach	11	.84	.82	.70
	Surface Approach	11	.70	.71	.62
Subscale	Deep Motive	7	.75	.75	.58
	Deep Strategy	4	.74	.66	.54
	Surface Motive	4	.61	.58	.42
	Surface Strategy	7	.70	.68	.53
Deep Motive Component	Intrinsic Interest	3	.83	.59	--
	Commitment to Work	4	.62	.70	--
Deep Strategy Component	Relating Ideas	2	.65	.48	--
	Understanding	2	.55	.59	--
Surface Motive Component	Fear of Failure	2	.71	.65	--
	Aim for Qualification	2	.66	.63	--
Surface Strategy Component	Minimizing Scope of Study	4	.56	.52	--
	Memorization	3	.66	.55	--

(c) Intercorrelations. Intercorrelations for the R-LPQ-2F scales, subscales and components are presented in Table 8. As indicated, Deep and Surface Approach scores were not significantly correlated, in contrast to the results reported by Kember et al. (2004), who found modest levels of positive correlation between these two broad scales. This finding suggests that for Singapore secondary school students, deep and surface approaches may not represent two opposing ends of a continuum, as is commonly perceived. It may, therefore, be possible for students to concurrently adopt different learning approaches for a particular learning task. It is also noted that Deep Motive and Deep Strategy scores were highly correlated, as would be expected, but the correlation between Surface Motive and Surface Strategy was only modest.

Table 8. Intercorrelations of the R-LPQ-2F main scales and subscales

Scale / Subscale	1	2	3	4	5	6
1. Deep Approach	–	.04	.94**	.87**	.17**	-.06
2. Surface Approach		–	.06	.01	.68**	.87**
3. Deep Motive			–	.64**	.16**	-.03
4. Deep Strategy				–	.15**	-.09
5. Surface Motive					–	.22**
6. Surface Strategy						–

**p*< .05, ***p*< .01

Table 9 shows the intercorrelations between the components of the R-LPQ-2F. Components 1 and 2 relate to Deep Motive; 3 and 4 to Deep Strategy; 5 and 6 to Surface Motive; and 7 and 8 to Surface Strategy. The correlations between the deep learning components (1-4) were positive and relatively high, as expected. With the exception of Aim for Qualification, the surface learning components (5-8) also exhibited similar patterns of correlations, albeit weaker.

In the theoretical framework of the R-LPQ-2F, Aim for Qualification and Fear of Failure, which are classified as surface motives, are perceived to be undesirable because these are likely to lead to the use of surface cognitive strategies, and consequently, to poorer academic outcomes (Biggs, 1993). While the results of this study similarly indicate that Fear of Failure was associated with greater use of surface strategies, Aim for Qualification was not significantly correlated with the Surface Strategy variables. Instead, it correlated positively with two deep motive components (Intrinsic Interest and Commitment to Work) and one deep strategy component (Understanding). These results, therefore, suggest that aspiring for a higher qualification may not be associated with negative outcomes in the Singapore secondary school context.

Table 9. Intercorrelations between the R-LPQ-2F components

Component	1	2	3	4	5	6	7	8
1. Intrinsic Interest (Deep Motive)	–	.50**	.47**	.45**	.03	.18**	-.19**	-.02
2. Commitment to Work (Deep Motive)		–	.53**	.48**	.12*	.11*	-.05	.13**
3. Relating Ideas (Deep Strategy)			–	.56**	.01	.09	-.07	-.04
4. Understanding (Deep Strategy)				–	.09	.28**	-.14**	-.04
5. Fear of Failure (Surface Motive)					–	.21**	.22**	.24**
6. Aim for Qualification (Surface Motive)						–	.03	.06
7. Minimizing Scope of Study (Surface Strategy)							–	.43**
8. Memorization (Surface Strategy)								–

*p< .05, **p< .01

Evidence Based on Relationships with External Variables

Correlations between the R-LPQ-2F and scores on the MSLQ Motivation subscales, and physics achievement test scores are presented in Table 10. As expected, the Deep Approach scale, subscale, and component scores all correlated positively with the 'positive' MSLQ motivation scale scores. With the exception of two components (Commitment to Work and Relating Ideas), all the Deep Approach variables also correlated positively with physics achievement. Surprisingly, the MSLQ Extrinsic Goal Orientation scale correlated positively with all of the Deep Approach variables and, similarly, the MSLQ Test Anxiety scores also correlated positively with the Deep Approach scale score, as well as with Deep Motive and Commitment to Work scores.

The latter two sets of results are surprising, given that both Extrinsic Goal Orientation and Test Anxiety are generally perceived to represent 'negative' aspects of motivation. The results are, however, aligned with results reported by Pintrich and Garcia (1991), who found evidence that deep learning can be associated with higher levels of extrinsic motivation. It might also reflect the influence of Confucius Heritage Culture (CHC) of Singapore, which places great emphasis on academic performance and qualifications, as well as the acquisition of deep knowledge (for a more comprehensive review of the CHC, see Watkins & Biggs, 1996).

Table 10. Correlations of R-LPQ-2F with MSLQ motivation variables and physics achievement test scores

R-LPQ-2F Variables	MSLQ 'Positive' Motivations				MSLQ 'Negative' Motivations		Physics Achieve -ment
	Intrinsic Goal Orientation	Task Value	Control of Learning Beliefs	Self-efficacy of Learning and Perf	Extrinsic Goal Orien-tation	Test Anxiety	
Deep Approach	.61**	.66**	.46**	.53**	.33**	.12*	.12*
Deep Motive	.57**	.60**	.41**	.46**	.35**	.14**	.09*
Deep Strategy	.53**	.59**	.42**	.50**	.23**	.05	.13**
Intrinsic Interest	.55**	.58**	.39**	.41**	.27**	.04	.10*
Commitment to Work	.45**	.47**	.32**	.40**	.34**	.19**	.07
Relating Ideas	.51**	.49**	.33**	.44**	.17**	.02	.10
Understanding	.43**	.57**	.43**	.45**	.23**	.07	.13**
Surface Approach	-.23**	-.10*	.01	-.16**	.42**	.50**	-.15**
Surface Motive	-.01	.20**	.23**	-.05	.48**	.58**	-.08
Surface Strategy	-.29**	-.26**	-.15**	-.17**	.22**	.27**	-.15**
Fear of Failure	-.06	.08	.10*	-.16**	.35**	.70**	-.12*
Aim for Qualification	.06	.25**	.29**	.10*	.41**	.14**	.02
Minimizing Scope of Study	-.34**	-.29**	-.12**	-.15**	.14**	.20**	-.12*
Memorization	-.15**	-.15**	-.14**	-.14**	.25**	.27**	-.15**

$^{*}p < .05$, $^{**}p < .01$

Results for the overall Surface Approach scale and the Surface Strategy subscale and component scores were also generally aligned with expectations. Surface Approach scale scores correlated negatively with three of the four positive MSLQ motivation variables (Intrinsic Goal Orientation, Task Value, and Self-Efficacy for Learning and Performance) and with physics achievement, but positively with the two negative MSLQ motivation variables (Extrinsic Goal Orientation and Test Anxiety). Surface strategy subscale scores and the two components of Surface Strategy, Minimising Scope of Study and Memorization, correlated negatively with all positive MSLQ variables and with physics achievement, while correlating negatively with the two positive MSLQ motivation variables of Extrinsic Goal orientation and Test Anxiety.

In contrast, the patterns of correlation obtained for Surface Motive and the two components of Surface Motive (Fear of Failure and Aim for Qualification) did not align well with expectations. While all three variables did correlate positively with the two negative MSLQ variables, amongst the three, only Fear of Failure was negatively correlated with physics achievement. Fear of Failure was also, as expected, negatively correlated with Self-Efficacy for Learning and Performance. Surprisingly, however, both Surface Motive and Aim for Qualification were positively correlated with two of the positive MSLQ motivation subscales (Task Value and Control of Learning Beliefs). Aim for Qualification was also positively correlated with Self-Efficacy for Learning and Performance. Thus, of the Surface components, the one that exhibited the most unexpected pattern was Aim for Qualification.

Conclusions and Implications

Results of this study indicate that the internal structure of the R-LPQ-2F in Singapore secondary students is similar to the original factor structure proposed by Kember et al. (2004). In this study, a structure comprising one deep factor and four surface factors fit the data well. Cronbach's α coefficients for the scales, subscales and components were generally also acceptable. Results of the intercorrelations within the R-LPQ-2F also supported the validity of the instrument.

Results of the correlations between the R-LPQ-2F Deep Approach scale and for the Surface Strategy subscale, MSLQ motivation scores, and physics achievement scores, similarly aligned with expectations derived from the theoretical basis of the R-LPQ-2F. This was not so, however, for the relationships between the Surface Motive subscale, MSLQ motivation, and physics achievement scores. This can be attributed primarily to the contribution of the Aim for Qualification component of the Surface Motive subscale. While these results were not expected based on previous results reported from

Western countries, they do align well with emerging views of the surface and deep motivations held by many Asian students. For example, Boekaerts (2003) argued that, in contrast to Western cultures, factors such as personal ambition and material reward will prompt many Chinese students to adopt deep learning strategies. Ramburuth and McCormick (2001) similarly reported that Asian students will often combine surface strategies with intrinsic or deep motivations in approaching their learning tasks. Based on these results, assumptions made about the negative implications of motivations classed as 'surface' oriented in Western countries may not hold in Asian samples.

Further research is needed to investigate implications of the Surface Motive components of the instrument within the Singapore context. It should be noted here also that this study only focused on upper secondary level students. More research is needed to ascertain whether the instrument can be used in other levels of the Singapore system. Given its potential utility in this context, further work could also be conducted to determine the suitability of the R-LPQ-2F in earlier grade levels.

Overall, the results of this study provide strong support for the R-LPQ-2F to assess students' learning approaches in Singapore secondary schools. While many teachers may already be adopting strategies to encourage the use of deep learning approaches in their classrooms, it is possible that they are not effectively monitoring the progress of their students in this domain. The R-LPQ-2F can be a very useful tool for such a purpose. This instrument has various other advantages, which make it highly suitable for use in classroom contexts, which include the fact that it is readily downloadable online, free to use, and, with only 22 items, efficient to administer and score. Collectively, these features suggest that the R-LPQ-2F has considerable potential as a tool to monitor students' learning processes, with the ultimate goal of enhancing overall schooling outcomes.

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Paper 3 – Brief Report: Preliminary Validation of a Physics Task Value Scale in a Singapore Secondary School

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This third paper was designed to confirm the construct validity of a researcher-developed instrument, the Physics Task Value Scale (PTVS), for use in the Singapore school context. This was conducted to ensure that the instrument was suitable for use in subsequent studies within the research programme. Bibilographic Details: Chow, C.W. & Chapman, E. (Submitted). Brief Report: Preliminary Validation of a Physics Task Value Scale in a Singapore Secondary School. Journal details: Educational Psychology, Print ISSN 0144-3410, Online ISSN 1469-5820, Impact Factor 0.667.

Abstract

To date, no instruments have appeared in the literature that focus specifically on assessing task value in the area of physics. In the current study, a new brief measure, the Physics Task Value Scale (PTVS), was validated with 455 students in Singapore. An exploratory factor analysis indicated that the instrument was unidimensional, and had a high level of internal consistency. The one-month test-retest reliability of the instrument was also high. These results suggest that the PTVS holds promise for assessing the extent to which physics is valued by students at the secondary school level in Singapore.

Keywords: construct validity, physics, task value, secondary school, Singapore

Introduction

Motivation is generally seen as a key determinant of all human behaviour. The concept of motivation, as it appears in the academic literature, was defined broadly by Mitchell (1982) as “those psychological processes that cause the arousal, direction, and persistence of voluntary actions that are goal directed” (p.81). Accordingly, motivation theories are generally concerned with the processes that activate and direct human behavior. Various motivation theories have appeared in the educational psychology literature since the 1970s. These include *content* theories, which focus on the factors that energize and direct human behavior, or “what” drives individuals’ behaviours (e.g., Maslow's theory on the hierarchy of needs, Alderfer's ERG theory, and McClelland's learned needs or three-needs theory), and *process* theories, which focus on the question of “how” motivation is activated and manifested, and how it sustains over time (e.g., Vroom’s Expectancy Theory). At present, it is generally agreed that both types of motivation theory have utility for explaining different aspects of human behavior.

In the context of school-based research, a significant body of research has now been generated which focuses on the notion of *achievement motivation*. Bigge and Hunt (1980) defined achievement motivation as the drive to work toward achievement-related goals with diligence and vitality, to steer persistently toward given academic targets, and to persevere in confronting challenging and difficult tasks. Achievement motivation is generally portrayed as a subjective and internal psychological drive, enabling individuals to pursue academic goals they perceive to be valuable. Whilst various definitions of achievement motivation have appeared within the literature, the notion of *achievement goals* is central to all of these theories. The different types of achievement goals that an individual adopts have been found to have a profound impact on the way a person performs a task (Harackiewicz, Barron, Carter, Lehto, &

Elliot, 1997). As a result, much of the research that has appeared on the topic of motivation in education contexts has focused on identifying the different types of goal orientations that students can adopt in confronting their academic tasks, the processes associated with these different goals, and the conditions that prompt them.

One of the key factors that has been identified to influence the goals that individuals adopt in academic contexts is the level of value the individual attaches to given academic tasks. The construct of task value incorporates aspects of intrinsic interest, utility value, attainment value and perceived costs of the task (Pintrich & Schunk, 2002; Ormrod, 2006). According to Eccles and Wigfield (2002), task values are subjective motivational constructs related to achievement behaviors and academic achievement. Motives to succeed or fear of failure in doing a particular task are deemed to be subjective, as these reflect the individual’s personal interest in the task, and the value he or she places personally on the task. An individual can also hold what is deemed to be an objective task value, which is based on socially agreed collective values of a task or activity. Subjective task values are generally deemed to play a more important role than objective task values in influencing an individual’s motivation and academic achievement, because these are related to the values and beliefs that the individual holds about a task or activity.

Eccles and Wigfield (2002) conceptualized task value to comprise four theoretically distinct constructs: attainment value (or importance), intrinsic interest (or intrinsic value), utility value and cost belief. *Attainment value* refers to the importance that a person puts on achieving a task or activity. According to expectancy-value theory, an individual’s perception of the importance that his or her social group places on the task or activity can have a significant influence on his or her own attainment value (Eccles, 2005). For example, the importance a child places on academic performance can arise from to the perceived expectations of his or her parents. Thus, while this form of value derives from agreed values within the individual's social context, the value can then be internalized by the individual and influence subsequent academic behaviors.

Intrinsic interest refers to the level of interest that an individual has in a task based on its inherent nature or character, rather than on the benefits that completing the task can yield. Intrinsic interest is generally reflected in the enjoyment that an individual experiences when engaged in a task or activity (Schunk, Pintrich & Meece, 2008). When a person is intrinsically interested in a particular task, the process of doing it is enjoyable. The task outcomes are less important than the means and pleasures that he or she experiences while working on the task. Intrinsic interest, in the value theory of Eccles and Wigfield (1992), is aligned with concepts of *intrinsic motivation* (i.e., the motivation that a person experiences because the activity itself is interesting – see Deci & Ryan, 1985), *personal interest* (i.e., interest that is enduring, personal, activated internally and topic-specific – see Urdan & Truner, 2005; Renniger, Hidi & Krapp, 1992), and *flow* (i.e., is the complete cognitive involvement that a person experiences when he or she is immersed in an activity – see Csikszentmihalyi, 1985).

Utility value refers to the perceived usefulness of doing a task. This perception can be based on expected outcomes that doing the task can bring about (e.g., in terms of educational advancement or career goal achievement – see Schunk, Pintrich & Meece, 2008). Utility value emphasizes anticipated ends of doing a task, and is related to the instrumental value of a task in achieving short- or long-term goals. Utility value is conceptualized as a positive value, in that high levels of utility value can prompt an individual to invest effort in an activity to reach his or her goals (Eccles & Wigfield, 1995). This concept is similar to the notion of extrinsic motivation posed by Deci and Ryan (1985), in that it focuses on tasks as means to other ends. Extrinsic and intrinsic motivation are generally posed as distinct constructs in the literature. While historically, these have been posed to relate negatively to one another, more recent research has suggested that they are entirely independent, and neither positively nor negatively associated (see Lepper, Corpus, & Iyengar, 2005, for a further discussion).

Cost belief refers to the estimated costs that an individual believes that he or she will incur through participating in a certain task. When a person is given choices, he or she selects one task after assessing the cost, taking into account how much effort to invest, how much time to invest, the opportunities that will be lost in participating in the task, and the resources and materials that will be needed to complete the task (Eccles & Wigfield, 2002). Cost belief reflects a person's perceptions of the negative aspects of choosing a particular task, as they give up alternative opportunities to engage in that task.

Researchers have found that attainment value, intrinsic interest, and utility value are academically significant motivational constructs, as they predict students' achievement behaviors such as course enrollment, task choices, self-regulated learning, effort, and persistence (Eccles & Wigfield, 1995; Ormrod, 2006; Schunk, Pintrich & Meece, 2008; Shell, Colvin, & Bruning, 1995; Wigfield, 1994; Zimmerman, 2000). In expectancy-value theory, attainment value, intrinsic interest, and utility value are strongly associated with expectancy constructs including self-efficacy beliefs and outcome expectancy (Eccles & Wigfield, 1995; Ormrod, 2006; Schunk, Pintrich & Meece, 2008; Shell, Colvin, & Bruning, 1995; Wigfield & Eccles, 2000; Zimmerman, 2000). Self-efficacy is a person's belief in his or her own abilities to synthesize and carry out certain actions in order to conduct a task successfully and eventually achieve goals (Bandura, 1997; Schunk, Pintrich & Meece, 2008; Wigfield & Eccles, 2000). Outcome expectancy is the belief that given actions will generate specific products (Wigfield & Eccles, 2000).

Previous studies have indicated that task value and expectancy constructs are positively related to students' academic achievement (e.g., Eccles & Wigfield, 1995; Schunk, Pintrich & Meece, 2008; Neuville, Frenay, & Bourgeois, 2007). Neuville, Frenay and Bourgeois also found that attainment value, intrinsic interest, and utility value were better predictors of students' actual school enrolment and course taking better than self-efficacy beliefs and outcome expectancy. In a more recent study, Lawanto, Santoso, Goodridge and Lawanto (2014) reported that task value was significantly related to undergraduate students' academic performance in engineering.

Despite its perceived importance in academic motivation, researchers have not yet agreed on the factor structure of task value. In Eccles and Wigfield's (1995) study of task value in mathematics with United States adolescents in Grades 5 through 12, attainment value, intrinsic interest, and utility value emerged as three distinct factors. Other researchers (Artino & McCoach, 2007; Oh, Jia, Mhora & LaBanca, 2013), however, have reported task value to be a unidimensional construct. For example, in the 2013 study by Oh and her colleagues, task value items were examined in secondary school in the United States in different domains such as science, technology and mathematics. The results of the factor analyses revealed that the task value constructs, which included attainment value, intrinsic interest, and utility value, formed a single factor.

In addition to enduring disagreements in the literature on the factor structure of task value, few instruments exist presently which focus specifically on this construct in education contexts. As a result, practitioners who wish to assess levels of task value in their students must often use their own, locally developed instruments, which have not been evaluated in terms of their validity. Further, most studies of task value in secondary school students that have appeared in the literature thus far have been conducted in the United States. Given previous research that has suggested key differences in the motivational goals adopted by Asian and American students, before applying these findings to Asian contexts, it is important to explore the applicability of the results to Asian students. For example, Asian students have been found to place significant value on academic achievement and job obtainment as indicators of their success (Lew, 2006). Parents of Asian students have also been found to perceive education as an important route for social mobility (Sue & Okasaki, 1990). According to a study by Yan and Lin (2005), which compared parents' expectations for their children's education performance across Asian American, African American, Caucasian American, and Hispanic American families, those of Asian American parents were the highest. This finding underscores the importance of examining the generality of motivation concepts across different cultures.

The primary goal of the present study was to evaluate the construct validity of a new instrument, developed by the researcher, for assessing levels of task value in the area of secondary school physics. The instrument was developed on the basis of the theoretical frameworks described earlier, as part of a larger study on the importance of learning processes in the development of conceptual understanding in physics. This broader study was conducted in the Singapore secondary school context. Whilst the instrument developed here focused specifically on the subject area of physics, it was anticipated that the instrument could be adapted readily for use in other subject areas.

Method

Participants

Participants were 455 Year 11 students in Singapore (261 males, 194 females). The average age of participants at the start of the study was 16.7 years (*SD* = 0.82). Of these, 99.3% were Chinese; the remaining 0.7% were Malays or Indians. The participants had a good command of the English language, which was studied as a first language. All participants were enrolled in a two-year physics course in the English language, which was based on the General Certificate of Education Advanced Level physics syllabus 9646 (Singapore Examination and Assessment Board, 2014). All measures were administered in the English language.

Instrument

The Physics Task Value Scale (PTVS) is a brief, five-item measure, focused on assessing the construct of task value. All five items within the instrument make specific reference to physics classes. Each item is described by two statements which represent opposing views: “I think that physics is a very boring subject” vs. “I find physics lessons very interesting”; “I would skip physics lessons if I were given the option” vs. “I look forward to my physics lessons”; “I am not interested in knowing more than I have to in physics” vs. “I find myself wanting to learn more about the things we do in physics lessons”; “I would only choose to do physics if I needed it for my future success” vs. “It is important to learn about physics, even if I don't need it to get into university/get a good job”; and “I can't see why anyone would study physics if they didn't have to” vs. “I can see the value of studying physics just for its own sake”. If participants agreed totally with the statement on the left hand side of the item, they gave a rating of 1 for that item. If they agreed totally with the statement on the right hand side of the item, they gave a rating of 7. If they did not agree totally with either statement, they would indicate a number between 1 and 7, depending on the extent to which they agreed with the statement on the left or the right.

Procedures

Approval to conduct the research was first obtained from the Human Research Ethics Committee of the authors' affiliated institution. All procedures used within the study were conducted in compliance with the National Health and Medical Research Council's (2007) Australian Code for the Responsible Conduct of Research. Permission was also granted by the Principal of the participating school.

All students who were enrolled in the two-year Physics course were invited to participate in the study. No student opted out of the study. The PTVS was administered to the participants using hardcopies of the questionnaires, who were provided with optical mark sheets to shade their responses. One month later, the PTVS was administered to the participants in the same manner. Prior to administering the PTVS, the participants were assured that their responses had no bearing on their course grades.

Results

Prior to the data analysis, the scores of all negatively worded items (i.e., those in which the negative statement appeared on the left) were first reversed. SPSS Version 19 (IBM Corporation, 2010) was then used to compute descriptive statistics, Cronbach's alpha (Cronbach, 1951) coefficients, bivariate correlations and an exploratory factor analysis, which was used to examine the factor structure of the instrument. Prior to performing the latter analysis, screening tests for conformity to underlying factor analysis assumptions were conducted. All screening tests produced satisfactory results.

Factor Structure of the PTVS

As the measure was designed by the researcher, the responses from the participants were subjected to exploratory factor analysis (EFA) to explore its latent structure, based on published best practice procedures (Conway & Huffuct, 2003; Fabrigar, Wegener, MacCallum, & Strahan, 1999). In accordance with this approach, the 'factorability' of the items was first examined. All bivariate correlation coefficients between the five items were found to be well above 0.3, suggesting reasonable factorability, as shown in Table 1. Further, the Kaiser-Meyer-Olkin measure of sampling adequacy was 0.78, which was above the commonly accepted cut-off value of 0.6. Bartlett's test of sphericity was significant (χ^2 (10) = 773.97, p < .001). The diagonals of the anti-image correlation matrix were also over 0.5. The communalities for the items were all above 0.3, further confirming that the items shared some common variance each other. These indicators suggest that factor analysis was appropriate for use with this instrument.

Table 1. Bivariate correlation between items

	Item 1	Item 2	Item 3	Item 4	Item 5
Item 1	–	.607	.562	.378	.481
Item 2		–	.487	.310	.439
Item 3			–	.384	.443
Item 4				–	.599
Item 5					–

Maximum likelihood was chosen as the extraction method in the factor analysis, as the data conformed well to the underlying assumptions of this approach (Fabrigar, Wegener, MacCallium & Strahan, 1999). Given that the factors were expected to correlate, an oblique rotation (Promax, Kappa=4) was used in the interpretation of results (Costello & Osborne, 2005). The scree plot was used to determine the number of factors that would be extracted, which has been identified as a preferred method of identification be several researchers (Costello & Osborne, 2005).

The results of the EFA indicated the presence of only one strong factor. The initial eigenvalues indicated that this single factor explained 57% of the total score variance. Factor loadings produced by the EFA are presented in Table 2. No item had to be removed as all factor loadings were relatively high.

Table 2. Factor loadings and communities

	Statement representing rating '1'	Statement representing rating '7'	Factor Loading	Communality
Item 1 (after reversal)	I think that physics is a very boring subject.	I find physics lessons very interesting.	.78	.61
Item 2	I would skip physics lessons if I were given the option.	I look forward to my physics lessons.	.70	.49
Item 3	I am not interested in knowing more than I have to in physics.	I find myself wanting to learn more about the things we do in physics lessons.	.69	.48
Item 4 (after reversal)	I would only choose to do physics if I needed it for my future success.	It is important to learn about physics, even if I don't need it to get into university/get a good job.	.57	.32
Item 5 (after reversal)	I can't see why anyone would study physics if they didn't have to.	I can see the value of studying physics just for its own sake.	.68	.46

Reliability of the PTVS

The internal consistency of the items was assessed using a Cronbach's alpha method. Nunnally and Bernstein (1994) suggested that an alpha coefficient of above 0.70 would demonstrate an acceptable level of consistency. The Cronbach alpha value obtained in this study was 0.81, suggesting a high level of internal consistency. Test-retest reliability was also measured using data from the administration of the measure one month after the first administration. Nunnally and Bernstein (1994) suggested use of the same cut-offs for test-retest reliabilities as used for the Cronbach's alpha. The test-retest coefficient obtained was 0.83, which also falls above most recommended cut-off values. As such, the results also suggested that the measure is relatively stable over time.

Conclusion

Overall, the results of this preliminary validation study suggested that the PTVS has sound psychometric properties. Results of the EFA suggested that the scale is unidimensional, and demonstrates a high level of internal consistency and test-retest reliability. As such, this instrument could be useful for assessing the level of physics task value in Singapore secondary school students. The development of the instrument is timely, in light of recent efforts to reverse declining levels of interest and enrolment trends in physics across the globe. The decline of interest in physics has been reported across various countries to commence in Grades 9–10 (students aged 15–16 years), and continues through Grades 11–12 (students aged 17–18 years), producing reduced enrolments in physics as a subject at the university level (see Oon & Subramaniam, 2010). Similar trends have been observed in recent years within the Singapore context, with the total number of students taking physics at the junior college level (17–18 years) declining from 80% in 2000 to 40% in 2009 (Oon & Subramaniam, 2010).

Assessing the value that students assign to physics as a subject area, and monitoring this closely, is proposed here as a strategy that teachers can use to guide their teaching practices, with the aim of reversing declining interest in the subject in the upper secondary school levels. Using the information generated in such assessments, physics teachers will be in a position to adjust their practices to increase student engagement levels in the subject area in a timely manner. While the question of ‘how’ this can be done is beyond the scope of the present paper, it is clearly important in the first instance to provide teachers with tools that can be used to assess student values in the classroom. The instrument presented here may prove to be useful for this purpose, owing to its brevity, which makes it a practical option for regular use in classrooms. Future research conducted by the authors will examine further the instrument's generality across subject areas and cultural contexts, as well as its relationships with other, well-established instruments used in the motivation realm.

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Paper 4 – Conceptual Understanding in Physics: Relationships with Learning Process Variables

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This fourth paper was designed to explore the relationships between conceptual understanding in physics and learning process variables. While previous literature has suggested that a large number of learning process variables, particularly in the motivation domain, predict learning gains across various subject areas, these studies have generally used measures taken at a single timepoint, rather than at multiple timepoints. The findings of the study reported here have significant implications for traditional assumptions about the directionality of the relationships between learning process variables and achievement, and thus, for classroom teachers who wish to enhance students' conceptual understanding in physics. Bibilographic Details: Chow, C.W., & Chapman, E. (Submitted). Conceptual understanding in physics: relationships with learning process variables. Journal details: Educational Psychology, Print ISSN 0144-3410, Online ISSN 1469-5820, Impact Factor 0.667.

Abstract

Two studies were conducted to explore relationships between levels of self-regulation and conceptual understanding in physics. Study 1 examined correlations between scores on the Motivated Strategies for Learning Questionnaire (MSLQ) and the Force Concept Inventory (FCI) in a sample of 787 Year 11 students in Singapore. Study 2 examined correlations between scores on the Two-factor Revised Learning Process Questionnaire (R-LPQ-2F) and the FCI in 402 Year 11 students from the same school. Results were similar to those reported in previous studies using concurrent, single time-point MSLQ, R-LPQ-2F and FCI scores, indicating positive relationships between them. A different pattern emerged, however, when three-month FCI gain scores were used as the criterion performance variable. Using the full study sample, only Deep Strategy subscale scores were positively correlated with FCI gain scores. The pattern of relationships between self-regulation and performance gains did vary, however, with students' starting FCI achievement levels. For those who started at a lower level, only MSLQ Intrinsic Goal Orientation scores were positively correlated with FCI gains. For those who started at a higher FCI achievement level, only R-LPQ-2F Deep Strategy scores were positively correlated with FCI gains. Implications for interpreting reported relationships between self-regulation and academic performance, and for differentiating strategies to enhance the learning gains of students at different starting achievement levels, are discussed.

Keywords: self-regulated learning, approaches to learning, physics, conceptual understanding, secondary school

Introduction

Physics is a key branch of science that is often described as the study of matter and energy. In addition to its importance as a stand-alone subject, physics concepts provide the building blocks for learning in various other Science, Technology, Engineering and Mathematics (STEM) subjects. Despite its importance, the science education literature over the past decade has been replete with reports of declining numbers of students who choose to major in physics and physics-related disciplines (such as engineering) at the tertiary level. These trends have been observed robustly in different countries across the world (e.g., Institute of Engineering and Technology UK, 2008; Kennedy, Lyons & Quinn, 2014; Mbamara & Eke Eya, 2015; Oon & Subramaniam, 2011). In light of these trends, a global workforce shortage in STEM areas has been projected to occur in the coming decades (ManpowerGroup, 2014).

The perceived difficulty of physics as a subject at the secondary school level has been proposed by various researchers to be a key contributing factor in the declining enrolment numbers observed at the tertiary level (e.g., Mbamara & Eke Eya, 2015). It has long been recognized that many secondary school students exhibit enduring difficulties in understanding physics concepts (e.g., Hake, 1998; McDermott, 1991; McDermott & Shaffer, 1992). By implication, facilitating students' conceptual understanding in physics at the secondary school level may contribute favourably toward reversing the declining enrolment trends observed at the tertiary level in recent years. Taking this approach will rely, in turn, on developing a sound understanding of the factors that can influence students' acquisition of physics concepts at the secondary school level.

One promising line of inquiry that has emerged to date on this topic has focused on exploring how students' self-regulated learning strategies and learning approaches moderate their acquisition of new concepts. Both of these variables have been found to correlate significantly with student learning outcomes across a range of subject areas. Despite this, relatively little research has been done to investigate their relationships with outcomes in the area of physics. Given the difficulties reported by students in this domain, it seems prudent to investigate whether these learning process variables can be used as a mechanism for enhancing students' understanding in this subject area.

Self-Regulated Learning Strategies

Whilst conceptualizations of self-regulated learning differ somewhat in the literature, the widely accepted framework posed by Pintrich and DeGroot (1990) identifies three core components of the construct. The first is the use of metacognitive strategies for planning, monitoring, and modifying cognitions. The second relates to the management and control of effort on tasks. The third relates to the use of specific cognitive strategies for learning. Self-regulated learning theories suggest that motivation and self-regulatory strategies are interdependent processes of learning. In other words, students will only use self-regulatory strategies if they are motivated to do so. Consistent with this conceptualization, Zimmerman (1986, pp. 55-66) described self-regulated learners as metacognitively, motivationally, and behaviourally active participants in their own learning process:

> They are proactive in their efforts to learn because they are aware of their strengths and limitations and because they are guided by personally set goals and task-related strategies, such as using an arithmetic addition strategy to check the accuracy of solutions to subtraction problems. These learners monitor their behavior in terms of their goals and self-reflect on their increasing effectiveness. This enhances their self-satisfaction and motivation to continue to improve their methods of learning. Because of their superior motivation and

> adaptive learning methods, self-regulated students are not only more likely to succeed academically but to view their futures optimistically.

Research has established positive relationships between self-regulated learning and learning outcomes across a wide range of academic disciplines (e.g., Corno & Mandinach, 1983; Corno & Rohrkemper, 1985). In a meta-analysis of 67 independent studies involving 19,900 college students majoring in different academic disciplines, Credé and Phillips (2011) found that variables related to self-regulated learning (e.g., self-efficacy, critical thinking) generally correlated positively with academic achievement measured both in terms of specific course grades and Grade Point Averages (GPAs). Zimmerman and Martinez-Pons (1986) also reported that higher-achieving students used more advanced learning strategies than lower-achieving students (Zimmerman and Martinez-Pons, 1986).

While self-regulated learning is defined in different ways in the literature, in operational terms, it is defined by the instruments used to measure it in research. One widely used instrument is the Motivated Strategies for Learning Questionnaire (MSLQ), developed by Pintrich, Smith, Garcia and McKeachie (1991). The MSLQ comprises two main sections: the motivation section and the learning strategies section. The motivation section is based on a broad social-cognitive model of motivation, which incorporates three main constructs: (i) Value, (ii) Expectancy and (iii) Affect (Pintrich, 1988). Each of the three constructs relates to students' purposes and beliefs in dealing with a particular task. The *Value* construct relates to students' goals and beliefs in the importance of performing the task. The *Expectancy* construct relates to students' perceptions of their ability to accomplish the task. The *Affect* construct relates to students' emotions in completing the task (Garcia & Pintrich, 1995).

The other section of the MSLQ, the learning strategies section, is based on a general cognitive model of learning and information processing (Weinstein & Mayer, 1986). It comprises three broad categories: (i) *Cognitive* Strategies, (ii) *Metacognitive* Strategies, and (iii) *Resource Management* Strategies (Garcia & Pintrich, 1995). Cognitive Strategies relate to how students process information from reading materials and lessons. Metacognitive Strategies relate to how students control and regulate their thinking processes, and Resource Management Strategies relate to how students control and use available resources. The structure of the MSLQ and description of its subscales are presented in Table 1.

Approaches to Learning

While instruments such as the MSLQ focus on the specific motivations and learning strategies used by individuals in particular situations, measures of students' approaches to learning tend to be broader. In general, students' approaches to learning can be identified as either *deep* or *surface* in nature (Marton & Säljö, 1976). Students who adopt a deep learning approach are intrinsically motivated to learn. They focus on understanding new information, making connections between this information and past experiences, and applying new concepts across different situations. In contrast, students who adopt a surface learning approach are motivated by external rewards, such as getting good grades, tending to rely primarily on rote-learning methods when confronted with new information (McAllister, Lincoln, McLeod & Maloney, 1997; Murphy & Tyler, 2005).

Table 1. Structure of the MSLQ and description of subscales

Scale	Construct	Subscale	Description of Subscale
Motivation	Value	Intrinsic Goal Orientation	Participation in a task for reasons such as challenge, curiosity and/or mastery.
		Extrinsic Goal Orientation	Participation in a task for external rewards such as for receiving good grades.
		Task Value	Perception of a task being interesting, important and/or useful.
	Expectancy	Control of Learning Beliefs	Belief that efforts will result in positive outcomes.
		Self-efficacy for Learning and Performance	Belief about one's ability to accomplish a task.
	Affect	Test Anxiety	Reflection of worries about test performance.
Learning Strategies	Cognitive and Metacognitive Strategies	Rehearsal	The technique of repeating information.
		Elaboration	The technique of making connections between ideas and consolidating information.
		Organization	The technique of selecting and arranging relevant information.
		Critical Thinking	The technique of applying previous knowledge to new situations to solve problems, make decisions or critical evaluations.
		Meta-cognitive Self-regulation	The process of planning, monitoring and making continuous adjustment of one's cognitive activities for improvement.
	Resource Management Strategies	Time and Study Environment	The effective use of time and developing the habit of studying in a conducive environment.
		Effort Regulation	The commitment to work hard and be self-disciplined in completing tasks.
		Peer Learning	The willingness to collaborate with friends for learning.
		Help Seeking	The willingness to find assistance from peers or teachers.

Again, whilst different conceptualisations of learning approaches have been posed, the construct is defined operationally by the instruments that are used to measure it. One of the most widely used instruments to assess students' approaches to learning at the secondary school levels is the Learning Process Questionnaire (LPQ; Biggs, 1987), which has been validated in a wide range of contexts (e.g. Bernardo, 2003; Cano, 2005; Peng & Bettens, 2002; Sachs & Gao, 2000). The most recent version of the instrument is the Two-Factor Revised Learning Process Questionnaire (R-LPQ-2F; Kember, Biggs, and Leung 2004), which comprises 22 items. These items are designed to assess two broad types of learning approach: Deep and Surface. Each of these two broad factors, in turn, includes two subscales, which relate respectively to students' motivation and learning strategies. The structure of the R-LPQ-2F and its item statements are presented in Table 2.

Numerous studies have indicated that students who use deep learning approaches achieve better learning outcomes than those who rely primarily on surface learning approaches. For example, in their seminal study, Marton and Säljö (1976) found that students who used deep learning approaches had a more complete understanding of an article that they were asked to read, and were able to recall more information from it, than those who used surface learning approaches. Shortly after, Svensson (1977) reported that students enrolled in a first-year education course at the tertiary level who adopted a deep learning approach achieved higher grades than those who used a surface approach.

Table 2. Structure of the R-LPQ-2F and item statements

Scale	Subscale	Item Statement
Deep approach	Deep motive	I find that at times studying makes me feel really happy and satisfied.
		I feel that nearly any topic can be highly interesting once I get into it.
		I work hard at my studies because I find the material interesting.
		I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes.
		I come to most classes with questions in mind that I want answering.
		I find I am continually going over my school work in my mind at times like when I am on the bus, walking, or lying in bed, and so on.
		I like to do enough work on a topic so that I can form my own conclusions before I am satisfied.
	Deep strategy	I try to relate what I have learned in one subject to what I learn in other subjects.
		I like constructing theories to fit odd things together.
		I try to relate new material, as I am reading it, to what I already know on that topic.
		When I read a textbook, I try to understand what the author means.
Surface approach	Surface motive	I am discouraged by a poor mark on a test and worry about how I will do on the next test.
		Even when I have studied hard for a test, I worry that I may not be able to do well in it.
		Whether I like it or not, I can see that doing well in school is a good way to get a well-paid job.
		I intend to get my A Levels because I feel that I will then be able to get a better job.
	Surface strategy	I see no point in learning material which is not likely to be in the examination.
		As long as I feel I am doing enough to pass, I devote as little time to studying as I can. There are many more interesting things to do.
		I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra.
		I find it is not helpful to study topics in depth. You don’t really need to know much in order to get by in most topics.
		I learn some things by rote, going over and over them until I know them by heart.
		I find the best way to pass examinations is to try to remember answers to likely questions.
		I find I can get by in most assessment by memorising key sections rather than trying to understand them.

In a more recent, large-scale study of the relationship between approaches to learning with variables such as self-concept, locus of control, learning environment, and academic grades, Watkins (2001) compared correlations for 15 different western and non-western countries across the globe. Based on the outcomes, Watkins reported that that deep learning approaches consistently predicted higher academic achievement across a range of subject areas and grade levels. Studies published since that time have reported similar results. For example, Hasnor, Ahmad and Nordin's (2013) study at the university level indicated that higher surface learning was associated with lower academic performance in 233 Malaysian students across different subject areas. O'Day and Garet (2014), in a study commissioned by the American Institute of Research, and involving 1748 students across 28 secondary school schools in the United States, reported similarly that students who adopted deep learning approaches achieved higher test scores across a range of subject areas, including reading, mathematics and science, than those who were more surface-oriented.

Rationale for the Present Research

As indicated, various previous studies have evaluated the extent to which self-regulation (including students' motivations, learning strategies and approaches) correlates with academic achievement. Three broad issues have not, however, been addressed in these previous studies. The overarching goal of the present research was to address these issues within the context of physics education.

The first issue addressed in the present research related to whether the associations reported in previous research between self-regulation variables (i.e., learning motivations, strategies, and approaches) and academic achievement extends to conceptual understanding in physics. Previous research in self-regulation has included a large range of academic achievement measures, but few studies have focussed specifically on conceptual understanding. It is possible that the influence of different learning motivations, strategies and approaches on academic achievement will vary with the kind of achievement measure used. If, for example, the achievement measure is primarily focussed at the recall level of the Bloom's taxonomy (Bloom, 1956), it may well be effective for students to use learning strategies based on rote memorisation. If, conversely, the achievement measure focuses on conceptual understanding, rote memorisation is unlikely to have a positive effect.

The second issue addressed in this study concerned the extent to which self-regulation variables predicted the gains made in physics conceptual understanding over a three-month time period. Most previous studies on self-regulation have only investigated the relationship between self-regulation and achievement at a single timepoint. Significant relationships have then been interpreted to indicate that higher levels of self-regulation *lead to* higher achievement levels. This, however, ignores the reverse possibility: That is, that higher achievement levels lead to increases in particular self-regulation variables (e.g., self-efficacy, intrinsic motivation, critical thinking). In studies that measure achievement only at single timepoints (generally, administered concurrently with the self-regulation measures), it is impossible to determine the direction of the relationship. If, however, the self-regulation variables do lead to higher achievement levels, it would be expected that these would not only correlate with concurrent measures of achievement, taken at a single timepoint: These would be expected to act as predictors of achievement *gains* over time.

The third issue that had not been addressed within the self-regulation literature at the time of writing concerned whether the relationships between self-regulation and achievement varied across ability levels. From an intuitive point of view, it would make sense that the advantages of using particular learning strategies may depend on the starting competency level of the students. For example, students at the very lowest startpoints may well benefit from some initial use of rote memorization, which will later free them up to focus on developing their understanding of higher-level concepts. Conversely, students at higher startpoints may benefit more from adopting deeper learning approaches (e.g., those that involve integrating new concepts with those previously learned).

The research presented in this paper comprised two separate studies. Study 1 focused specifically on addressing the three issues raised above with respect to self-regulated learning variables. Study 2 then focused on addressing the same questions with respect to students' learning approach variables. In all, a total of 1355 students participated in the research (900 in Study 1; 455 in Study 2). All were Year 11 students in Singapore, who were enrolled in a unit on forces at the time of the study.

Study 1: Self-regulation variables

Study 1 focused on the relationships between self-regulated learning variables, and students' learning gains in the context of physics education. As indicated above, both studies reported in this paper were conducted to address three unresolved issues within the self-regulated learning literature. The specific research questions addressed in Study 1 were:

- *Research Question 1* – Do the associations between self-regulated learning variables and academic achievement reported in previous research replicate when a measure of conceptual understanding in physics is used?

- *Research Question 2* – To what extent do self-regulated learning variables predict learning gains in physics conceptual understanding over an extended time period?
- *Research Question 3* – To what extent do the relationships between self-regulated learning variables and gains in physics conceptual understanding vary with students' startpoint competency levels?

Method

Participants

Study 1 was conducted with 900 Year 11 physics students (555 male and 345 female) from a secondary school in Singapore. The participants were predominantly ethnic Chinese, with fewer than 1% representing other ethnic groups. All participants were enrolled in a three-month mechanics physics module, which was taught based on the General Certification of Education Advanced Level physics syllabus 9646 (Singapore Examination and Assessment Board, 2014). At the start of the study, their ages ranged from 16 to 18 years (M = 16.7 years, SD = 0.82). All measures were also administered in the English language, which should not have posed any challenge to the students as English is the first language in Singapore schools.

Instruments

The MSLQ (Pintrich et al., 1991, 1993) was used to assess facets of students' self-regulated learning. The MSLQ is a well-established and widely used instrument in the area of self-regulated learning (Duncan & McKeachie, 2005). The instrument consists of two main sections. The motivation section of the MSLQ comprises six scales with a total of 31 items. The learning strategies section comprises nine scales with a total of

50 items. All items are scored on a seven-point scale, from '*not at all true of me*' to '*very true of me*'.

Previous studies of the psychometric properties of the MSLQ have generally indicated that the instrument has sound psychometric properties (e.g., Pintrich & Gracia, 1991; Garcia & Pintrich, 1995). Using data from the current study, a high level of internal consistency of the MSLQ was demonstrated, which was comparable to the results obtained by Pintrich et al. (1991), as presented in Table 3. The average Cronbach alpha values obtained for the motivation and learning strategies sections were 0.76 and 0.71 respectively, with all subscales except Help Seeking achieving either above or approach the commonly accepted cut-off value of 0.7 (Kline, 2000). These results were comparable with those obtained by Garcia and Pintrich (1995), including the lower Cronbach alpha value for the Help Seeking subscale. Biggs (1993) argued that low Cronbach alpha values should not be a major concern for subscales with small number of items or where multidimensionality is evident. In the case of the Help Seeking subscale, the relative low internal consistency does appear to reflect the multidimensionality of this construct (Garcia & Pintrich, 1995).

Table 3. Internal consistency of the MSLQ subscales

Section	Subscale	Cronbach Alpha	
		Current Study	Pintrich et al.'s (1991) Study
Motivation	a) Value Components		
	• Intrinsic Goal Orientation	.69	.74
	• Extrinsic Goal Orientation	.72	.62
	• Task Value	.84	.90
	b) Expectancy Components		
	• Control of Learning Beliefs	.67	.68
	• Self-efficacy for Learning and Performance	.94	.93
	c) Affective Component		
	• Test Anxiety	.71	.80
	Average	.76	.78
Learning Strategies	a) Cognitive and Metacognitive Strategies		
	• Rehearsal	.68	.69
	• Elaboration	.77	.76
	• Organization	.77	.64
	• Critical Thinking	.81	.80
	• Metacognitive Self-regulation	.77	.79
	b) Resource Management Strategies		
	• Time and Study Environment	.72	.76
	• Effort Regulation	.69	.69
	• Peer Learning	.68	.76
	• Help Seeking	.49	.52
	Average	.71	.71

Physics conceptual understanding was assessed using the Force Concept Inventory (FCI: Hestenes, Wells & Swackhamer, 1992). The FCI is widely used to assess concept mastery in the area of Newtonian mechanics (Hestenes, Wells & Swackhamer, 1992). According to Hestenes and Halloun (1995), the face validity of the FCI has been confirmed by content area experts, and its content validity has been established through interviews with large student samples. At both timepoints, the FCI also demonstrated good internal consistency using data of the current study (timepoint 1 alpha = 0.81, timepoint 2 alpha = 0.80). The FCI includes 30 multiple choice questions, each with five response options. There is only one correct answer for each question. In this study, total FCI scores reflected the number of correct responses made by students, expressed as a mark out of 100 (see Hestenes et al., 1992).

Procedures

Approval to conduct the research was first obtained from the Human Research Ethics Committee of the authors' research institution. Permission was also granted by the Principal of the participating school. Participants completed the MSLQ and the FCI at the beginning of a three-month Newtonian mechanics module within their Year 11 physics course. The two instruments were completed within a single session, in hard copy format. Participants responded using optical mark sheets, which were then scanned for the purposes of data collation. The FCI was administered again at the end of the three-month module. Participants were assigned unique codes at the pretest to allow matching of their pretest MSLQ, pretest FCI, and posttest FCI responses. Prior to completing the MSLQ and the FCI, however, students were told that their individual responses would not have any bearing on their course grades.

Results and Discussion

Data were first inspected for missing cases. For both the MSLQ and the FCI, any forms with more than 10% missing item responses were excluded from the final data pool. Responses to all negatively-worded statements of the MSLQ were reverse-coded.

Pretest scores for the FCI were examined, and any students who had already reached mastery, defined as achieving a score of 85% or more, at the start of the module, were excluded from the data pool. This was done to ensure that the gains made were not attenuated by ceiling effects. The cut-point of 85% was used in determining mastery levels was based on recommendations of Hestenes and Halloun (1995). This reduced the total sample size from *n*=900 to *n*=787.

The FCI gain scores in this study were computed using a formula suggested by Hake (1998), referred to as *normalised gain scores*. These are computed as the posttest score minus the pretest score, divided by the difference between the maximum possible total score and the pretest score. Hake found that normalized gain scores is a more meaningful measure of improvement than raw gains, after analysing the FCI scores of 6000 students. Based on his formula, the normalised gain scores used in this study represent improvement in terms of the maximum possible gains that a student could make. For example, if a student's normalised gain score was 0.30, this indicates that the student improved by 30% of the maximum improvement in scores that he or she could possibly have made. Descriptive statistics for all variables in this study are presented in Table 4.

Table 4. Descriptive statistics for FCI and MSLQ subscales

Measure	Group					
	Full Sample (*n*=787)		Low Startpoint (*n*=433)		High Startpoint (*n*=354)	
	M	*SD*	*M*	*SD*	*M*	*SD*
FCI-Pretest	56.96	14.23	46.11	7.85	70.23	7.40
FCI-Gain	0.37	0.29	0.38	0.22	0.36	0.35
Intrinsic Goal Orientation	5.19	0.85	5.04	0.83	5.39	0.84
Extrinsic Goal Orientation	5.26	0.97	5.23	0.97	5.30	0.98
Task Value	5.39	0.80	5.29	0.78	5.50	0.82
Control of Learning Beliefs	5.60	0.74	5.52	0.74	5.70	0.74
Self-efficacy for Learning and Performance	4.92	0.99	4.69	0.94	5.21	0.97
Test Anxiety	4.21	1.13	4.24	1.06	4.17	1.21
Rehearsal	4.63	0.94	4.69	0.91	4.55	0.98
Elaboration	5.10	0.84	5.05	0.82	5.15	0.85
Organization	5.01	1.05	5.06	1.01	4.95	1.11
Critical Thinking	4.80	0.93	4.65	0.91	4.98	0.92
Metacognitive Self-regulation	4.88	0.69	4.83	0.66	4.95	0.72
Time and Study Environment	4.96	0.79	4.97	0.74	4.95	0.84
Effort Regulation	5.03	0.79	4.98	0.77	5.09	0.81
Peer Learning	4.89	0.72	4.84	0.71	4.95	0.72
Help Seeking	5.00	0.82	5.07	0.81	4.91	0.84

To address Research Question 1 (i.e., Do the associations between self-regulated learning variables and academic achievement reported in previous research replicate when a measure of conceptual understanding in physics is used?), correlations were first performed between the scores on FCI-Pretest scores and those on the MSLQ motivation subscales, and also between the scores on FCI-Pretest and those on the MSLQ learning strategies subscales (Table 5, column (A)). The correlations reported here are similar to those reported in previous studies (e.g., Pintrich & DeGroot, 1990; Pintrich et al., 1993; Rotgans & Schmidt, 2010). FCI-Pretest scores were positively correlated with Intrinsic

Goal Orientation, Task Value, Control of Learning Beliefs, and Self-Efficacy for Learning and Performance, whilst being negatively correlated with Test Anxiety. Extrinsic Goal Orientation was not significantly correlated with FCI-Pretest scores. For the MSLQ learning strategies subscales, the FCI-Pretest scores were positively correlated with the scores on Elaboration, Critical Thinking, Metacognitive Self-regulation, whilst being negatively but weakly correlated with the scores on Rehearsal and Help Seeking.

Table 5. Correlations between MSLQ subscales with FCI-Pretest and FCI-Gain

Scale	Subscale	Group			
		Full Sample (n=787)		Low Startpoint (n=433)	High Startpoint (n=354)
		(A) FCI-Pretest	(B) FCI-Gain	(C) FCI-Gain	(D) FCI-Gain
MSLQ Motivation	Intrinsic Goal Orientation	.25**	.07	.16**	.02
	Extrinsic Goal Orientation	.05	-.02	-.05	.02
	Task Value	.15**	.06	.01	.07
	Control of Learning Beliefs	.11**	.01	.01	.01
	Self-efficacy for Learning and Performance	.32**	.06	.09	.07
	Test Anxiety	-.07*	.00	-.02	.01
MSLQ Learning Strategies	Rehearsal	-.09*	-.04	-.09	-.02
	Elaboration	.08*	.01	.04	-.02
	Organization	-.06	-.05	-.04	-.06
	Critical Thinking	.21**	.08*	.09	.10
	Metacognitive Self-regulation	.09*	.06	.04	.07
	Time and Study Environment	-.02	.02	.04	.00
	Effort Regulation	.06	.03	.02	.04
	Peer Learning	.07	.05	.02	.08
	Help Seeking	-.08*	.04	-.05	.10

To address Research Question 2 (i.e., To what extent do self-regulated learning variables predict the gains in physics conceptual understanding over an extended time period?), bivariate correlations between scores on the MSLQ subscales and FCI normalised gain scores were computed for the full sample. These results are incorporated alongside those for the FCI-Pretest in Tables 4 (column B). As indicated, when gains, rather than FCI-Pretests were used as the criterion measure, all bar one relationships were no longer significant. The single exception to this was a modest (r=0.08) significant relationship between Critical Thinking and FCI normalised gains. Whilst statistically significant, the latter correlation was very weak. This effect, therefore, is of little practical significance. Thus, using the normalised gain scores, none of the associations previously seen between the MSLQ subscales and the FCI-Pretests as achievement measures, were retained.

To address Research Question 3 (i.e., To what extent do the relationships between self-regulated learning variables and gains in physics conceptual understanding vary with students' startpoint competency levels?), the sample was first split into startpoint competency bands based on their FCI pretest scores. This banding was based on the recommendations of Hestenes and Halloun (1995), who reported that a score of 60% on the FCI represented an 'entry threshold' level. Thus, students within the 60-85% band (n=354) were assigned to the high startpoint group, while students scoring below 60% (n=433) were assigned to the low startpoint group. Similarly, the MSLQ subscales scores were then correlated with FCI normalised gain scores, with the results shown in column C and D in Table 5. As indicated, only Intrinsic Goal Orientation and FCI-Gain scores had a significant positive correlation for the low startpoint group, and there were no other significant correlations between MSLQ and FCI-Gain scores for either group.

Study 2: Approaches to Learning

Study 2 investigated the relationship between students' approaches to learning and their academic achievement. As in Study 1, students' achievement levels were assessed using the FCI. Students' approaches to learning were assessed using the R-LPQ-2F (Kember et al., 2004), the 22-item instrument developed for use at the secondary school levels. The specific research questions addressed in Study 2 were:

- *Research Question 1* – Do the associations between learning approach variables and academic achievement reported in previous research replicate when a measure of conceptual understanding in physics is used?
- *Research Question 2* – To what extent do learning approach variables predict gains in physics conceptual understanding over an extended time period?
- *Research Question 3* – To what extent do the relationships between learning approach variables and gains in physics conceptual understanding vary with students' startpoint competency levels?

Method

Participants

Study 2 was conducted with a separate cohort of physics students from those who participated in Study 1. These students were also from the same school as those in Study 1, and had completed the same mechanics module in the following year for the same duration of time (i.e., three months). The full sample comprised 455 Year 11 physics students (266 male and 189 female). The demographics of the students were also similar to the participants in Study 1: their ages ranged from 16-18 years old (M = 16.7, SD = 0.39), they are predominately ethnic Chinese with less than 1% from other ethnic groups.

Instruments

Students' achievement was also assessed using the FCI, which again demonstrated good internal consistency at both timepoints (timepoint 1 alpha = 0.80, timepoint 2 alpha = 0.81). Students' approaches to learning were assessed using the Two-factor Revised Learning Process Questionnaire (R-LPQ-2F: Kember et al., 2004). Previous research has established the psychometric properties of the R-LPQ-2F (e.g., Kember et al., 2004; Phan & Deo, 2007). The R-LPQ-2F also demonstrated good internal consistency using data from current study. The Cronbach alpha values for the subscales are presented in Table 6. It is noted that Surface Motive only achieved Cronbach alpha value of 0.61. Again, the low alpha value was a consequence of multidimensionality and small number of items (Kember et al., 2004).

Table 6. Cronbach α coefficients for the R-LPQ-2F

Subscale	Cronbach Alpha	
	Current Study	Kember et al.'s (2004) Study
Deep Motive	.75	.75
Deep Strategy	.74	.66
Surface Motive	.61	.58
Surface Strategy	.70	.68
Average	.70	.67

The R-LPQ-2F includes two main scales, Deep Approach and Surface Approach. In total, there are four subscales, two within the Deep Approach scale (Deep Motive, 7 items; Deep Strategy, 4 items), and two within the Surface Approach scale (Surface Motive, 4 items; Surface Strategy, 7 items). In all, the instrument includes 22 item statements, to which students respond on a five-point scale, ranging from *'never or* *only rarely true of me*' to '*always or almost always true of me*'. In this study, as suggested by Kember et al. (2004), the score for each subscale was computed by taking the average item score within the subscale. Thus, the score range for each subscale was from 1 ('*never or only rarely true of me*') to 5 ('*always or almost always true of me*').

Procedures

Study 2 was approved under the same ethics protocol number as Study 1. The R-LPQ-2F and the FCI were completed by participants at the beginning of the three-month Newtonian mechanics module. The FCI was then administered again at the end of the module. All other procedures were the same as those used in Study 1.

Results and Discussion

Data were first inspected for missing cases. Again, for both the R-LPQ-2F and the FCI, any forms with more than 10% of item responses missing were excluded from the final data pool. Unlike in the MSLQ, there are no reverse-scored items within the R-LPQ-2F scales. Thus, high scores on the Surface Approach subscales reflect high levels of surface motives or strategies; the same is true for the Deep Approach subscales. Again, pretest scores for the FCI were examined, and any students who had already reached the mastery level on this instrument at the start of the module were excluded from the data pool, using the 85% cut-point suggested by Hestenes and Halloun (1995). This reduced the total sample size from n=455 to n=402. The remaining students were then grouped into startpoint competency groups using the same approach as in Study 1. This produced n=190 in the high startpoint group, and n=212 in the low startpoint group. Descriptive statistics for all variables in Study 2 are presented in Table 5.

The correlations reported in Table 7 address Research Question 1 (i.e., Do the associations between learning approach variables and academic achievement reported in previous research replicate when a measure of conceptual understanding in physics is used?) in terms of students' approaches to learning. As indicated, FCI-Pretest scores were positively correlated with the scores of Deep Strategy, and negatively correlated with the scores of Surface Strategy. Both Deep Motive and Surface Motive scores were however not significantly correlated with FCI-Pretest scores.

Table 7. Descriptive statistics for FCI and R-LPQ-2F subscales

Variable	Full Sample (*n*=402)		Low Startpoint (*n*=190)		High Startpoint (*n*=212)	
	M	*SD*	*M*	*SD*	*M*	*SD*
FCI-Pretest	58.81	14.05	46.54	8.65	69.80	69.80
FCI-Gain	0.22	0.32	0.21	0.22	0.22	0.38
Deep Motive	3.10	0.65	3.10	0.62	3.10	3.10
Deep Strategy	3.51	0.73	3.40	0.73	3.62	3.62
Surface Motive	3.74	0.67	3.79	0.68	3.69	3.69
Surface Strategy	2.31	0.62	2.44	0.58	2.19	2.19

The results concur with those reported by Entwistle, Tait and McCune (2000), based on a study of 1,969 undergraduates across seven universities in the United Kingdom and a South African university. The researchers demonstrated that a deep learning approach is associated with high achievement scores in assessment that focussed on conceptual understanding, although the study did not examine the relationship of specific subscales (motives and strategies) with achievement scores.

The bivariate correlations between scores on the R-LPQ-2F and the FCI normalised gain scores for the full sample are also presented in Table 8. These correlations address Research Question 2 (i.e., To what extent do learning approach variables predict the gains in physics conceptual understanding over an extended time period?). Similar to the pattern that emerged for the MSLQ, when gains, rather than FCI-Pretests were used as the criterion measure, all bar one of the relationships was no longer significant. The exception to this was a significant relationship between Deep Strategy scores and FCI-Gain scores.

Table 8 also presents the correlations relevant to Research Question 3 (i.e., To what extent do the relationships between gains in physics conceptual understanding and learning approach variables vary with students' startpoint competency levels?). Despite the positive association between Deep Strategy and FCI gains for the full sample, results for the low and high startpoint groups indicated that this relationship was only significant for students who started at a relatively high level of the FCI-Pretests. No other correlations were significant for either group.

Table 8. Correlations between R-LPQ-2F with FCI-Pretest and FCI-Gain

Scale	Subscale	Group			
		Full Sample (n=402)		Low Startpoint (n=190)	High Startpoint (n=212)
		(A) FCI-Pretest	(B) FCI-Gain	(C) FCI-Gain	(D) FCI-Gain
Deep Approach	Deep Motive	.05	.03	.01	.02
	Deep Strategy	.16**	.17**	-.10	.19**
Surface Approach	Surface Motive	-.05	.05	-.08	.05
	Surface Strategy	-.22**	-.06	.04	-.06

Conclusions

The two studies reported in this paper were conducted to address three major research questions. With respect to Research Question 1 for the two studies, results indicated that using an achievement measure based on physics conceptual understanding produced similar correlations between students' learning motivations, strategies and approaches (as measured by the MSLQ and the R-LPQ-2F) and academic performance. Using data collected at the same single timepoint, the correlations obtained aligned well with expectations based on the results of previous studies (e.g., Credé and Phillips, 2011; Entwistle, Tait and McCune, 2000; Watkins, 2001). Thus, the two studies conducted confirm that the correlations between self-regulation and learning approaches with academic performance extend to conceptually-based performance measures.

Correlations for the full sample were performed to address Research Question 2. When FCI gains, rather than concurrent FCI scores, were used as the criterion measure, only two correlations reached significance. This finding raises an interesting possibility. As indicated previously, the associations between achievement and self-regulated learning/learning approaches reported in previous studies are typically ascribed (either explicitly or implicitly) to a *causal* effect of self-regulated learning/learning approaches on achievement. The results of the full sample analyses suggest that while self-regulation/learning approaches *correlates* with achievement measured at the same timepoint, none of the specific components of self-regulated learning or learning approaches predicted performance gains over time. This result casts doubt on the hypothesis that students with higher levels of self-regulation will make greater gains than others over time.

Based on the results of the present research, any of the following alternatives could plausibly contribute to the correlations observed between concurrent measures of self-regulated learning/learning approaches and performance seen in this and prior studies. First, academic performance may have a causal impact on self-regulation levels and learning approaches. Second, there may be reciprocal causal links between self-regulated learning/learning approaches and academic performance levels. Third, academic performance and self-regulated learning/learning approaches may not be causally linked, but both could be the products of one or more external factors (e.g., home environment or intelligence). A final possibility is that the correlation between these constructs reflects some complex combination of these mechanisms.

The findings of this research, therefore, have significant potential implications for the field. Take, as an example, the first alternative hypothesis suggested (i.e., that academic performance has a causal impact on self-regulated learning/learning approaches). This hypothesis is plausible: that is, the higher self-efficacy levels commonly observed for higher ability students may simply reflect the fact that they have a realistic sense of their own competence levels. These students may also be better placed to use deep learning strategies such as critical thinking than lower ability students, because these strategies presume a certain level of starting competence. The implications of this possibility are significant: For example, this would mean that fostering specific learning strategies or motivations will *not* enhance academic performance over time. Increases in self-regulation levels or deep learning may, however, *follow* increases in academic performance.

A somewhat more complex pattern of relationships between self-regulated learning and learning approaches with FCI gains emerged when the sample was split into high and low startpoint groups (Research Question 3). For lower startpoint students, there was a positive correlation between FCI gains and the MSLQ Intrinsic Goal Orientation subscale. This subscale includes four item statements: “In a class like this, I prefer course material that really challenges me so I can learn new things”; “In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn”;

“The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible”, and “When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade”. Based on these statements, the results of Study 1 suggest that lower ability students will make greater gains if they approach learning tasks with the goal of concept mastery, rather than of high task performance. Research has indicated that teachers can have a significant impact on the goal orientations adopted by students (Pintrich, 2000). This can be achieved through a range of strategies, which include: (i) modifying the types of tasks assigned (e.g., increasing variety to increase interest, and ensuring that the level of challenge posed aligns with individual needs); (ii) encouraging autonomy (e.g., involving children in decision-making and allowing students pace themselves in learning tasks); and (iii) establishing an incentive structure which focuses on individual accomplishments (e.g., recognising individual progress and improvements), rather than relative performance across students (see Valentini & Rudisill, 2005, for a review of these strategies).

Study 2 also indicated that, while learning approaches did not predict FCI gains for lower startpoint students, one R-LPQ-2F subscale (Deep Strategy) did predict the gains made by higher startpoint students. This subscale includes four items: “I try to relate what I have learned in one subject to what I learn in other subjects”; “I like constructing theories to fit odd things together”; “I try to relate new material, as I am reading it, to what I already know on that topic”; and “When I read a textbook, I try to understand what the author means”. Given the content of the subscale, the fact that deep strategies were positively related to FCI gains for higher, but not for lower, startpoint, students is intuitively reasonable. Given the items within the subscale, a certain level of understanding would be needed in many cases to apply deep learning strategies (e.g., relating new material to learning in other subjects and constructing new theories). Thus, the results suggest that encouraging deep learning may be beneficial for students who have already attained some level of mastery in a subject; they will not necessarily be useful for those at a lower or more entry-level of understanding.

For high startpoint students, research has indicated that teachers can impact the likelihood that students will adopt deep strategies in confronting their learning tasks. Much of this research is grounded in Biggs's notion of constructive alignment (e.g., Biggs & Tang, 2007). This notion is based on the premise that students must be able to construct meaning from what they do (e.g., by linking new concepts to old) in order to learn. To increase constructive alignment, educators need to align the assessment tasks and learning activities they set with specific intended learning outcomes. Meyers and Nulty (2009) posed further that, to ensure constructive alignment, educators should ensure that learning tasks are: (i) related to 'real-world' practices; (ii) properly sequenced and interlinked; (iii) challenging and interesting to students; (iv) internally consistent and aligned with targeted learning outcomes; and (v) introduced such that they demand the use of progressively higher-order cognitive processes for students to succeed.

As discussed above, the results of the present research cast doubt on the presumption that self-regulated learning, as measured by students' learning motivations and strategies, have a causal impact on academic performance. A longitudinal study is needed to cast further light on this issue, which allows for the mapping of growth trajectories across the two domains. Future research could also seek to clarify the different motivations and learning strategies that are most beneficial for lower and higher startpoint students. One particular line could focus on students who have and have not mastered certain threshold concepts within a subject. Meyer and Land (2003) describe a threshold concept as a "conceptual gateway", or a "transformed way of understanding, or interpreting, or viewing something, without which the learner cannot progress" (p.1). Extrapolating from the results of the current research, it is possible that only students who have mastered certain threshold concepts within an area would be in a position to apply deep learning strategies. Those who have not yet mastered these may benefit more from learning environments that promote increased task persistence. Both lines of inquiry would help to clarify the complex constellation of relationships that are likely to exist between these two broad constructs.

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Paper 5 – Effects of Assessment Expectations on Student Learning Processes and Outcomes in Secondary School Physics

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This fifth paper reports an experiment conducted to explore whether assessment expectations make a difference to students' learning processes and outcomes. Bibilographic Details: Chow, C.W., & Chapman, E.S. (Submitted). Effects of assessment expectations on students' learning processes and outcomes in year 11 physics. Journal details: Educational Assessment, Evaluation and Accountability, Print ISSN 1874-8597, Online ISSN 1874-8600, Journal Impact Factor 0.583.

Abstract

This study investigated the effects of assessment expectations on students' approaches to learning, conceptual understanding and interest in secondary school Physics. A randomised experimental design was employed to study the effects of simply informing students in a three-month physics unit that they would be taking either a multiple choice or a short structured question format assessment at the end of the unit. This was the only intervention. Three measures were employed in the study: the *Revised Two-factor Revised Learning Process Questionnaire* (to assess students' approaches to learning); the *Force Concept Inventory* (to assess students' conceptual understanding in physics); and a researcher-developed *Physics Task Value Scale* (to assess students' perceptions of value in the subject area). Four hundred and seventy Year 11 students (276 males, 194 females) participated in the study, who were assigned on a stratified random basis either to the multiple choice or the short structured question condition. Results indicated a significant main effect of condition on Deep Strategy vs. Surface Strategy ratio scores (derived from the Two-factor Revised Learning Process Questionnaire); a significant condition by gender interaction effect on the Force Concept Inventory scores; and a significant main effect of condition on the Physics Task Value Scale scores. These results indicate that only a minor shift in assessment expectations can significantly impact students' learning behaviours and outcomes in physics. Implications for further research are discussed.

Keywords: Expected Assessment Format, Approaches to Learning, Conceptual Understanding, Interest, Physics, Secondary school

Introduction

On a global level, the demand for expertise in the domains of Science, Technology, Engineering and Mathematics (STEM) is expected to explode over the next decade (Craig, Thomas, Hou, & Mathur, 2011). A report prepared by the United States President's *Council of Advisors on Science and Technology* (PCAST, 2010) underscored the critical role that STEM will play in driving economic development in the future (p. v):

> STEM education…. will help produce the capable and flexible workforce needed to compete in a global marketplace. It will ensure our society continues to make fundamental discoveries and to advance our understanding of ourselves, our planet, and the universe. It will generate the scientists, technologists, engineers, and mathematicians who will create the new ideas, new products, and entirely new industries of the 21st century. It will provide the technical skills and quantitative literacy needed for individuals to earn liveable wages and make better decisions for themselves, their families, and their communities.

In a public address at the opening of the Singapore University of Technology and Design's new campus in 2015 (see Khamid, 2015), the Prime Minister, Mr Lee Hsien Loong, noted the historical importance of STEM in taking Singapore from a Third to a First World country. He underscored further its ongoing importance in the nation's economic success. Results of the most recent *Programme for International Student Assessment* (OECD, 2014) and *Trends in International Mathematics and Science Study* (TIMSS & PIRLS International Study Centre, 2011) provide testimony to the high quality of STEM education currently offered in Singapore. In these international assessments, Singapore has been ranked as one of world's best performing nations in terms of students' performance in Mathematics and Science. It is essential that these standards be maintained for Singapore to remain competitive in a global context that is changing both continuously and rapidly.

The demand for STEM talents worldwide has, however, far outstripped its supply (ManpowerGroup, 2014). For example, in the United States, there is currently a shortage of about 500,000 STEM talents to fit existing positions, and the gap is expected to increase to 1.3 million by 2020 if the trend continues (Swaminathan, 2015). Singapore is facing the same dire situation: between the years 2008-2013, the number of local STEM graduates has fallen by almost 42% (Singapore Department of Statistics, 2013). To address this issue, more students need to pursue STEM-related qualifications at the tertiary levels. This, in turn, will demand more concerted efforts on the part of educators to increase interest and competency in STEM-related disciplines at the pre-tertiary level.

Research on Students' Interest and Understanding in Physics

Secondary school physics is a prerequisite for most STEM-related courses at the tertiary level (Thorne Group Research and Education, 2013). However, research has suggested many secondary school students are not interested in physics. Girls, in particular, have been found to shy away from physics because they perceive that it is a masculine subject (Cartwright, 2013). For example, in the United Kingdom, between the years of 2010 and 2012, on average only about 20% of students who chose A-Level physics were girls (Cartwright, 2013). Another factor that has been cited for the lower uptake of physics by girls is simply that girls tend not to do as well as boys in the subject. Historically, international studies of STEM-based achievements provided some support for this position. For example, results of the Trends in Mathematics and Science Study in 2000 showed a strong pattern of relatively low scores in the physics domain for girls, which was consistent across countries. Indeed, within that study, girls did not outperform boys on the average in a single country (TIMSS International Study Center, 2000). Given that prior achievement has been found consistently to relate to subject choice at the secondary school level (Stewart, 1998), girls may be less inclined to choose this subject due to their expectation of doing more poorly than boys.

Many students, both males and feamles, also perceive that physics concepts are difficult to learn (e.g., Williams, Stanisstreet, Spall, Boyes, Dickson, 2003; Barmby & Defty, 2006; Funda, William, Robinson & Mark, 2008). Reddish (1994, pp. 801) proffers the following explanation of why students found physics so challenging:

> Physics as a discipline requires learners to employ a variety of methods of understanding and to translate from one to the other – words, tables of numbers, graphs, equations, diagrams, maps. Physics requires the ability to use algebra and geometry and to go from the specific to the general and back. This makes learning physics particularly difficult for many students.

Learning Approaches as a Means to Enhance Understanding in Physics

Students' approaches to learning relate to the reasons why, and the ways in which, they undertake a learning task (Biggs, 1987). Two distinct approaches were identified by Marton and Säljö (1976): deep and surface approaches. When confronted with a new learning task, students who adopt a deep approach in their learning will focus on understanding and seeking meaning in the new information, by making connections with past knowledge and organizing seemingly fragmented information in a coherent manner (Ramsden, 1988). They also reflect on their learning, constantly monitoring the progress of their understanding, and making adjustments to their learning strategies to improve that understanding (Entwistle, McCune, & Walker, 2001). In contrast, students who adopt a surface approach tend not to focus on understanding, but instead rely on rote-memorization and reproduction of information in order to satisfy assessment criteria (Ramdsen, 1988).

Numerous empirical studies have provided evidence for a link between approaches to learning and conceptual understanding. For example, in a study of 69 first-year psychology college students, Van Rossum and Schenk (1984) found that students who adopted a deep learning approach achieved higher scores for questions that required higher-order learning than students who adopted a surface approach. Two other studies, one conducted by Trigwell and Posser (1991) with 122 first-year nursing college students, and another conducted by Hazel, Prosser, and Trigwell (1996) with 272 first-year Biology students, revealed similar results.

Assessment Expectations and Learning Approaches

Research suggests that students' approaches to learning are not stable psychological traits, but can be modified according to the learning environment (e.g., Biggs, 1987; Ramsden, 1984). Biggs (1999) emphasized the importance of three components that will influence students' approaches to learning: learning objectives, learning activities and assessment. First, the learning objectives need to be clearly articulated, including the intended level of understanding. Second, the learning activities should be designed to achieve the intended level of understanding. Last, and arguably most important, assessment tasks must be designed to evaluate learning at the intended level of understanding. In order to foster deep learning, these three components must be aligned to achieve the intended level of deep understanding, which Biggs termed "constructive alignment".

Educators and researchers around the world have evaluated various strategies to enhance deep and reduce surface learning, with varying degrees of success. As an example, *Peer Instruction*, pioneered by Stanford professor Eric Mazur, is an interactive teaching method that involves students doing assigned readings before attending class, and during class, the instructors will ask questions based on the assigned readings and engage them in peer discussion using a pedagogy known as "Just In Time Teaching" (see Mazur, 1997, for further information). This method has been demonstrated to significantly improve physics conceptual understanding by increasing the use of deep learning approaches (Crouch & Mazur, 2001).

However, many strategies, such as *Peer Instruction*, that have been found to increase use of deep learning strategies, require substantial investments of teachers' time and effort, which might not be sustainable. The question is whether there are other effective strategies that can achieve similar effects on an ongoing basis, without imposing prohibitive additional demands on the part of teachers. A few studies conducted at the tertiary level have suggested that merely changing assessment expectations can have a significant impact on learning approaches (Scouller, 1996, 1998). These results are consistent Biggs' (1999) notion that, to foster the use of deep learning approaches, assessment methods must be constructively aligned with the intended learning outcomes.

In one of the studies that has been published on this topic, Scouller (1996) investigated the effects of assignment essays versus end-of-course short answer examination (which was known to the students in advance) with 140 first-year Sociology students at the University of Sydney. It was found that the students perceived the assignment essays to be assessing higher levels of intellectual abilities and skills than the short answer examination, even though no deliberate attempt was made for either mode of assessment to be testing higher or lower levels of knowledge. The survey that was conducted at the end of the course indicated that students were more inclined to use a deep learning approach when preparing for assignment essays than for short answer examinations. Similarly, they were less inclined to use a surface learning approach for assignment essays than for short answer examinations. Students' expectations of the intellectual demand of assessments relating to a particular assessment format could therefore encourage or discourage the use of one learning approach over another.

In another study, Scouller (1998) compared the learning approaches of 206 second-year Education tertiary students in preparing for a multiple-choice and an essay examination. Students were found to be use more surface-oriented approaches in studying for the multiple-choice examination, and perceived the examinations to be assessing lower levels of thinking. In contrast, students were more inclined to use deep learning approaches in preparing for the essay examination, and perceived the essay examination to be focussed more on higher levels of thinking.

Rationale for the Present Study

Despite the importance of deep learning, researchers have yet to establish strategies for the vast majority of teachers to use on an ongoing basis to foster deep learning approaches in students. Based on the findings from the few studies that have been conducted thus far, the expectation of a certain assessment format alone can influence students' learning approaches. However, the research that has done thus far has focussed exclusively on tertiary level students. No research could be located which focussed on secondary school students. Furthermore, research has yet to establish the effects of the expectation of assessment formats on other learning variables, such as students' conceptual understanding and interest in the subject matter.

The goal of the current study was to establish how assessment expectations affected students' approaches to learning, conceptual understanding and interest in the subject matter. The study was conducted in the context of physics education. Two assessment formats commonly used in physics education were studied: the short structured question (SSQ) versus the multiple choice question (MCQ) format. The specific research questions were as follows:

- *Research Question 1.* Does the expected assessment format affect students' approaches to learning, and if so, does this effect vary across males and females?
- *Research Question 2.* Does the expected assessment format affect students' conceptual understanding in physics, and if so, does this effect vary across males and females?
- *Research Question 3.* Does the expected assessment format affect students' interest in physics, and does this effect vary across males and females?

Method

Participants

Participants were 470 Year 11 students in Singapore (276 males, 194 females). The average age of participants at the start of the study was 16.7 years (*SD* = 0.82). Of these, 99.3% were Chinese; the remaining 0.7% were Malays or Indians. All participants were enrolled for a three-month mechanics physics unit in the English language, which was taught based on the General Certificate of Education Advanced Level Physics syllabus 9646 (Singapore Examination and Assessment Board, 2014). All measures were administered in the English language.

Instruments

Approaches to Learning. The most recent version of the Learning Process Questionnaire developed originally by Biggs (1987), the *Two-factor Revised Learning Process Questionnaire* (R-LPQ-2F: Kember, Biggs, & Leung 2004), was used to assess students' approaches to learning prior to and following the intervention. The R-LPQ-2F is a widely used, 22-item instrument which focuses on students' learning approaches at the secondary school level (e.g. Bernardo, 2003; Cano, 2005). The R-LPQ-2F includes two main scales to measure deep and surface learning approaches, respectively. There are four subscales in all, two within the Deep Approach scale (deep motive, 7 items; deep strategy, 4 items), and two within the Surface Approach scale (surface motive, 4 items; surface strategy, 7 items). Students respond to each of the 22 item statements on a five-point scale, ranging from 'never or only rarely true of me' to 'always or almost always true of me'. In this study, as suggested by Kember et al. (2004), the score for each subscale was computed by taking the average item score. Thus, the score range for each subscale was from 1 ('never or only rarely true of me') to 5 ('always or almost always true of me').

The focus in this study was on whether the intervention altered students' relative preferences for deep versus surface learning motives and strategies. As a result, deep and surface motive and learning strategy scores were computed and converted respectively to standard scores. Two difference scores were then generated: one for the difference between deep and surface learning motives; the other for the difference between deep and surface learning strategies. These difference scores were then used as the dependent measures to represent relative preference for deep and surface learning approaches.

Physics Conceptual Understanding. The *Force Concept Inventory* (FCI: Hestenes, Wells & Swackhamer, 1992) was used to assess physics conceptual understanding. The FCI is widely used to assess concept mastery in the area of Newtonian mechanics (Hestenes et al., 1992). According to Hestenes and Halloun (1995), the face validity of the FCI has been confirmed by content area experts, and its content validity has been established through interviews with large student samples. The FCI includes 30 multiple choice questions, each with five response options. There is only one correct answer for each question. In this study, total FCI scores reflected the number of correct responses made by students, expressed as a mark out of 100, as per the recommended scoring guidelines (see Hestenes et al., 1992).

Physics Task Value. Students' task value in physics was measured using a five-item, researcher-developed instrument (the *Physics Task Value Scale, or PTVS*). This instrument was designed to measure students' situational interest in physics classes, based on Linnenbrink-Garcia et al.'s (2010) definition. Linnenbrink-Garcia et al. posed that situational (as opposed to individual) interest emerges in response to features in the environment, and can be divided further into two types – *triggered* interest, which refers specifically to the initiation of interest, and *maintained* interest, a more involved form in which individuals begin to forge a meaningful connection with the content of the material and realize its deeper significance. As noted by Linnenbrink-Garcia et al., there are very few measurement tools available to assess situational interest with respect to the broader classroom environment.

The instrument designed in this study used a 7-point bipolar item statement format, which contrasted five statements representing both triggered and maintained situational interest: "I find physics lessons very interesting" vs. "I think that physics is a very boring subject"; "I would skip physics lessons if I were given the option" vs. "I look forward to my physics lessons"; "I am not interested in knowing more than I have to in physics" vs. "I find myself wanting to learn more about the things we do in physics lessons"; "It is important to learn about physics, even if I don't need it to get into university/get a good job" vs. "I would only choose to do physics if I needed it for my future success"; and "I can see the value of studying physics just for its own sake" vs. "I can't see why anyone would study physics if they didn't have to". In the instructions to students, they were told: "If you agree totally with the statement on the left, shade 1, or if you agree totally with the statement on the right, shade 7. If you do not totally agree with either statement, find a number between 1 and 7 that best describes your response".

Prior to using the PTVS in subsequent analyses, an initial principal components' analysis (PCA) was performed using the pretest scores of the full student sample. Based on Kaiser's criterion and Cattell's scree test, the PCA indicated that the questionnaire included that the PTVS comprised only one component, which accounted for 57.63% of the total item variance. All communalities and item loadings on this component were high (h^2 range 0.48 to 0.65; loading range 0.69 to 0.81). The Cronbach's alpha for the five items in the questionnaire was r_{xx} = 0.81, which confirmed a high level of internal consistency for the five-item scale. In light of these results, the item scores were summed into a single total score for use in further analyses.

Design and Procedures

Approval to conduct the research was first obtained from the Human Research Ethics Committee of the authors' affiliated institution. Permission was also obtained from the Principal of the participating school. Participants completed all pretests within the two weeks prior to commencing a three-month Newtonian mechanics module within their

Year 11 Physics course. All pretest instruments were completed within three sessions, in hard copy format. Participants responded using optical mark sheets, which were then scanned for the purposes of data analysis. The posttests were administered within two weeks of the completion of the study. Participants were assigned unique codes at the pretest to allow matching of their pre- and posttest responses.

After completing the pretests, participants were assigned on a stratified random basis to one of two conditions: the multiple choice or the short structured question condition. To stratify students based on their prior physics conceptual understanding, students were first ranked on the basis of their pretest FCI scores. They were then assigned to pairs based on rank order within the list (e.g., the two students within the list with the lowest pretest FCI scores would be paired; the next two lowest scoring students would then form another pair, and so on). Within each pair, the students were assigned at random to one of the two experimental conditions. This procedure was used to ensure that there were no systematic differences between the groups in terms of baseline conceptual understanding.

All participants in the study attended the same lectures for the course unit, and they had access to the same teaching and learning resources. The only difference between the conditions was in what the students were told they would be completing as their end of unit assessment. In the first lecture, the participants were told that one group of them (the MCQ condition group) would be assigned to take an MCQ assessment and another group (the SSQ condition group) would take a SSQ assessment at the end of the unit. They were also told which assessment that each participant would be taking.

The participants were presented with the item below as an example of what would be in the MCQ assessment:

A mass accelerates uniformly when the resultant force acting on it

a) is zero.

b) is constant but not zero.

c) increases uniformly with respect to time.

d) is proportional to the displacement of the mass from a fixed point

Similarly, an item was also presented as an example of what would be in the SSQ assessment:

Explain the difference between an elastic and an inelastic collision.

In the SSQ condition, students were told they were to write in full sentences, if any explanation was required, and that some questions would involve calculations, for which they would be expected to show the full workings.

The participants were told that the marks for these assessments would not count toward their reported semester grades, but they were urged to do their best, as these provided preparation for the end of semester examination (which would include both MCQ and SSQ items). Two emails were sent to all participants while they were completing the unit (once half-way through the unit, and once more in the week just prior to the posttest), to remind them of the format of the assessment that they would undertake at the end of the unit. The tutors again reminded them periodically of their assigned assessments. At the end of the unit, the students completed either the MCQ or SSQ assessment to which they had been assigned. They also completed the same questionnaires that they completed at the pretest, as well as the FCI posttest.

Results

Data were first inspected for missing cases. Data from any participants who did not complete the full set of pretest and posttests, or had more than 10% missing item responses within any of the pre- or posttest measures, were removed from the analysis. This reduced the total sample size from n = 470 to n = 455. For the FCI, any students who had reached a near-ceiling score on the pretest (i.e., had demonstrated mastery, or a score of greater than 85 – see Hestenes et al., 1992) at pretest were removed, as these students would not be able to demonstrate significant pre-post change. This further reduced the total sample size for all FCI analyses from n = 455 to n = 402. No ceiling effects were observed on the other variables (i.e., the PTVS and the R-LPQ-2F). Given that mastery on the FCI was not anticipated to have an impact on the affective variables (i.e., R-LPQ-2F, PTVS), no cases were excluded for other analyses.

Multivariate and univariate analyses of covariance (MANCOVAs and ANCOVAs) were used to compare the posttest scores of male and female students in the two experimental conditions, based on a two (condition: multiple choice versus structured response) by two (gender: male versus female) factorial design. In each analysis, posttest scores were entered as dependent variables, with relevant pretest scores entered as covariates. Prior to performing any analysis, all pretest and posttest data were screened for violations of multivariate and univariate analysis of covariance assumptions (see Tabachnick & Fidell, 2013). All of these preliminary analyses produced satisfactory results.

Research Question 1: Effects on Students' Learning Approaches

The first research question was, does the expected assessment format affect students' approaches to learning, and if so, does this effect vary across males and females? To address this question, a MANCOVA was performed. In the MANCOVA, pretest deep to surface ratios were entered as covariates, with posttest ratios entered as dependent variables. The two independent variables were experimental condition and gender. All preliminary tests for conformity to MANCOVA assumptions produced satisfactory results. Descriptive statistics for this analysis are shown in Tables 1 and 2.

Table 1. Descriptive statistics for deep to surface motive ratio scores

Condition	Gender	*N*	Pretest M_{RAW} (*SD*)	Posttest M_{RAW} (*SD*)	Posttest $M_{ADJ.}$ (*SE*)
MCQ	Male	130	1.50(0.43)	1.53(0.39)	1.55(0.03)
	Female	93	1.50(0.35)	1.46(0.37)	1.46(0.03)
	Total	223	1.50(0.40)	1.50(0.39)	1.51(0.02)
SSQ	Male	136	1.61(0.43)	1.67(0.53)	1.61(0.03)
	Female	96	1.44(0.36)	1.40(0.28)	1.45(0.03)
	Total	232	1.54(0.41)	1.56(0.46)	1.53(0.02)
Total	Male	266	1.56(0.43)	1.60(0.47)	1.58(0.02)
	Female	189	1.47(0.35)	1.42(0.33)	1.46(0.02)
	Total	455	1.52(0.41)	1.53(0.43)	1.52(0.02)

Table 2. Descriptive statistics for deep to surface strategy ratio scores

Condition	Gender	*N*	Pretest M_{RAW} (*SD*)	Posttest M_{RAW} (*SD*)	Posttest $M_{ADJ.}$ (*SE*)
MCQ	Male	130	0.93(0.41)	0.87(0.33)	0.90(0.02)
	Female	93	1.05(0.45)	0.87(0.33)	0.84(0.23)
	Total	223	0.98(0.43)	0.87(0.33)	0.87(0.02)
SSQ	Male	136	0.99(0.45)	0.96(0.42)	0.96(0.02)
	Female	96	1.01(0.46)	0.91(0.32)	0.90(0.03)
	Total	232	1.00(0.45)	0.94(0.38)	0.93(0.02)
Total	Male	266	0.96(0.43)	0.91(0.38)	0.93(0.02)
	Female	189	1.03(0.46)	0.88(0.33)	0.87(0.02)
	Total	455	0.99(0.44)	0.90(0.36)	0.90(0.01)

The MANCOVA indicated no significant multivariate interaction effect between gender and condition, Wilks' $\lambda = 1.00$, $F(2,448) = 0.39$. There was, however, a significant main effect for gender, Wilks' $\lambda = 0.95$, $F(2,448) = 10.72$, $p < 0.001$, partial $\eta^2 = 0.04$, and a significant main effect for condition, Wilks' $\lambda = 0.99$, $F(2,448) = 3.18$, $p = 0.04$, partial $\eta^2 = 0.01$.

Univariate ANCOVAs, performed separately for the motive and strategy ratio scores, indicated that the main effects of gender were significant both for the Deep Motive vs. Surface Motive scores, and for the Deep Strategy vs. Surface Strategy scores, $F(1,449) = 18.95$, $p < 0.001$, partial $\eta^2 = 0.04$ and $F(1,449) = 5.12$, $p = 0.02$, partial $\eta^2 = 0.01$, respectively. In both cases, the ratio was higher for males. There was no significant condition by gender interaction effect either on the Deep Motive vs. Surface Motive scores, $F(1,449) = 1.67$, $p = 0.20$, or on the Deep Strategy vs. Surface Strategy scores, $F(1,449) = 0.06$, $p = 0.81$. Results were also non-significant for the main effect of condition on the Deep Motive vs. Surface Motive scores, $F(1,449) = 0.63$, $p = 0.43$. There was, however, a significant main effect of condition on Deep Strategy vs. Surface Strategy scores, $F(1,449) = 6.21$, $p = 0.01$, partial $\eta^2 = 0.01$. The latter effect indicated a higher deep to surface strategy ratio in the SSQ condition (see Table 2).

Research Question 2: Effects on Physics Conceptual Understanding

The second research question was, does the expected assessment format affect students' conceptual understanding in physics, and if so, does this effect vary across males and females? To address this question, an ANCOVA was performed, with pretest and posttest FCI scores entered as covariates and dependent variables, respectively. Condition and gender were the two independent variables in this analysis, producing a two by two design. Descriptive statistics for FCI scores across conditions and gender are shown in Table 3.

Table 3. Descriptive statistics for pre and posttest FCI scores

Condition	Gender	*N*	Pretest M_{RAW} (*SD*)	Posttest M_{RAW} (*SD*)	Posttest $M_{ADJ.}$ (*SE*)
MCQ	Male	113	60.71(13.35)	71.03(16.60)	69.52(1.07)
	Female	82	56.46(14.62)	63.25(17.09)	65.11(1.25)
	Total	195	58.92(14.02)	67.76(17.20)	67.32(0.82)
SSQ	Male	115	61.42(13.49)	69.74(14.19)	67.67(1.06)
	Female	92	55.29(14.20)	65.11(15.37)	67.90(1.19)
	Total	207	58.70(14.11)	67.68(14.87)	67.78(0.79)
Total	Male	228	61.07(13.40)	70.38(15.41)	68.60(0.76)
	Female	174	55.84(14.37)	64.23(16.18)	66.50(0.87)
	Total	402	58.81(14.05)	67.72(16.02)	67.55(0.57)

The ANCOVA on these scores indicated that the main effect for gender approached, but did not reach, significance at the 0.05 level, $F(1,397) = 3.25$, $p = 0.07$, partial $\eta^2 = 0.008$. There was no significant main effect for condition on FCI scores, $F(1,397) = 0.17$, $p = 0.68$. There was, however, a significant condition by gender interaction effect, $F(1,397) = 4.14$, $p = 0.04$, partial $\eta^2 = 0.01$. Based on the means shown in Table 3, this indicates that, while the mean adjusted FCI posttest score for males was higher than for females within the MCQ condition (*M*s = 69.52 versus 65.11, respectively), adjusted FCI posttest scores for males and females were almost identical in the SSQ condition (*M*s = 67.67 versus 67.90, respectively). Cell mean comparisons confirmed that males and females differed significantly in the MCQ condition, $F(1,220) = 4.87$, $p = 0.03$, partial $\eta^2 = 0.02$, but not in the SSQ condition, $F(1,229) = 0.14$, $p = 0.71$.

Research Question 3: Effects on Physics Task Value

The results for the third research question was, does the expected assessment format affect students' interest in physics, and does this effect vary across males and females? To address this question, a univariate ANCOVA was performed, with pretest and posttest PTVS scores entered as covariates and dependent variables, respectively. Condition and gender were the two independent variables in this analysis, producing a two by two design. Descriptive statistics for the PTVS scores across conditions and gender are shown in Table 4.

Table 4. Descriptive statistics for pre and posttest PTVS scores

Condition	Gender	*N*	Pretest M_{RAW} (*SD*)	Posttest M_{RAW} (*SD*)	Posttest $M_{ADJ.}$ (*SE*)
MCQ	Male	130	24.25(5.55)	23.30(5.87)	23.30(0.40)
	Female	93	25.84(4.74)	24.12(4.48)	24.12(.39)
	Total	223	23.64(5.34)	23.64(5.34)	23.73(0.27)
SSQ	Male	136	25.21(5.47)	25.33(4.85)	25.33(0.35)
	Female	96	24.08(4.27)	24.08(4.27)	24.08(0.36)
	Total	232	25.30(4.63)	24.82(4.65)	24.61(0.27)
Total	Male	228	61.07(13.40)	24.34(5.46)	24.52(0.25)
	Female	174	55.84(14.37)	24.10(4.36)	23.82(0.29)
	Total	455	24.24(5.03)	24.24(5.03)	24.52(0.25)

The ANCOVA on PTVS scores indicated that there was no significant gender by condition interaction in this case, $F(1,450) = 2.49$, $p = 0.12$. The effect for gender approached significance at the 0.05 level, $F(1,450) = 3.25$, $p = 0.07$, partial $\eta^2 = 0.01$, and there was a significant main effect for condition, $F(1,450) = 5.21$, $p = 0.02$, partial $\eta^2 = 0.01$. As indicated by the means in Table 4, the main effect that approached significance for gender indicated that males were marginally higher in their physics interest than females (*M*s = 24.52 versus 23.82, respectively). The main effect for condition indicated that overall, those in the SSQ condition had higher levels of task value than those in the MCQ condition (*M*s = 24.61 versus 23.73, respectively).

Discussion

The results of this study indicate that effects on conceptual understanding in physics, as well as affective variables, can be seen just by creating an expectation for an assessment that is of a particular format. All that it took was to inform students at the beginning of a unit, with reminders in between, that they would take an assessment at the end of the unit either in the MCQ or the SSQ format. Effects of the intervention were modest, as the intervention period was only 12 weeks (which was the duration of the unit), but over time, the effects would be expected to increase.

With regard to Research Question 1 **(**Does the expected assessment format affect students' approaches to learning, and if so, does this effect vary across males and females?), results were non-significant for the main effect of condition on the Deep Motive vs. Surface Motive scores, but there was a significant main effect of condition on Deep Strategy vs. Surface Strategy scores. The latter effect indicated a higher Deep to Surface Strategy ratio in the SSQ condition. There was no significant interaction effect between condition and gender for either ratio. The results suggest that students were inclined to use more deep strategy and/or less surface strategy when they were expecting the SSQ format assessment, which aligned with the findings reported by Scouller (1998), from her study of tertiary-level students. This could be associated with the students' mindset that the SSQ assessment was linked to a requirement for deep thinking in the assessment, and perceived that adopting a deep learning approach was necessary. Teachers can therefore capitalize on such a mindset to foster in students a deep learning approach and discourage a less desirable surface-oriented approach to learning, simply by altering students' assessment expectations.

With regard to Research Question 2 (Does the expected assessment format affect students' conceptual understanding in physics, and if so, does this effect vary across males and females?), no significant main effect for condition was found, but there was a significant condition by gender interaction effect. Males scored significantly higher than females within the MCQ condition, while males and females were almost identical in the SSQ condition. This result may shed further light on a longstanding issue that has emerged within the gender in education field. Specifically, the result obtained in the MCQ condition is consistent with numerous previous findings which have indicated that males tend to outperform females on MCQ assessments (Bolger & Kellaghan, 1990; Lumsden & Scott, 1987; Mazzeo, Schmitt, & Bleistein, 1993). This has been ascribed primarily to an increased tendency on the part of males to guess within the testing situation (Bridgeman, 1992; Baldiga, 2013; Kelly & Dennick, 2009). In the current study, however, it was found that this difference was entirely absent in the SSQ condition, despite the fact that the actual test taken (i.e., the FCI) was entirely multiple-choice.

Given that in previous studies of gender effects on multiple-choice tests' performance, it is likely that students were told about the kind of test that they would confront, the present study suggests that the superior performance exhibited by males may not reflect behaviour within the test itself. Alternatively, this may reflect differences in the ways that males and females prepare for multiple-choice assessments. As no interaction effect was observed on the R-LPQ-2F, however, it appears that these differences fall beyond the realm of deep versus surface learning approaches. No other data were available in the present study to determine how the preparatory behaviours differed across males and females. Thus, this remains a topic for future research at this point.

With regard to Research Question 3 (Does the expected assessment format affect students' task value in physics, and does this effect vary across males and females?), a significant main effect for condition was obtained, with the participants in the SSQ condition showing higher levels of interest than those in the MCQ condition. In this case, there was no significant condition by gender interaction effect. This suggests that the use of SSQ assessments may promote a higher level of task value in the subject matter in comparison to MCQ assessments. Teachers could therefore consider placing greater emphasis on SSQ assessments, when the objective is to foster favourable affective responses to physics learning tasks.

In summary, results of the current study indicated that creating an expectation for different assessment formats over a short duration of 12 weeks can have a significant, albeit modest, impact on key learning outcome variables in physics. Results indicated that students who expected to confront the SSQ assessment used a higher proportion of deep to surface learning strategies, and had higher levels of task value in the subject matter, than did those who expected to confront the MCQ assessment task. Furthermore, while the well-established pattern of male superiority emerged within the MCQ condition, in the SSQ condition, there was no significant difference in the performance of male and female students. The latter was true despite the fact that all participants completed the same posttest (i.e., FCI).

It should be highlighted also that the effects reported here were produced through a very minimalist intervention. In light of this, stronger effects are likely to arise over time. Furthermore, it should be noted that students knew that the assessments that they would confront here would not have any significant bearing on their semester grades. Thus, stronger effects would also in anticipated in a real-world context, where every assessment can impact future prospects. Thus, the findings of this study have established how powerful assessment expectations can be in driving students' learning behaviours and outcomes. Further research could tease out in more detail the mechanisms responsible for the differences observed within the study.

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Conclusions

The overarching goal of this research programme was to investigate the role of student learning processes in enhancing physics conceptual understanding. Over 2000 Year 11 students from a large secondary school in Singapore were involved in the research. Five journal papers have been prepared and submitted for publication based on the results. This chapter presents implications and recommendations that arise from the findings of all five studies, for teachers and education policy-makers. These recommendations are based upon the results reported in this thesis, as well as the candidate's own professional experience and other papers drawn from the scholarly research literature.

Summary of Results

Papers 1 through 3 in this thesis reported upon the validity of three instruments used in the research programme: the Motivated Strategies for Learning Questionnaire (MSLQ); the Two-Factor Revised Learning Process Questionnaire (R-LPQ-2F); and a researcher-developed Physics Task Value Scale (PTVS). In general, the MSLQ, the R-LPQ-2F and the PTVS all demonstrated sound psychometric properties within the Singapore secondary school context. These results suggested that the instruments were suitable for use within the research, taking into account the particular characteristics of the sample.

Paper 4 reported results from a study of the relationships between self-regulated learning, learning approaches and physics conceptual understanding. Results reported in this paper indicated that while significant relationships were observed between FCI scores and several MSLQ and R-LPQ-2F variables, most of these relationships were not apparent when *gains* in FCI scores were used as the criterion variable, instead of concurrent FCI scores. These results suggest that, contrary to the assumed direction of the relationships posed in previous studies, a more complex pattern of directionality in these relationships could be present.

Paper 5 reported on the effects of assessment expectations on students' approaches to learning, conceptual understanding, and task value in physics. Results presented in Paper 5 suggest that students' learning approaches can be altered significantly using different assessment approaches. Specifically, results of this study indicated that students who expected to confront a short structured question format assessment at the end of a physics unit tended to use more deep strategies and/or fewer surface strategies, and had developed a higher level of task value in the subject matter, than those who expected a multiple choice question format assessment.

Implications for Practice

The results in the current research programme indicated that students with a lower level of conceptual understanding in physics may benefit if teachers are able to foster a higher level of intrinsic motivation in physics tasks. Students at a higher level of conceptual understanding will benefit also from strategies that foster the use of deep learning strategies. Research suggests that teachers can boost students' intrinsic motivation by adopting an autonomy supportive style in the classroom (Froiland, 2011; Froiland, Smith & Peterson, 2012). An autonomy supportive style relates to the interpersonal behaviours teachers who provide identify, nurture, and build students' inner motivational resources (Deci & Ryan, 1985; Reeve, Deci, & Ryan, 2004). It is often characterized by the willingness to listen and appreciate the students' perspective, providing opportunities for students to make choices and to solve problems, highlighting the value of the learning tasks, and focussing on what they have learned rather than their grades (Froiland, 2011; Reeve, & Jang, 2006).

To foster deep learning in students, Biggs (1999) highlighted the importance of aligning learning objectives, learning activities and assessment, which he termed as *constructive alignment*. Based on this notion, learning objectives should include those that relate to deeper learning; learning activities should be sufficiently challenging to achieve the learning objectives; and assessments must be designed to assess students' ability to solve authentic and complex problems. Once these three components are aligned, students will naturally be prompted to adopt deep learning strategies.

Results of this research programme also indicated that assessment expectations can have a profound impact on students' learning process and outcome variables. Different assessment expectations can influence how students prepare for the assessments. Students who expected a structured question format were found to use more deep strategies than surface-oriented strategies, when compared with students who expected a multiple choice format. They also reported higher levels of task value in physics than their peers, who expected a multiple choice format test. It therefore seems that there are clear benefits to incorporating some structured question formats within examinations, rather than relying wholly on multiple choice type items.

Concluding Remarks

Many developed and developing nations have recognized the importance of STEM (Science, Technology, Engineering and Mathematics), as the engine for economic growth. In particular, STEM has contributed significantly to the economic success of

Singapore, and it will continue to play a critical role for the continued prosperity of Singapore, according to Prime Minister Mr Lee Hsien Loong. It has been reported that there is a world-wide shortage of STEM graduates, which is related to students not choosing to study physics at the secondary school levels. Many secondary school students are not interested in studying physics because they perceive that learning physics is difficult. Research has suggested that secondary school students indeed have difficulties understanding physics concepts. It is therefore crucial to investigate how students can enhance their physics conceptual understanding.

In this research, we have investigated how several learning process variables can help to enhance physics conceptual understanding. In particular, students' self-regulated learning, in terms of their learning motivations, strategies, and their approaches to learning have been examined. Results indicated that there is no 'one size fits all' solution. For students with an initially lower level of understanding, focusing on developing intrinsic motivation can have a positive effect on improving their physics conceptual understanding, whilst for students are at a higher level, encouraging them to adopt deep learning strategies can be beneficial in enhancing understanding.

In another study, it was also found that assessment expectations can influence how students prepare for their tests, hence modifying their learning effectiveness. Results suggested that informing students to prepare for a short structured question assessment, compared with a multiple choice one, can have positive effects in enhancing their task value, and fostering greater use of deep strategies or reduced use of surface strategies. Although this particular study did not show that this will lead to greater physics conceptual understanding, in the long term, this outcome would be expected, given that deep strategies have been shown robustly to improve conceptual understanding in previous studies. It is critical that there be continued efforts to identify ways to enhance students' learning processes and outcomes in the areas of physics education, for Singapore to remain competitive and to thrive as a knowledge-based economy.