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Student Motivation and Learning in Mathematics and Science: A Cluster Analysis

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Abstract The present study focused on an in-depth understanding of student motivation and self-regulated learning in mathematics and science through cluster analysis. It examined the different learning profiles of motivational beliefs and self-regulatory strategies in relation to perceived teacher autonomy support, basic psychological needs (i.e. autonomy, competence, and relatedness), motivational regulations, and academic achievement. Grounded in self-determination theory, this study examined the learning profiles of 782 students from eight secondary schools in Singapore. The cluster analyzes revealed four distinct learning profiles, and they were compared in association with perceived teacher autonomy support, needs satisfaction, motivational regulations, and grades. Cluster profiling enables teachers to have better understanding of their students' self-regulated learning so that they can apply effective teaching strategies to foster their motivation. The findings offer a perspective to secondary students' psychological needs along with some insights into their perceived task value and self-efficacy in the contexts of mathematics and science.

Keywords Cluster analysis · Motivation · Needs satisfaction · Self-regulated learning · Task value

Introduction

Motivation and self-regulation have been widely investigated in educational settings in recent studies (e.g. Kim, Park, & Cozart, 2013; Yin, Lee, & Zhang, 2009). Past research showed that metacognition and cognitive strategies were associated with academic

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achievement (Shivpuri, Schmitt, Oswald, & Kim, 2006; Zimmerman & Schunk, 2008). However, student motivation declined during their junior high and middle school years in the USA as well as in Australia and New Zealand (e.g. Woods-McConney, Oliver, McConney, Maor, & Schibeci, 2013). With recent research on adolescents' declining motivation in learning mathematics and science over time (Plenty & Heubeck, 2013; Vedder-Weiss & Fortus, 2012), it has been challenging for teachers to maintain greater student interest and achievement in these two subjects.

In the context of self-regulated learning, research (Bong, 2005; Hadwin, Winne, Stockley, Nesbit, & Woszczyna, 2001) revealed that student motivational beliefs and regulatory actions differed across academic domains (e.g. mathematics, science). Many theorists contended that self-regulated learning can be taught across contexts and situations (Cleary & Zimmerman, 2004). With the shift of educational paradigm from efficiency- to ability-driven, students' education is tailored according to their learning needs, and schools are given autonomy to develop curriculum and pedagogies (Hung, Ng, Koh, & Lim, 2009). Such autonomy is viewed as a harmonious yet political process to mediate the expectations of various key stakeholders in the Singapore's educational system (Ng, 2010). Despite the combined efforts of researchers, teachers, and stakeholders to promote motivation in students, there is still a research gap in the evaluation of self-regulated learning for mathematics and science in the Singaporean context, in particularly the secondary schools.

This paper sought to understand the learner profiles in terms of varying capabilities for motivation and learning strategies use. Based on the framework by Pintrich & De Groot (1990), this study looked into individual differences in self-regulated learning from the self-determination theory (SDT) perspective (Deci & Ryan, 1985). Specifically, the cluster analytic approach examined students' self-regulated learning in relation to characteristics of their self-determination and academic grades.

Purpose of the Study

The main goal of the present study was to uncover an in-depth and meaningful understanding of different student learning outcomes via a person-centered approach. First, it was hypothesized that the clusters would show diverse learning profiles, with good profile exhibiting high levels of task value, self-efficacy, and learning strategies use, but low level of anxiety (Hypothesis 1). Second, good profile with highly perceived teacher autonomy support would exhibit greatest psychological needs satisfaction, self-determined motivation, and achievement (Hypothesis 2).

Literature Review

Motivation and Self-Regulated Learning in Mathematics and Science

This paper focused on students' motivation and self-regulated learning from the framework outlined by Pintrich & De Groot (1990) as well as self-determination theory perspective. Aligned with social cognitive perspective of motivation, motivational beliefs, namely self-efficacy, task value, and anxiety, play important roles in students' cognitive processing. Self-efficacy is defined as students' beliefs about competencies to

perform a task (Zusho, Pintrich, & Coppola, 2003). Task value refers to the perceived value in a given task (Pintrich & Garcia, 1991). Anxiety is defined as general worry and negative emotions about accomplishing task in class. Anxiety can cause negative consequences on cognition and performance (Zeidner, 1995). Recent evidence has shown that achievement was negatively associated with negative emotions in junior high schools (e.g. Ahmed, van der Werf, Kuyper, & Minnaert, 2013).

Self-efficacy plays an important role in improving mathematical problem-solving skills of middle school students (e.g. Pajares & Graham, 1999) and science achievement in high schools (e.g. Zusho et al., 2003). For instance, self-efficacy had direct influence on mathematics achievement of mathematically gifted high school students (Malpass, O'Neil, & Hocevar, 1999), and was a significant predictor of chemistry achievement in college students (Zusho et al., 2003). Students with highly perceived self-efficacy in mathematics were more likely to use higher-order cognitive and metacognitive strategies (Berger & Karabenick, 2011). Likewise, science has an emphasis on the importance of inquiry skills where students discover, produce, and evaluate scientific knowledge (Kim, Tan, & Talaue, 2013; Yoon, 2009). Coupled with scientific thinking and reasoning skills, students are encouraged to experience the knowledge construction process (Chinn & Malhotra, 2002). Inquiry learning should be structured such that student learning is facilitated to plan and conduct own investigation (Berg, Bergendahl, Lundberg, & Tibell, 2003). In this approach, students are likely strategic and engaged in learning contexts such as mathematics and science.

Self-regulated learning is an active process whereby individuals learn through monitoring, regulating, and controlling their cognition, motivation, and behavior, which can be guided and constrained by their goals and the contextual features in the environment (Pintrich, 2000). It is an important facet of student learning and academic performance as students use relevant strategies to regulate their effort (Corno & Rohrkemper, 1985). Within a typical classroom, there will be differences in academic grades, highlighting varying capabilities for self-regulated learning (Liu et al., 2014). For instance, high-ability students exhibited high levels of motivation and self-efficacy in both mathematics and science (Andersen & Cross, 2014). Self-efficacy towards mathematics and science revealed different trajectories over adolescence (Barth et al., 2011), suggesting that these two subjects should be evaluated separately.

The abovementioned motivational beliefs and self-regulated learning form Pintrich's model, in which there is a direct link between students' motivation and their ability to self-regulate their learning activities. This framework assumes that "motivation is dynamic and contextually bound and that learning strategies can be learned and brought under the control of the student" (Duncan & McKeachie, 2005, p. 117). Hence, the motivation and learning strategies are not static traits of the learner, as the learner's motivation and learning strategies may vary from course to course. Based on this conceptual framework, the Motivated Strategies for Learning Questionnaire (MSLQ) was designed to assess students' motivation and self-regulated learning in a domain or specific context (Pintrich, Smith, García, & McKeachie, 1993). Previous research used cluster analytical approach to uncover profiles of MSLQ variables (Berger, 2012; Liu et al., 2014; Suárez Riveiro, Cabanach, & Arias, 2001). In this study, MSLQ Junior High version (Pintrich & De Groot, 1990) comprising of motivational beliefs (task value, self-efficacy, and test anxiety) and self-regulated learning (learning strategies) scales was tested on students from Singapore secondary schools.

Self-Determination in Educational Settings

With classroom settings becoming a focus of cognitive-motivational research, there is a need to examine the processes of self-regulation and motivation in the context of learning. The context of learning includes social and cultural elements as well as educational or instructional factors (Pintrich, 2004). Research findings showed that social–contextual relations have significant impact on students' motivation, self-regulation, and achievement in middle and high schools (Tang & Neber, 2008; Yoon, 2009). Autonomy support refers to identifying and fostering students' intrinsic motivation by giving them choices or opportunities; fostering understanding and interest with respect to learning; providing rationales and informational feedback; as well as encouraging self-regulated learning (Reeve, 2002). From the self-determination theory perspective, teacher autonomy support promotes a sense of volitional learning whereby students are allowed to act upon their personal interests (Reeve, 2009). As such, perception of teacher autonomy support is measured by the Learning Climate Questionnaire (Williams & Deci, 1996).

Within SDT, a social learning context that supports the three basic psychological needs will provide the fulfillment of student needs for autonomy, competence, and relatedness. Autonomy refers to being the source of one's behavior (Deci & Ryan, 1985), competence is experiencing optimal self-proficiency, while relatedness refers to a sense of belongingness with individuals and community (Deci & Ryan, 1985). Satisfaction of these three needs is measured by the Basic Psychological Needs Scale (BPNS; Deci & Ryan, 2000). Teachers have to create a need-supportive environment that fosters autonomous motivation by facilitating the satisfaction of students' needs for autonomy, competence, and relatedness (Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009).

Autonomous motivation is viewed as the motivational basis of intentional learning and is explained by degree of a learner's experience as self-determined (Gagné & Deci, 2005). Intrinsic motivation entails doing something for inherent reasons such as pleasure and satisfaction, whereas extrinsic motivation refers to doing something for reasons that are external to the activity itself. The four types of extrinsic motivation central to SDT are external, introjected, identified, and integrated regulation. External regulation refers to "behaviors for which the locus of initiation is external to the person" (Deci, Vallerand, Pelletier, & Ryan, 1991), introjected regulation involves one to internalize rules and behave due to internal pressure, identified regulation involves identification of the process in which the person feels a sense of choice, and integrated regulation is congruent with many qualities of intrinsic motivation (Ryan & Deci, 2000). The former two motivational regulations are represented as controlling motivational styles, whereas the latter two are depicted as autonomous motivational styles, which are assessed by Academic Self-Regulation Questionnaire (SRQ-A; Ryan & Connell, 1989).

Autonomy-supportive teaching demonstrated positive educational outcomes such as enhanced engagement (Jang, Reeve, & Deci, 2010), autonomous motivation (Roth, Assor, Kanat-Maymon, & Kaplan, 2007), and higher academic achievement (Taboada, Kidd, & Tonks, 2010). SDT research advocated the benefits of learner needs satisfaction and teacher autonomy support (Furtak & Kunter, 2012; Jang, Kim, & Reeve, 2012; Reeve, Jang, Carrell, Jeon, & Barch, 2004). Social interaction also plays an important role

in children's cognitive and social development (e.g. Davis, 2003; Ryan, Connell, & Deci, 1985). A recent intervention study (Tessier, Sarrazin, & Ntoumanis, 2010) in a physical education setting revealed that teacher interpersonal involvement (i.e. interactions with students) was salient in autonomy-supportive behaviors, promoting students' psychological need satisfaction in relatedness but not in autonomy and competence. As such, there is a need to examine students' perceived teacher autonomy support and its influence on their psychological needs satisfaction and self-regulation towards academic subjects.

Previous SDT research supported the benefits of autonomy-supportive structure such as intrinsic enjoyment (Mouratidis, Vansteenkiste, Lens, & Sideridis, 2008), self-regulated learning (Sierens, Vansteenkiste, Goossens, Soenens, & Dochy, 2009), and academic achievement (Jiang, Yau, Bonner, & Chiang, 2011). As SDT specifies the contextual environments that foster intrinsic motivation, this theory complements with Pintrich's framework of self-regulated learning. According to von Eye & Bogat (2006), distinct subgroups of perceived autonomy support can best be exhibited by cluster analysis. Liu et al. (2014) used cluster analysis to examine college students' motivation and learning strategies profiles in chemistry, physics, and economics, but they did not test for any subject difference. Based on existing knowledge, this study differed from existing research as it used person-oriented analyses to demonstrate the individual nature of need satisfaction (autonomy, competence, and relatedness) and type of regulation along SDT continuum towards academic subjects (mathematics and science). It extended and distinguished different types of regulation among all clusters in terms of amotivation, external motivation, and more self-determined motivation (e.g. identified regulation).

Method

Participants and Procedure

Data were collected from 782 students ($M = 14.58$, $SD = 0.57$) studying in eight Singapore secondary schools. The sample comprised of 392 male and 382 female students (8 did not state gender) from Secondary 2 (i.e. grade 8) and Secondary 3 (i.e. Grade 9). These two grade levels were chosen as students would have enough experience as learners in secondary school settings and they were not involved in any national examination. The sampling included students from two main academic streams: express stream students ($n = 544$) who complete their secondary schooling in 4 years, while normal stream students ($n = 238$) with weaker ability complete their education in 5 years.

Prior to the sample collection, ethic clearance from the university review board and permission from the Ministry of Education were attained. For a representative sampling of local secondary students, schools from four cluster zones (north, east, south, and west) were invited to participate in this study. This was an example of convenience sampling that depended on accessibility to schools, classrooms, and students. Participants were briefed on the purpose of the study and assured of the confidentiality of their responses. They were informed that their participation was voluntary. The questionnaires specific to mathematics ($n = 105$) and science ($n = 677$) were administered in English, and the participants took about 35 min to complete them.

Measures

For self-report measures, students rated all the items on a 7-point Likert scale, from 1 (*not at all true of me*) to 7 (*very true of me*). The scores for the individual scales were computed by taking the mean of items that make up the scale. Psychometric properties of the measures are described in the electronic supplementary materials (ESM).

Motivated Strategies for Learning Questionnaire . Twenty-five items of MSLQ Junior High version (Pintrich & De Groot, 1990) designed to measure secondary student motivational beliefs and learning strategies were modified in the specific academic context (mathematics or science). Five scales concerning mathematics or science included self-efficacy (e.g. "Compared with other students in this class, I think I know a great deal about Mathematics"; "Compared with other students in this class, I think I know a great deal about Science"; five items); task value (e.g. "I prefer Mathematics work that is challenging so I can learn new things"; "I prefer Science work that is challenging…"; five items); test anxiety (e.g. "I am so nervous during a test that I cannot remember facts I have learned"; four items); learning strategies (e.g. "When I study for a Mathematics test, I practise saying the important facts over and over to myself"; "When I study for a Science test, I practise saying the important facts over…"; eight items); and lack of self-regulation (e.g. "When Mathematics work is hard, I either give up or study only the easy parts"; "When Science work is hard, I either give up …"; three items).

Learning Climate Questionnaire (LCQ). The 15-item instrument was used to measure perceived teacher autonomy support (Williams & Deci, 1996). An example of the items was "I feel that my teacher provides me choices and options."

Basic Psychological Needs Scale. Twelve items of this instrument were used to measure student autonomy, competence, and relatedness (Deci & Ryan, 2000). An example of the items for autonomy was "I am free to express my ideas and opinions …" (four items), competence was "In school, I feel pretty competent" (three items), and relatedness was "I feel close to my school mates" (five items).

Academic Self-Regulation Questionnaire. The 12-item instrument was used to measure the motivational orientations in the context of academic subjects (Ryan & Connell, 1989). Statements representing an autonomous motivational style (identified regulation and intrinsic motivation) and a controlling motivational style (external regulation and introjection) were modified in the specific academic context (mathematics or science). The stem for the SRQ-A was "My reasons for doing my work in Mathematics …" or "My reasons for doing my work in Science …". A sample item that measured each type of regulation in specified subject (i.e. mathematics and science) was included. For autonomous motivation, an item for identified regulation was "because I want to improve in Mathematics" or "because I want to improve in Science", and for intrinsic motivation was "because Mathematics is fun" or "because Science is fun." For controlling motivational style, an item for external regulation was "because I'll get into trouble if I don't," and introjection was "because I'll feel bad about myself if I don't".

Grades

At the end of the survey administration, students' grades for the particular academic subject (i.e. mathematics or science) were collected. To ensure anonymity, students indicated their school term test grades (out of 100 marks). Their scores on this test ranged from 3 to 98 ($M = 58.36$, SD = 16.36).

Data Analysis

To explore the construct validity of the measures used in this study, confirmatory factor analyzes (CFA) were conducted using AMOS 18.0. Subsequent analyzes were carried out using SPSS 18.0. As a preliminary check for group differences, independent *t* tests were performed to determine if any variable differed statistically as a function of demographic characteristics (gender, academic stream, grade level, and academic subject). Due to page limit, these results were reported in ESM. To handle any potential missing data on one variable, pairwise deletion method in SPSS was used in the analysis (Schlomer, Bauman, & Card, 2010).

In the main analysis, cluster analysis was conducted to identify homogeneous groupings of participants with distinct profiles of motivational beliefs, strategy use, and test anxiety. The five clustering variables were based on MSLQ variables, namely task value, self-efficacy, learning strategies, lack of self-regulation, and test anxiety. Hierarchical cluster analysis using Ward's method with Euclidean distance as a measure of similarity (Hayenga & Corpus, 2010) was conducted. Ward's method was chosen because it searches the proximity matrix and divides the learners into homogeneous subgroups (Borgen & Barnett, 1987). As cluster analysis solution can be unstable, a *k*-means clustering method was used to confirm the clusters (Wang & Biddle, 2001). The *k*-means cluster profiles were in agreement with those obtained from hierarchical cluster analysis, thus supporting the four-cluster solution.

A multivariate analysis of variance (MANOVA) was conducted to test whether SDT variables significantly differed across the four clusters. Using a Bonferroni adjusted a priori *p* value of 0.05, the population means for the four clusters were judged to be unequal on the SDT variables (Grice & Iwasaki, 2007). All multivariate *F* values were reported based on Pillai's Trace value. The Pillai's Trace is a more important criterion to determine the multivariate effect (Tabachnick & Fidell, 2007) as it is more robust to violations of multivariate normality assumption (Tang & Neber, 2008). Finally, a separate ANOVA was conducted to examine differences in academic achievement (i.e. grade) across the four clusters.

Results

Descriptive Statistics and Correlations

Table 1 presents the scale means, standard deviations, and correlations between the measured variables with academic achievement (i.e. grade). All the variables were significantly correlated, with the exception of learning strategies and test anxiety. These correlational analyzes revealed significant relationships between the grade and MSLQ

Table 1 Means, standard deviation, and correlations of the key variables ($N = 782$)

Variable	*M*	SD	1	2	3	4	5	6	7	8	9
Autonomy support	4.57	1.18									
Autonomy	4.15	0.63	0.56***								
Competence	4.35	0.83	0.51***	0.54***							
Relatedness	4.85	0.97	0.40***	0.41***	0.37***						
Task value	4.89	1.02	0.57***	0.43***	0.53***	0.34***					
Self-efficacy	4.07	1.03	0.41***	0.39***	0.51***	0.25***	0.63***				
Test anxiety	4.13	1.24	−0.09**	−0.24***	−0.32***	−0.06*	−0.12***	−0.26***			
Learning strategies	4.67	1.06	0.42***	0.24***	0.36***	0.32***	0.58***	0.49***	0.01		
Lack of self-regulation	3.48	1.29	−0.25***	−0.34***	−0.41***	−0.19***	−0.37***	−0.35***	0.49***	−0.29***	
Grade	58.36	16.36	0.29***	0.30***	0.37***	0.18***	0.35***	0.40***	−0.25***	0.24***	−0.28***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

variables. More specifically, task value was strongly correlated with self-efficacy ($r = .63$, $p < .001$) and learning strategies ($r = .58$, $p < .001$). No significant relationship was revealed between learning strategies and test anxiety. On the contrary, there were significant associations of the SDT variables (i.e. three psychological needs) with all MSLQ variables. Significant negative correlations were found between the three psychological needs and test anxiety. Generally, all SDT and MSLQ variables correlated significantly with grade.

Profiling of the MSLQ Variables

Table 2 shows the descriptive statistics of four clusters. Standardized z scores ($M = 0$, $SD = 1$) for each cluster's profile on the MSLQ variables are presented in Fig. 1. z scores close to ±0.5 were set as criteria to describe clusters that scored "high" or "low," whereas scores close to ±0.3 described clusters that scored "moderate high" or "moderate low."

The first cluster was labeled "low motivated strategies for learning" or "low MSL" profile because 213 students (27.2 %) scored low in motivational beliefs, learning strategies, and anxiety, and moderate low in lack of self-regulation. In contrast, the second cluster, labeled "high MSL" profile, contained 235 students (30.1 %) who reported close to high positive scores of motivational beliefs, anxiety, learning strategies, and lack of self-regulation. The third cluster, labeled "good MSL" profile, comprised of 199 students (25.4 %) with very high in motivational beliefs, cognition, and self-regulation, but low level of anxiety. Finally, cluster 4, labeled "poor MSL" profile, had 135 students (17.3 %) with the lowest scores on motivational beliefs, cognition, and self-regulation, but high in anxiety. Table 3 summarizes the comparison of these four profiles.

Cluster Differences in SDT Variables

Four clusters differed significantly in these variables, Pillai's Trace = 0.59, $F(24, 2319) = 23.54$, $p < .001$, $\eta_p^2 = .20$. Effect size is large when η_p^2 value is more than .14 (Richardson, 2011). Table 4 presents the comparison of the four-cluster profiles in association with perceived teacher autonomy support, needs satisfaction, and motivational regulations.

Table 2 Descriptive statistics of the four clusters

Variable	Cluster 1 ($n = 213$) "Low MSL"		Cluster 2 ($n = 235$) "High MSL"		Cluster 3 ($n = 199$) "Good MSL"		Cluster 4 ($n = 135$) "Poor MSL"	
	M (z)	SD	M (z)	SD	M (z)	SD	M (z)	SD
Task value	4.38 (−0.50)	0.68	5.28 (0.39)	0.69	5.74 (0.83)	0.65	3.74 (−1.13)	0.87
Self-efficacy	3.70 (−0.36)	0.73	4.43 (0.35)	0.73	4.87 (0.77)	0.83	2.87 (−1.16)	0.73
Anxiety	3.87 (−0.52)	0.81	5.04 (0.73)	0.82	3.17 (−0.78)	1.02	4.98 (0.68)	1.01
Learning strategies	3.97 (−0.65)	0.78	5.21 (0.51)	0.68	5.46 (0.74)	0.71	3.65 (−0.94)	0.90
Lack of self-regulation	3.23 (−0.20)	0.82	3.95 (0.36)	1.00	2.20 (−1.00)	0.76	4.94 (1.12)	0.95

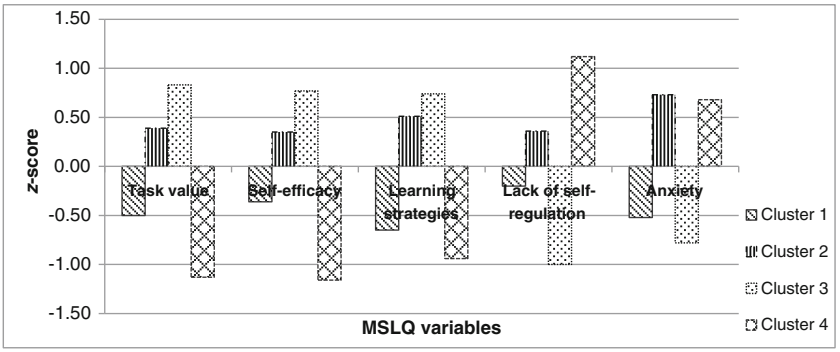

Fig. 1 Cluster profiling on MSLQ scores

Low MSL exhibited low levels of perceived teacher autonomy support, needs satisfaction, and motivational regulations. In contrast, high MSL showed high levels of perceived autonomy support, needs satisfaction, and motivational regulations. Among the four clusters, good MSL scored the highest for perceived autonomy support, needs satisfaction, and self-determined motivations (i.e. identified and intrinsic) but lowest for extrinsic motivation. Poor MSL exhibited very low levels of perceived autonomy support, needs satisfaction, and intrinsic motivation, but high in extrinsic motivation. Students in this cluster also showed the highest levels of amotivation and extrinsic motivation.

Based on effect sizes, statistically significant differences existed for all SDT variables (see Table 4) across all clusters. Among needs satisfaction, perceived competence had the greatest effect on all clusters. Although the four clusters differed in all types of regulation, the differences in identified regulation and intrinsic motivation were more pronounced. Subsequently, pairwise comparisons with Tukey's honestly significant difference (HSD) were conducted to uncover an in-depth description of the four clusters. Comparing the SDT variables, low and high MSL profiles displayed homogeneity for autonomy, competence, amotivation, and grade. Homogeneity in relatedness, introjection, and identification was also observed in both low and poor MSL clusters. All four clusters differed significantly in intrinsic motivation.

Cluster Differences in Academic Achievement

Results revealed that all four clusters differed significantly: $F(3, 778) = 40.14$, $p < .001$, $\eta_p^2 = .18$. For academic achievement, low and high MSL clusters performed moderately

Table 3 Summary of the four profiles

Cluster	1	2	3	4
Profile	Low motivational beliefs Low strategy use Low anxiety	High motivational beliefs High strategy use High anxiety	High motivational beliefs High strategy use Low anxiety	Low motivational beliefs Low strategy use High anxiety
Label	Low MSL	High MSL	Good MSL	Poor MSL

Table 4 Comparison of the four-cluster profiles on SDT variables and academic achievement

Variable	Low MSL ($n=213$)		High MSL ($n=235$)		Good MSL ($n=199$)		Poor MSL ($n=135$)		F	η_p^2
	M (z)	SD	M (z)	SD	M (z)	SD	M (z)	SD		
Perceived teacher autonomy support	4.11 (−0.39)^a	1.04	4.86 (0.24)^b	0.94	5.31 (0.62)^d	0.95	3.72 (−0.71)^c	1.24	84.91*	.25
Autonomy	4.07 (−0.11)^a	0.53	4.15 (0.01)^a	0.56	4.53 (0.59)^b	0.59	3.73 (−0.65)^c	0.66	53.94*	.17
Competence	4.18 (−0.20)^a	0.58	4.34 (−0.00)^a	0.72	4.97 (0.75)^b	0.79	3.69 (−0.78)^c	0.81	91.07*	.26
Relatedness	4.57 (−0.28)^c	0.88	4.90 (0.06)^a	0.85	5.35 (0.52)^b	0.91	4.48 (−0.38)^c	1.07	34.81*	.12
Amotivation	3.38 (0.10)^a	1.22	3.31 (0.06)^a	1.37	2.33 (−0.64)^c	1.22	4.18 (0.67)^b	1.26	59.57*	.19
Extrinsic motivation	4.41 (−0.14)^c	1.18	4.93 (0.24)^a	1.28	4.09 (−0.38)^c	1.53	5.08 (0.35)^a	1.11	22.79*	.08
Introjected motivation	3.74 (−0.32)^c	1.14	4.69 (0.43)^b	1.16	4.25 (0.08)^a	1.33	3.68 (−0.37)^c	1.19	31.50*	.11
Identified motivation	4.89 (−0.55)^c	1.01	5.90 (0.37)^a	0.82	6.17 (0.61)^b	0.78	4.74 (−0.68)^c	1.13	110.38*	.30
Intrinsic motivation	3.92 (−0.32)^a	1.17	4.79 (0.28)^b	1.24	5.15 (0.53)^d	1.35	3.28 (−0.77)^c	1.35	75.83*	.23
Grade	56.35 (−0.12)^a	15.27	58.64 (0.02)^a	15.67	66.82 (0.52)^b	13.59	48.60 (−0.60)^c	16.75	40.14*	.13

Means in the same row with different superscript letters differ significantly at $p<.05$ in the Tukey's HSD comparison

*$p<.001$

well, good MSL scored the best, and poor MSL fared the worst. Pairwise comparisons showed that good and poor MSL clusters differed significantly ($p < .05$), whereas low and high MSL profiles were homogeneous groups (see Table 4).

Discussion

The ultimate goal of the present study was to provide empirical evidence for the different MSLQ profiles in terms of perceived autonomy support, needs satisfaction, motivational regulations, and academic achievement. The current findings were consistent with the two hypotheses of this study. First, the cluster analyses revealed four distinct learning profiles, with good MSL being the most adaptive profile exhibiting high levels of task value, self-efficacy, and self-regulation, but low level of anxiety (Hypothesis 1). Second, good MSL with highly perceived teacher autonomy support exhibited greatest psychological needs, self-determined motivation (i.e. identified and intrinsic regulation), and achievement (Hypothesis 2). The findings suggest that the cluster differences in self-regulated learning correspond well with the expected differences in academic achievement, perceived autonomy support, needs satisfaction, and other SDT variables. Furthermore, the characteristics of individual clusters highlight the role of SDT variables in explaining the differences in motivational-cognitive profiles among secondary students.

Independent *t* tests showed no gender, stream, and level difference in academic achievement. There was only subject difference in academic achievement, indicated by students' higher grades in science than in mathematics. This noticeable difference may imply that secondary students in Singapore are likely to have higher self-efficacy and lower test anxiety in science than in mathematics (see Table 1, ESM), which is consistent with the correlational results. Self-efficacy promotes science and math achievement (Griggs, Rimm-Kaufman, Merritt, & Patton, 2013) in terms of improving scientific skills in high schools and mathematical problem-solving skills in middle schools, respectively (Pajares & Graham, 1999; Zusho et al., 2003). Correlational results herein revealed that perceived autonomy support was strongly related to autonomy, competence, relatedness, task value, and self-efficacy. Consistent with previous empirical findings in academic domains (Reeve et al., 2004; Soenens & Vansteenkiste, 2005; Stefanou, Perencevich, DiCintio, & Turner, 2004), autonomy-supportive learning climates have positive impact on students' need satisfaction and are linked to self-determined motivation.

The clusters in the present study revealed some interesting and unique learning profiles that contrasted from Liu et al. (2014) in terms of mean scores, cluster sizes, and profile labels. All four clusters differed significantly in a specific fashion, with varying levels of motivational beliefs (i.e. task value and self-efficacy) and self-regulatory strategies. High MSL was more adaptive than low MSL in terms of positive MSLQ *z* scores. Surprisingly, high MSL obtained high scores in cognitive-motivational strategies, lack of self-regulation, and anxiety. It was expected that self-regulated learners engaged in cognitive and metacognitive strategies. Yet, this was not the case. Students' lack of self-regulation may occur when faced with a mundane task that is less gratifying or challenging task that is self-defeating (Suárez Riveiro et al., 2001), possibly leading to increased anxiety. Evidently, both good and poor MSL clusters differed. Students

with very low cognitive-motivational characteristics reported very high anxiety level and vice versa (Liu et al., 2014). The low mean scores for self-efficacy may indicate that students in Singapore schools have the tendency to report lower self-related motivational variables. This noteworthy finding was supported by Tang & Neber (2008) who found that Chinese students reported lower scores for self-efficacy in chemistry learning than American students.

Differences Between the Clusters

The four MSL profiles differed statistically in perceived teacher autonomy support, needs satisfaction, motivational regulations, and academic achievement, with significant effect sizes. Perceived competence seemed to be the most pertinent need across the four groups, with the greatest effect size among three psychological needs. Low and poor MSL profiles had similar scores for perceived autonomy and competence. Perceptions of autonomy and competence interact closely with each other to enhance well-being (Deci & Ryan, 2000; Levesque, Zuehlke, Stanek, & Ryan, 2004). Specifically, in school settings where knowledge and skills are essential for academic success, an autonomy-supportive context could foster need satisfaction. On the other hand, it is interesting to note that students with the lowest anxiety level reported highly for relatedness, suggesting that they may experience less anxiety with high sense of relatedness. The quality of the teacher–student relationship is related to students' social and cognitive outcomes (Davis, 2003), which may in turn influence their affect. Hence, the findings of this study not only add to the extensive literature of needs for autonomy, competence, and relatedness towards school in adolescents, but these results also support the importance of the need satisfaction in learners across different cognitive-motivational learning profiles.

Given that intrinsic motivation differed significantly across four groups (see post hoc comparison in Table 4), it is likely the key variable that differentiated the cluster profiles in terms of SDT variables. Students with higher self-efficacy and better learning strategies showed more signs of intrinsic motivation (Liu et al., 2014). Intrinsic motivation being inherent will be catalyzed when individuals are in favorable conditions (Deci & Ryan, 2000), explaining its variability and distinctive characteristic across the clusters. This finding supports the evidence that intrinsic motivation has a functional significance in different groups of learners, thus contributing to the field of educational research. Concerning academic achievement, results revealed significant differences across the four clusters of learners. As a classroom environment stresses on academic achievement, students depend on their cognitive abilities and adopt learning strategies to excel in studies (Berger, 2012). This supports the cluster-analytic results in this study: Good MSL with very high motivational beliefs, cognitive abilities, identified and intrinsic motivation, but low test anxiety performed academically well. The present findings were similar to Liu et al. (2014) in terms of positive relationships between cognitive-motivational constructs and needs satisfaction, as well as between needs satisfaction and self-determined behavior, thus leading to improved academic achievement. Hence, students in high and good MSL were likely to exercise control over their learning and fulfill their basic psychological needs than those in low and poor MSL.

Overall, the present study offered an in-depth perspective of intra-relations across each need satisfaction and each type of regulation for learning mathematics and

science. Cluster analysis, which is a person-oriented approach, offers an in-depth understanding of the learners' profiles. All four profiles differed significantly in the most self-determined behavior, that is, intrinsic motivation plays a very important role on student psychological factors and academic achievement. Such findings offered empirical evidence for unique learning behaviors among secondary students, which could contribute to an applied perspective for teachers' practice. Teachers may look for signs of profiles that could be supporting or undermining student learning in their classrooms. Subsequently, they may apply appropriate teaching strategies to promote student adoption of adaptive profiles.

Limitations

The main limitation of this cross-sectional study is that it has a less in-depth analysis based on self-reports at one time point. In addition, the use of self-reports to assess learning and motivation may limit to students' subjective perception. Another limitation is the difficulty in making causal statement or conclusion without longitudinal analyzes. Although the person-centered analysis offered an in-depth view of each need satisfaction and motivational regulation across diverse learners, the impact of teacher autonomy support on students' needs and motivation could not detected. Finally, the disproportionate group sizes indicated a smaller sampling of students taking mathematics than those taking science. Future research should include similar sampling sizes of students taking these two subjects.

Implications and Conclusion

The present findings provided the evidence that students in good MSL seemed to perceive competence as a more prevalent need than autonomy. Teachers may consider endorsing more student autonomy in terms of providing autonomy-supportive feedback so that students will inherently develop interest in schoolwork and understand the task value of learning. When students perceive autonomy-supportive behavior from their teacher, they may take ownership in learning. One possible recommendation that teachers may do in their class to improve student learning is through mindful teaching (Hargreaves, 2012). Being mindful, teachers are aware of critical learning and challenging teaching, as well as how to engage deeply with students. A teacher cannot transmit a value to a learner, but can impact the learner's motives, values, and goals through interpersonal interactions (Ryan & Niemiec, 2009). Teachers can make a difference in student learning by influencing student trajectories of motivation. Teachers should provide opportunities of challenging tasks to those students with increased feelings of competence, empower students to learn, and make own decisions during their learning process. With the provision of flexible yet relevant cognitive structures, teachers can promote intrinsically motivated learning amongst students (Deci & Ryan, 1985, 2000). Finally, the four-cluster results suggest that the profiles that students adopt could be influenced by their perception of the teacher and how the subject is taught. Future research should consider the teacher's years of experience and its impact on the learning opportunities made available to the students, which could in turn influence their perception of teacher autonomy support.

To summarize, students in good MSL perceived teacher autonomy support the most and scored the highest in academic achievement. Additionally, their levels of needs satisfaction (i.e. competence and relatedness) and self-determined motivation (i.e. identified and intrinsic) were the highest across all clusters. For students to be self-determined, their psychological needs must be fulfilled in social contexts (Ryan & Deci, 2000). Hence, such empirical findings echoed the need for a paradigm shift in educational policy and practice, advancing towards a more innovative and sustainable future in student learning and achievement (Hargreaves, 2012; Hargreaves & Shirley, 2009). Findings of this study contributed to the research field by documenting the importance of needs satisfaction, motivation, and self-regulation. Furthermore, it recognized the central role of the need for competence among secondary students in the Singapore educational context. By establishing the different learning profiles, intrinsic motivation was identified as the key antecedent to promote positive learning outcomes and academic achievement in schools. However, longitudinal analyzes may address the role of autonomy support on motivational-cognitive beliefs and academic achievement at points of time, as well as examine the changes in students' motivation over time.

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