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The impact of perceived teachers' autonomy support on students' mathematics achievement: evidences based on latent growth curve modelling

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Abstract

According to the self-determination theory, autonomy-supportive teaching is considered an effective approach to motivate students to learn. The present study investigates the effect of students' perceived autonomy support on math achievement over time, i.e. from grades 4 to 6, using a longitudinal survey administered in Chinese elementary schools. A total of 1624 participants were assessed over four waves. Autonomy need satisfaction and classroom engagement were included as predictors of achievement growth. Latent growth curve modelling (LGCM) indicated that perceived autonomy support accounted for more variance in mathematics achievement among 4th- and 5th-grade students than it did for 6th-grade students. Furthermore, student autonomy need satisfaction positively predicted the growth rate of their achievement, while behavioural engagement significantly and positively predicted both the growth rate and the average initial level of mathematics achievement.

Keywords Perceived autonomy support · Autonomy need satisfaction · Engagement · Mathematics achievement · Latent growth curve modelling

Intrinsic motivation is defined as the performance of an activity for its inherent satisfaction rather than for some external consequence (Ryan and Deci 2000). Intrinsic motivation is widely recognized as one of the most efficient driving forces for learning (e.g. Fortus and Vedder-Weiss 2014; Pintrich and Harris 2003; Olsen et al. 2011; Stroet et al. 2013). Unfortunately, many studies conducted in China suggest that student motivation to learn declines more steeply as the

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students advance through the grades, especially once they enter middle school (e.g. Wu and Wu 2007). More specifically, according to a large-scale assessment in China, students' intrinsic motivation towards the learning of mathematics declines throughout their years in school (Cheng et al. 2013). In the Chinese education system, mathematics is a core course from the first grade in elementary school through the 12th grade in high school. In the famous Chinese Gaokao system, only mathematics, Chinese, and English are required of all students regardless of the student's chosen major for college. As a result, how to motivate and engage students in mathematics has been discussed and addressed in many previous studies (e.g. Cheng et al. 2013; Zhang, Fu, Liu, & Liu, 2018).

Intrinsic motivation is regarded as the prototype of autonomy (Deci and Ryan 2000; Shih 2009), which is important for optimal learning and achievement, as proposed in self-determination theory (SDT; Deci and Ryan 1985, 2000). Each individual has a psychological need for autonomy; in other words, we have an innate desire for self-regulation and for our own perceptions of volition, vitality, and initiative (Deci and Ryan 2000). Researchers have proven that autonomy support, which fulfils the individual's psychological need by establishing an autonomous climate (e.g. Deci and Ryan 1985), is to motivate individuals to become autonomous, as it enables them to feel self-motivated, self-determined, and less controlled (e.g. Oga-Baldwin et al. 2017; Reeve 2009; Chirkov and Ryan 2001; Pintrich 2000; Zhou et al. 2009). Therefore, autonomy support in teaching and learning practices is considered an effective approach to address the problem of a lack of motivation among students towards learning (e.g. Zhang et al. 2018; Carreira 2012; Shih 2009; Jang et al. 2009), which is considered one of the most serious and persistent problems in education (e.g. Cheng et al. 2013). Specifically, teachers' autonomy support in the classroom has been the focus of much research. Enhancing intrinsic motivation could then improve students' classroom engagement and academic achievement (e.g. Carreira et al. 2013; Jang et al. 2012; Standage and Gillison 2007).

Previous studies have established the positive relationships between students' perceived autonomy support from teachers and academic performance (e.g. Jang et al. 2012; Schuitema,Peetsma, & van der Veen, 2016; Zhang et al. 2018). There is growing evidence that also highlights the causal inference among the relevant variables, including classroom engagement and the psychological need satisfaction of autonomy (e.g. Jang et al. 2012; Oga-Baldwin et al. 2017). For instance, autonomy need satisfaction and classroom engagement have been used to explain the effect of perceived teacher autonomy support on student academic achievement (e.g. Jang et al. 2012; Zhang et al. 2018). However, it is regrettable that few studies have investigated the effect of autonomy support on the growth of student achievement over time (Stroet et al. 2013; Schuitema et al. 2016). This gap in the literature might be due to difficulties associated with tracking the participants and collecting data over multiple time points. As we know, cross-sectional data do not provide robust evidence regarding the causality of a relationship. Therefore, the current study employed longitudinal data from mathematics classes in Chinese elementary schools to investigate the growth trajectory of student math achievement over time and examine the potential causal inferences related to the influences of autonomy support by teachers.

SDT

Perceived teacher autonomy support

Autonomous supportive teaching, which refers to the amount of psychological freedom students are allowed when making decisions regarding their own behaviours (e.g. Assor et al. 2002; Reeve 2009), is an important instructional strategy based on the SDT. Teachers who rely on an autonomy support style generally vitalize student intrinsic motivation (e.g. Jang et al. 2009; Carreira 2012; Zhang et al. 2018) and learning outcomes (e.g. Deci et al. 1981; Reeve 2009; Jang et al. 2012)(in terms of psychological need satisfaction), while teachers who rely on a style that emphasizes control generally neglect or even undermine student motivation and positive classroom engagement (Deci et al. 1981; Reeve 2009). Researchers find that teachers can create a motivationally supportive environment by offering choices and explaining the rationales for learning tasks, introducing meaningful learning goals, incorporating interesting activities, listening to students' perspectives, and avoiding excessive controlling behaviours (Jang et al. 2010; Reeve et al. 2004; Skinner and Belmont 1993). Students experience autonomy in learning when they perceive autonomy-supportive behaviours from their supervisors (Dupont et al. 2014). In autonomy-supportive learning contexts, although the teachers are in a position of authority, they acknowledge the perspectives of the students, respect their feelings, especially their negative feelings, and minimize the tendency to make demands and place pressure on students (Deci et al. 1994).

Recent studies based on the SDT propose that teachers' autonomy-supportive strategies promote intrinsic and autonomous motivation in students and, in turn, influence other learning outcome, such as academic achievement (Carreira 2012; Carreira et al. 2013; Noels et al. 2000; Noels 2013; Soenens and Vansteenkiste 2005; Vansteenkiste et al. 2005; Vansteenkiste et al. 2009). When students are autonomously motivated, they engage in an activity for the sake of the activity rather than for the purpose of obtaining an outcome that is separate from the activity. Studies also show that students with greater intrinsic motivation employ more deep-level learning strategies and achieve better grades (Senécal et al. 2003; Vansteenkiste et al. 2005). Furthermore, a mediation analysis of students in seven grades in Chinese schools determined that students who perceive higher levels of autonomy support exhibit higher levels of intrinsic motivation towards learning and thus demonstrate better academic achievement in the learning of both Chinese and mathematics (Zhang et al. 2018).

Autonomy need satisfaction

According to the SDT, the need for autonomy is one of the three psychological needs related to intrinsic motivation (e.g. Deci and Ryan 1985; Ryan and Deci 2000). The other two needs are competence and relatedness. The need for competency represents the individual's tendency to experience challenges and mastery in different activities (White 1959), while the need for relatedness is the tendency to establish strong and stable interpersonal relationships with others (Ntoumanis 2001; Ryan and Deci 2000). Theoretically, these needs nourish and sustain high-quality motivation and psychological wellness related to people's activities. When the social context is supportive, a person's basic needs are fulfilled and the level of engagement in learning activities ultimately increases (Connell and Wellborn 1991; Skinner et al. 2008). Many studies have concluded that the positive motivational influences arise from the satisfaction of psychological needs in educational contexts (e.g. Carreira et al. 2013; Oga-Baldwin et al. 2017).

The mediating role of autonomy need satisfaction on the relationship between perceived autonomy and student learning performance has been confirmed in previous studies (Reeve et al. 2006; Carreira et al. 2013; Jang et al. 2012). A well-accepted finding is that teachers provide autonomy support by nurturing autonomous classroom climates and that this autonomy support fulfils the needs for autonomy, thus leading to higher levels of classroom engagement or intrinsic motivation to learn, which, in turn, predicts course-related learning outcomes such as academic achievement (Hardré and Reeve 2003; Jang et al. 2012; Jang et al. 2009; Vansteenkiste et al. 2010; Carreira 2012; Carreira et al. 2013). Carreira et al. (2013) examined a motivation model of learning English in Japanese elementary school students and concluded that teacher autonomy supportive climates that satisfy student autonomy needs promote intrinsic motivation. Zhang et al. (2018) further posit that the satisfaction of the autonomy need and the enhanced intrinsic motivation mediate the effect of the perceived teacher autonomy support on student achievement. These two factors play separate mediating roles in the prediction of achievement in both mathematics and Chinese for seventh-grade students in China.

Classroom engagement

Classroom engagement is a multifaceted concept consisting of behavioural engagement, emotional engagement, and cognitive engagement (e.g. Fredricks et al. 2004; Archambault et al. 2009; Fredricks and McColskey 2012; Shernoff 2013). Behavioural engagement refers to students' learning behaviours and their participation in different school activities, including finishing homework on time; emotional engagement refers to students' affective feelings towards learning, including their interest and enjoyment; and cognitive engagement refers to students' judgement about learning, including their use of self-regulated learning strategies (Fredricks et al. 2004).

Student classroom engagement is closely related to teacher autonomy support, according to previous studies. Oga-Baldwin and Nakata (2015) found positive influences of a well-structured and autonomy supportive environment on students' in-class engagement in Japanese elementary classes. Jang et al. (2010) investigated students from nine public high schools through hierarchical linear modelling (HLM). The results showed that if the teachers were rated by observers as providing autonomy support, higher levels of collective behavioural engagement could be observed in students. Dupont et al. (2014) also provide evidence showing that if students perceive autonomy-supportive behaviours from their supervisors, they are more likely to show cognitive engagement. Hospel and Galand (2016) conducted a multilevel analysis of French speaking students in grade 9 and found that autonomy support is associated with emotional engagement.

Together, these forms of engagement have shown meaningful effects on achievement (Jang et al. 2012, 2016; Oga-Baldwin et al. 2017). By engaging actively and enthusiastically in academic activities, students acquire knowledge, develop skills, and make progress (Jang et al. 2012). Hence, both the extent and the quality of student classroom engagement positively affect student achievement (Alexander et al. 1993; Ladd and Dinella 2009). Through path analysis based on longitudinal design, evidence was also provided that positive engagement has direct effects on student learning and achievement (Jang et al. 2012; Oga-Baldwin et al. 2017).

Previous longitudinal findings

Several intervention-based longitudinal studies have investigated the effectiveness of autonomy support. An early study was the 10-week intervention study conducted by Reeve et al. (2004). These authors recruited participants from high schools and found that when teachers frequently used autonomy-supportive instructional behaviours, their students exhibited greater engagement throughout the intervention. More recently, Zhang, Bobis, Wu, & Cui (2018) also explored the impact of a 9-month autonomy-supportive teaching intervention on a physics teacher and 147 grade 8 students attending a Chinese middle school. Mixed methods were used to confirm that the increased use of autonomy support improved student need satisfaction and engagement.

In addition, longitudinal empirical studies conducted in different countries in recent years have aimed to investigate the co-varying relationships between autonomy support and other variables related to learning performance. For example, Jang et al. (2012) administered a hypothesized motivation mediation model using a three-wave longitudinal design to 8th-grade students in Korea. A multilevel path analysis was conducted to explore the causal effect, reciprocal effect, and stationary effects among student perceived autonomy support, autonomy need, engagement, and achievement. In a study conducted in a Norwegian school, Diseth et al. (2018) examined the causal and reciprocal relationship between perceived autonomy support and autonomy need satisfaction by using longitudinal data with two waves. Furthermore, Oga-Baldwin et al. (2017) investigated how elementary school students' motivation developed over the course with the latent analysis based on structure equation models (SEM). These longitudinal data were collected in five waves of implementation throughout one Japanese school year in which perceptions of teacher support, need satisfaction, and engagement were measured successively in the middle three waves, and a students' self-reported motivation was measured in a pre-test administered in the first wave and in a post-test in the fifth wave. Together, these studies provided support for the causal relationship between teacher autonomy support and achievement, as well as the effect of basic need satisfaction and classroom engagement on that relationship, using path analysis methods and longitudinal data.

The rationale for the present study

In this article, a longitudinal empirical study was conducted to address how teacher autonomy support predicts student mathematics achievement and the achievement growth trajectory among elementary students from grades 4 to 6 in Chinese schools. By using latent growth curve modelling (LGCM; e.g. Laursen and Little 2012; Muthén 1991), the current study modelled the perceived autonomy support from teachers as time-varying predictive variables of the mathematics achievement across different assessments over time. In addition, autonomy need satisfaction and classroom engagement were included in the models. It is assumed that the co-varying effects between each of the two indicators and the perceived autonomy support on the prediction of achievement over time are explained by considering perceived autonomy support as a single time-varying predictive variable, since they (perceived autonomy support and achievement) are strongly associated with each other based on previous studies (e.g. Jang et al. 2012; Schuitema et al. 2016). Therefore, by simultaneously modelling autonomy need satisfaction and engagement as time-invariant covariates, their effect on the prediction of achievement growth rate can be assessed. Furthermore, demographic data regarding gender and social economic status (SES, Bradley and Corwyn 2002) are included in the survey.

Accordingly, this study aimed to answer three specific questions:

Question 1: What does the mathematics achievement growth trajectory look like for elementary school students from grade 4 to 6?

Hypothesis 1: It is hypothesized that there are differences in individual students' mathematics achievement over time as students advance from the 4th to the 6th grades. In addition, individual differences in the growth trajectory among students exist.

Question 2: How does the perceived autonomy support from teachers predict final achievement of students over time with respect to mathematics learning?
Hypothesis 2: It is hypothesized that perceived autonomy support positively predicts student mathematics achievement over time from the 4th grade to 6th grades.
Question 3: How do the covariates of student autonomy need satisfaction and engagement predict the growth trajectory of mathematics achievement?
Hypothesis 3: It is hypothesized that both autonomy need satisfaction and classroom engagement are significant predictors of the growth trajectory of mathematics achievement, and important results are expected among the different covariates, including the different facets of engagement.

Methods

Data and participants

The data used for this study were collected as part of a large-scale educational assessment for all schools in the Mentougou School District, which is located in the western area of Beijing. The education quality of this district is considered to be in the middle level compared with all districts in Beijing. Given that this assessment provides a comprehensive evaluation for the local government, all students in 4th grade from 67 classes of all 25 elementary schools were enrolled in the study, and no sampling techniques were employed. In the Chinese education system, the fall semester usually starts at the beginning of September and ends in mid-January, and the spring semester starts in the beginning of March and ends in the beginning of July. The assessments were implemented four times between 2013 and 2016. In total, 1624 participants (852 males and 772 females) were involved in the baseline data collection in October 2013 when they were in grade 4. Data were collected over four waves, with 10 to 12 months between each wave. Therefore, the baseline assessment took place at the beginning of grade 4 (named T1); the second, third, and fourth assessments tracked the same group at the end of grade 4, grade 5, and grade 6 (named T2, T3, and T4, respectively).

Given that the whole study lasted for approximately 3 years, the non-participation rate of the participants varied across different time points. As shown in Table 1, the non-participation rate was approximately 7% in the middle two waves, while the last wave, the rate increased to 13.4%. As explained by the school principals, some parents choose to send their children to other school districts when they advanced to the 6th grade, with the aim being to enrol their children in better middle schools. Hence, considering all four assessments, 287 cases were missing from at least one measurement. The demographic data, social economic status (SES), and gender of students who completed all four waves ($n = 1337$) were compared with those of the students who were missing data from one or more waves ($n = 287$).When comparing the proportion of male and female students in the two groups using chi-square, no significant

Table 1 Sample sizes of the four waves

	Time 1	Time 2	Time 3	Time 4
Sample size	1624	1511	1501	1407
Missing rate (%)	0 (0%)	113 (6.9%)	123 (7.6%)	217 (13.4%)

difference was noted. In addition, the mean scores of the students' SES in the two groups were analysed using a *T* test. The results of this test revealed that the cases with missing data had a lower SES mean score than did those who participated in all four waves ($t(1622) = 4.44$, $p < .001$, $d = 0.87$).

Measures

Participants were assessed at all four waves using a cognitive test and a non-academic questionnaire at each assessment. Student mathematics achievement was measured via the administration of a test, while background information and other variables of interest were investigated through the questionnaire.

Student perceived autonomy support

Data regarding student perceived autonomy support across all four waves were collected as the mean scores based on a six-item short version of the Learning Climate Questionnaire (LCQ; Williams and Deci 1996), which has been widely used in classroom-based investigations of autonomy support (Black and Deci 2000; Jang et al. 2009; Jang et al. 2012). Sample items include, "I feel that my teacher provides me with choices and options", "I feel understood by my teacher", and "My teacher encourages me to ask questions". Scales ranged from 1 (strongly disagree) to 5 (strongly agree). In the present study, the instrument showed strong reliability across the four time points. Specifically, Cronbach's α is 0.892, 0.883, 0.936, and 0.946 at T1, T2, T3, and T4, respectively.

Autonomy need satisfaction

Student autonomy need satisfaction was measured at T1. The mean scores for this variable were assessed by the following four items: "I can express my thoughts freely", "I have the opportunity to discuss with classmates", "I feel relaxed", and "I have the opportunity to be myself". The instrument showed strong reliability at 0.838. Previous studies have found the English version of this measure produces scores with strong psychometric properties and correlates highly with other measures of autonomy need satisfaction (the perceived autonomy subscale was from the Basic Psychological Needs Satisfaction Scale; Gagné 2003) (Hardré and Reeve 2003; Jang et al. 2009; Reeve et al. 2003; Reeve and Tseng 2011).

Classroom engagement

The study investigated student classroom engagement using the mean scores of 21 integrated items. The result was a multidimensional construct composed of behavioural engagement (e.g. "I can listen carefully in class" and "I can always come up with solutions when I meet difficulties in my studies"), emotional engagement (e.g. "I often feel happy when I solve a problem in my studies" and "I feel confident in my learning ability"), and cognitive engagement (e.g. "I think it important to study hard" and "I always hope to acquire new knowledge") (Archambault et al. 2009; Fredricks and McColskey 2012; Shernoff 2013; Fredricks et al. 2004). This instrument was administered at T1 and showed reliability at each dimension with Cronbach's α scores of 0.836, 0.749, and 0.751, respectively.

Mathematics achievement

Achievement tests were developed according to the mathematics curriculum standards issued by the Ministry of Education of the People's Republic of China. Students' responses on each mathematics examination were calibrated into a standard score to reflect their latent mathematics ability by using a Rasch model (Rasch 1960) and partial credit model (PCM; Masters 1982) at each wave. By applying the equating techniques, students' latent mathematics capability at the four waves were aligned on the same scaled, thus ensuring that the students' measured mathematics achievement scores across the four time points were comparable.

Data characteristics

The descriptive statistical characteristics are presented in Table 2, and the correlations among perceived autonomy support, math achievement, classroom engagement, and autonomy need satisfaction are presented in Table 7 of the Appendix. Of the 1624 participants involved in this study, 52.5% were male and 47.5% are female. The students' SES scores have a mean of 0.13 and a standard deviation of 2.20, which indicates that there was substantial individual variability with respect to the SES. In addition, it is shown that there were a notable number of valid values for the measures of cognitive engagement and perceived autonomy support at T2 to T4 and for math achievement across all four waves. Given that the loss of participants over the four waves is related to their SES scores, the data are not missing completely at random (MCAR). Therefore, multiple imputation (MI) was used to hand calculate the missing values, and the final results were obtained based on the scores of 5 imputations.

Table 2 Descriptive statistics

Variables	Number	Number (%)	Original		MI	
			Mean	SD	Mean	SD
Gender	1624					
1 = male		852 (52.5%)				
2 = female		772 (47.5%)				
SES	1624		0.13	2.20	/	/
Classroom engagement						
Behavioural engagement	1624		4.01	0.64	/	/
Emotional engagement	1624		4.19	0.68	/	/
Cognitive engagement	1623		4.53	0.64	4.53	0.64
Autonomy need satisfaction	1624		4.21	0.90	/	/
Perceived autonomy support						
T1	1624		4.27	0.84	/	/
T2	1508		4.34	0.78	4.34	0.77
T3	1498		4.36	0.70	4.25	0.68
T4	1404		4.45	0.84	4.45	0.80
Math achievement						
T1	1522		− 1.0	0.55	− 1.0	0.544
T2	1525		− 0.91	0.65	− 0.92	0.64
T3	1398		0.86	0.77	0.84	0.76
T4	1415		1.45	0.90	1.44	0.87

N is the number of valid values for a certain measure; *Original* is the original data with missing values; *MI* is the integrated data complemented by mean scores of 5 imputations; "/" indicates that there are no missing data for this variable

As shown in Table 2, engagement, autonomy need satisfaction, and perceived autonomy support across the four waves exhibited similar distributions. The mean scores for perceived autonomy support gradually increased across the four waves, with the exception of T3. The mean scores for student mathematics achievement across the four waves gradually increased, as did the standard deviation. These findings indicate that student mathematics achievement improved over time and exhibited larger variations among individuals.

Analysis

The LGCM describes the growth path of the dependent variable by the estimation of growth factors, including an intercept that represents the initial value and a slope that represents the rate of change over time. In this study, a nonlinear LGCM was applied by freeing the loadings of the slope at T2 and T3 in the estimations. The loadings of the slope at T1 and T4 were fixed at 0 and 3, and the loadings of the intercept at T1 to T4 were fixed at 1. The three models were tested using Mplus (Muthén and Muthén 2007), including an unconditional LGCM (model 1) that identified the pattern of growth, an LGCM with only a time-varying covariate (model 2) that explored the associations between perceived autonomy support and achievement over time, and an LGCM with both time-invariant and time-varying covariates (model 3) that discussed their influence on the estimate of growth factors. In both model 2 and model 3, both the time-varying and invariant covariates are exogenous variables, thus set to be correlated with each other.

All analyses were conducted in Mplus using an MLR estimator (Muthén and Muthén 2007).To evaluate model fit, chi-square tests and goodness-of-fit indices, such as the comparative fit index (CFI), the Tucker-Lewis index (TLI) (Bentler et al. 1980), root mean square error of approximation (RMSEA) (Browne and Cudeck 1993), and standardized root mean square residual (SRMR) (Maydeu-Olivares et al. 2018), can be applied. For a good fit model, the values of the CFI and TLI should exceed 0.95 (Hu and Bentler 1998), the RMSEA should be below 0.08 (Hooper et al. 2008), and the SRMR should be below 0.05 (Byrne 1998) for a model that fits well.

Results

Preliminary analyses

With respect to the nested structure of the data (students are nested in schools), hierarchical linear modelling (HLM) was initially used to determine whether meaningful between-group differences existed in the variations of the research variables, including the variables of perceived autonomy support, math achievement, classroom engagement, and autonomy need satisfaction across all measures. The interclass correlation coefficients (ICC) for all of the measures were less than 0.10 with only one exception, i.e. math achievement at T3 (0.105) (see Table 3). Given the slight interclass correlation, it is reasonable to consider that the between-school effect has no significant impact on the subsequent analysis (Lee 2000). Accordingly, a one level model was employed.

The unconditional LGCM

Based on the exploration of the unconditional free-loading LGCM (see Fig. 1), it was determined that the nonlinear latent growth curve model exhibited a good model fit: $\chi^2 = 106.555$, $df = 3$,

Table 3 ICC and design effect for all variables

Variable	ICC	Design effect	Variable	ICC	Design effect
Math_T1	0.079	2.81	Per_T3	0.055	2.26
Math_T2	0.072	2.65	Per_T4	0.048	2.10
Math_T3	0.105	3.48	Enge_B	0.038	1.87
Math_T4	0.084	2.93	Enge_E	0.049	2.12
Per_T1	0.094	3.16	Enge_C	0.019	1.43
Per_T2	0.056	2.28	Auto_need	0.081	2.86

ICC was calculated based on the formula $\tau_{00}/_{\tau_{00}+\sigma^2}$, where $\tau_{oo}$is the variation between groups and σ^2 is the variation within groups; Design effect was calculated based on the formula $D_{\mathrm{eff}} = 1 + (m - 1)\rho$, where m is the observations in each cluster and ρ is the ICC

Per_T1 perceived autonomy support at T1, …, *Math_T1* math achievement at T1, …, *Enge_B* behavioural engagement, *Enge_E* emotional engagement, *Enge_C* cognitive engagement, *Auto_need* autonomy need satisfaction

CFI = 0.962, TLI = 0.925, RMSEA = 0.146, and SRMR = 0.081 (see Table 4), suggesting that student mathematics achievement growth from T1 to T4 was not a linear trajectory. In this free-loading LGCM, the first and the last slope factor loadings were fixed at 0 and 3, respectively, while the second and the third loadings were estimated freely. The estimated loadings of T2 and T3 on slope were 0.13 and 2.27, respectively, and the estimated intervals were shorter than the real implemented time spans between T1 and T2 and between T3 and T4. The final nonlinear growth pattern verified the steep enhancement observed in the mean score changes from T2 to T3, as well as a much smoother growth pattern in student mathematics achievement in the early period from T1 to T2 compared with that from T3 to T4.

In the unconditional model, the mean of the intercept of the latent factors denoted the average initial scores of student mathematics achievement, and the mean of the slope represented the average growth over the time. As shown in Table 4, student mathematics achievement exhibited a significant increase over time based on the average initial score of − 1.012. Furthermore, the intercept variance was 0.202 ($p < 0.001$), suggesting that initial mathematics achievement varied

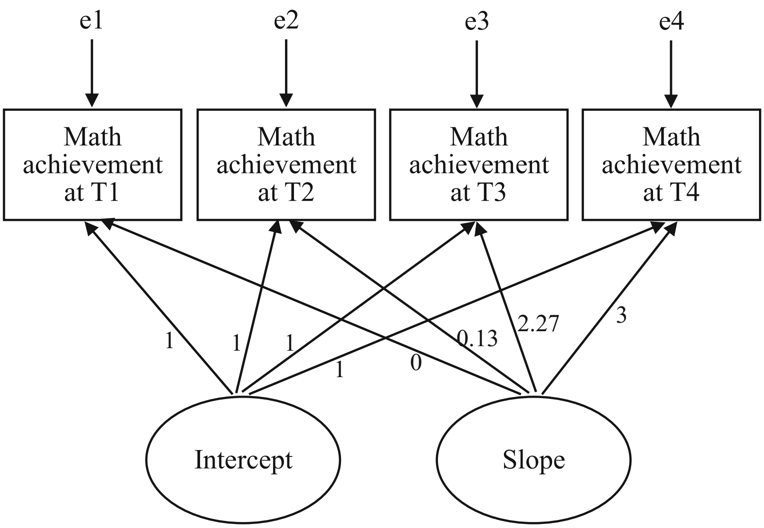

Fig. 1 Unconditional LGCM depicting nonlinear growth of math achievement overtime (model 1)

Table 4 Parameter estimates for unconditional LGCM of math achievement change over time (model 1)

Parameter	Estimate	S.E.	Estimate/S.E.
Growth factor			
Intercept mean	− 1.013***	0.013	− 77.92
Slope mean	0.818***	0.006	136.33
Intercept variance	0.202***	0.01	20.20
Slope variance	0.012***	0.002	6.00
Intercept ← → slope covariance	0.037***	0.003	12.33
Residual variance			
Math achievement at T1	0.138***	0.008	17.25
Math achievement at T2	0.145***	0.007	20.71
Math achievement at T3	0.133***	0.008	16.63
Math achievement at T4	0.245***	0.014	17.50
R^2			
Math achievement at T1	0.594***	0.020	29.70
Math achievement at T2	0.594***	0.019	31.26
Math achievement at T3	0.763***	0.014	54.50
Math achievement at T4	0.683***	0.017	40.18

Model fit: χ^2 = 106.555, df = 3, CFI = 0.962, TLI = 0.925, RMSEA = 0.146, SRMR = 0.081

***$p < 0.001$

significantly among individuals. Although the variance of the slope was quite small ($\delta^2 = 0.012$, $p < 0.001$), it was significant, suggesting variability in individual trajectories across time. The positive covariance between the intercept and slope ($r = 0.037$, $p < 0.001$) suggested that higher initial scores in student mathematics achievement exhibited a steeper increase over time.

The LGCM with perceived autonomy support as time-varying covariates

To explore the association between student perceived autonomy support and their achievement in mathematics in the four waves, the perceived autonomy support at the four time points was incorporated into the nonlinear LGCM. Given that a nonlinear relationship had already been identified and modelled in the first step, a nonlinear LGCM (model 2) of the mathematics achievement trajectory over time with time-varying covariates is presented in Fig. 2. This model produced very good fit indices: $\chi^2 = 111.991$, $df = 15$, CFI = 0.969, TLI = 0.955, RMSEA = 0.063, and SRMR = 0.042 (see Table 5). The estimated loadings on slope at T2 and T3 were 0.66 and 2.41, respectively, which are similar to those in the unconditional model.

The four estimated path coefficients between perceived autonomy support and mathematics achievement were significant at all four waves, suggesting a significant predictive relationship with perceived autonomy support. However, the direction of the prediction varied over different time points. Positive predictive relationships were observed at T1 ($\beta = 0.044$, $p = 0.009$), T3 ($\beta = 0.056$, $p < 0.001$), and T4 ($\beta = 0.083$, $p < 0.001$), which suggest that students with higher scores on perceived autonomy support in mathematics demonstrated better mathematics achievement. In contrast, a negative correlation between perceived autonomy support and mathematics scores at T2 was revealed ($\beta = -0.065$, $p < 0.001$), which indicated that an increase in teacher autonomy support at the classroom was related to a decrease in student mathematics achievement for grade 4 students at the end of a school year. Nevertheless, the growth factors showed a consistent trajectory for mathematics achievement when compared with the unconditional model. It should be noted that, given that the time-varying factor of perceived autonomy support was accounted for in the model, the growth factor

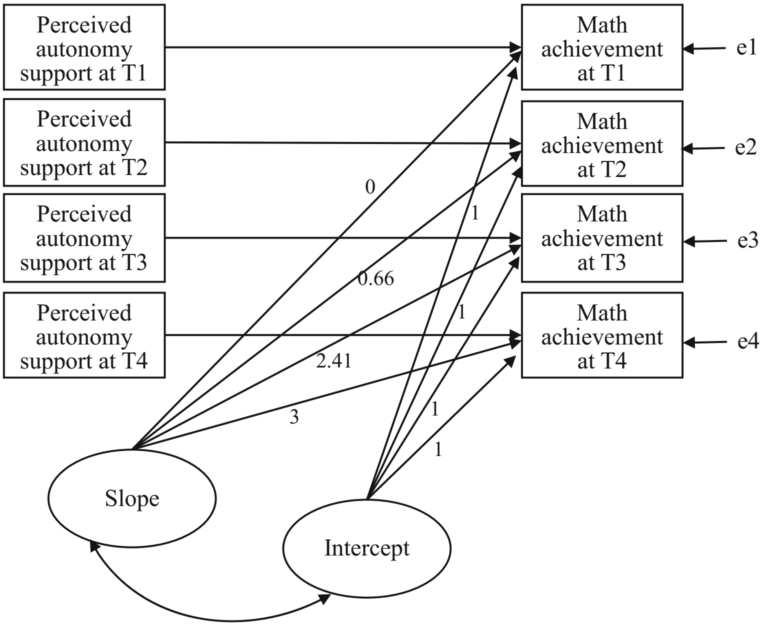

Fig. 2 LGCM of the math achievement trajectory over time with time-varying predictors: perceived autonomy support (model 2)

intercept and slope in model 2 actually capture the adjusted math achievement change after controlling for the influences of perceived autonomy support at each time point.

The LGCM with both time-varying and time-invariant covariates

In the last step, time invariant covariates were added to the model, including gender, SES, student classroom engagement (behavioural, emotional, and cognitive), and autonomy need satisfaction, to explore their effects on the growth factors. The growth factors in model 3 describe the adjusted growth trajectory, which is the same as that of model 2. As depicted in Fig. 3, both the adjusted intercept and the slope growth factors were regressions on the six-time invariant covariates. Model 3 showed quite good fit indices: $\chi^2 = 133.048$, $df = 27$, CFI = 0.969, TLI = 0.948, RMSEA = 0.049, and SRMR = 0.023 (see Table 6).

The effects of students' perceived autonomy support on mathematics achievement corresponded with model 2 in all four waves. The results indicated that the background variables were significantly related to the students' initial level of mathematics achievement after controlling for the influences of perceived autonomy support but that they were not significantly related with achievement change over time. The negative coefficient of gender for intercept ($\beta = -0.149$, $p < 0.001$) suggested that, on average, boys outperformed girls at the initial time point. The positive coefficient of SES ($\beta = 0.034$, $p < 0.001$) meant that, on average, students with higher SES levels performed better in mathematics at the initial time point. In addition, student autonomy need satisfaction in math class could positively predict the adjusted change rate in mathematics achievement ($\beta = 0.023$, $p = 0.001$), although it has no significant effect on the prediction of initial mathematics scores ($\beta = -0.025$, $p = 0.145$).

Table 5 Parameter estimates for the LGCM of the math achievement trajectory over time with time-varying predictors: perceived autonomy support (model 2)

Parameter	Estimate	S.E.	Estimate/S.E.
Growth factors			
Intercept mean	−1.137***	0.050	−22.74
Slope mean	0.723***	0.033	21.91
Intercept variance	0.182***	0.011	16.55
Slope variance	0.015***	0.002	7.50
Intercept ←→ slope covariance	0.035***	0.003	11.67
Standardized path coefficients of time-varying covariates			
Perceived autonomy support at T1	0.044**	0.017	2.59
Perceived autonomy support at T2	−0.065**	0.017	−3.82
Perceived autonomy support at T3	0.056**	0.014	4.00
Perceived autonomy support at T4	0.083***	0.018	4.61
Residual variance			
Math achievement at T1	0.132***	0.009	14.67
Math achievement at T2	0.141***	0.007	20.14
Math achievement at T3	0.131***	0.008	16.38
Math achievement at T4	0.242***	0.015	16.13
R^2			
Math achievement at T1	0.581***	0.024	24.21
Math achievement at T2	0.625***	0.017	36.76
Math achievement at T3	0.771***	0.015	51.40
Math achievement at T4	0.687***	0.018	38.17

Model fit: $\chi^2 = 111.991$, $df = 15$, CFI = 0.969, TLI = 0.955, RMSEA = 0.063, SRMR = 0.042

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

The three facets of classroom engagement exhibited distinguished effects with respect to the prediction of mathematics achievement growth factors when controlling for perceived autonomy support. Specifically, behavioural engagement ($\beta = 0.204$, $p < 0.001$) and emotional engagement ($\beta = -0.112$, $p < 0.001$) were significant predictors of the intercept, while cognitive engagement was not ($\beta = 0.032$, $p = 0.207$). This result suggested that students with higher scores in behavioural engagement and lower scores in emotional engagement exhibit better mathematics achievement scores at the initial time point. Similarly, the association between each of the three facets of engagement and mathematics achievement change rates ($\beta = 0.033$, $p = 0.005$ for behavioural engagement; $\beta = -0.041$, $p < 0.001$ for emotional engagement; $\beta = -0.001$, $p = 0.929$ for cognitive engagement) suggested that students with higher scores in behavioural engagement and lower scores in emotional engagement were associated with larger growth rates in mathematics achievement. Cognitive engagement, however, had no significant effect on growth factors.

Discussion

This study examined the associations between students' perceptions of teacher autonomy support and mathematics achievement in Chinese elementary schools based on longitudinal data from four waves. Using latent growth curve modelling (Laursen and Little 2012; Muthén 1991), the data from four different time points were successfully modelled, and the changing trends in the relationship between these two core variables

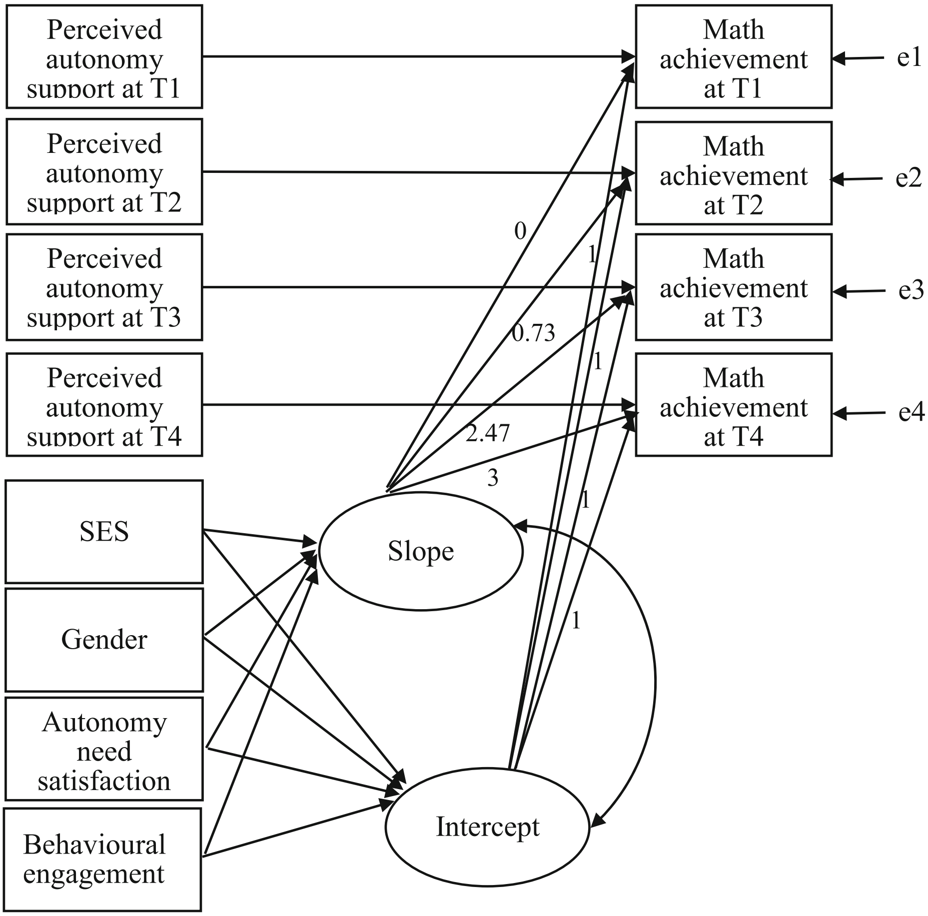

Fig. 3 LGCM of the math achievement trajectory over time with both time-varying and time-invariant covariates (model 3)

over 4 years were examined. In addition, the effect of time-invariant covariates on the prediction of growth factors, i.e. intercept and slope of change, of mathematics achievement was also evaluated (Grimm et al. 2013; Hancock and Choi 2006; McArdle 2009; Meredith and Tisak 1990). The methodological improvement through a longitudinal design assesses the variability of the predictive relationships between autonomy support and student achievement over time and reduces the intra-individual variation bias while the grade-adjusted individual variation remains at the same level (Polyhart and Vandenberg 2010).

The growth trajectory of mathematics achievement

By using the LGCM with free-loaded slopes on time points, a nonlinear growth trajectory of mathematic achievement for students from 4th to 6th grades was identified in this study. Generally, student achievement in mathematics was improved as they advanced to the next grade. This trend became particularly steep at the interval from the end of grade 4 to the end of

Table 6 Parameter estimates for LGCM of the math achievement trajectory over time with both time-varying and time-invariant covariates (model 3)

Parameter	Estimate	S.E.	Estimate/S.E.
Growth factor			
Intercept			
Baseline	− 1.364***	0.100	−13.64
Gender	− 0.149***	0.025	−5.96
SES	0.034***	0.006	5.67
Behavioural engagement	0.204***	0.028	7.29
Emotional engagement	− 0.112***	0.026	−4.31
Cognitive engagement	0.032	0.026	1.23
Autonomy need satisfaction	− 0.025	0.017	−1.47
Slope			
Baseline	0.664***	0.048	13.83
Gender	0.018	0.010	1.80
SES	− 0.003	0.002	−1.50
Behavioural engagement	0.033**	0.010	3.30
Emotional engagement	− 0.041***	0.010	−4.10
Cognitive engagement	− 0.001	0.010	−0.10
Autonomy need satisfaction	0.023***	0.007	3.29
Intercept ←→ slope covariance	0.033**	0.003	11.00
Standardized path coefficients of time-varying covariates			
Perceived autonomy support at T1	0.063**	0.021	3.00
Perceived autonomy support at T2	− 0.068**	0.017	−4.00
Perceived autonomy support at T3	0.048*	0.014	3.43
Perceived autonomy support at T4	0.082***	0.019	4.32
Residual variance			
Math achievement at T1	0.128***	0.009	14.22
Math achievement at T2	0.143***	0.007	20.43
Math achievement at T3	0.128***	0.008	16.00
Math achievement at T4	0.246***	0.015	16.40
Intercept	0.158***	0.010	15.80
Slope	0.015***	0.002	7.50
R^2			
Math achievement at T1	0.587***	0.024	24.46
Math achievement at T2	0.625***	0.016	39.06
Math achievement at T3	0.776***	0.015	51.73
Math achievement at T4	0.684***	0.018	38.00
Intercept	0.123***	0.020	6.15
Slope	0.062**	0.022	2.82

Model fit: χ^2 = 133.048, df = 27, CFI = 0.969, TLI = 0.948, RMSEA = 0.049, SRMR = 0.023

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

grade 5, which implies that this is a critical period for learning performance growth of elementary students in the Chinese education system. This finding can be attributed to the perceived pressures by 5th-grade students related to entering key middle schools, and the 5th and 6th grades are considered critical periods for the students to develop a sense of learning objectives (e.g. Sun 2012). In addition to the intra-individual effects, the individual differences in growth trajectory among students were determined to be statistically significant. More succinctly, the individual students demonstrated significantly different growth rates over time in mathematics achievement and in their initial mathematics scores. Furthermore, students with higher initial scores on mathematics achievement assessments had steeper increasing trends than those with lower initial scores.

The relationship between perceived autonomy support and achievement

The findings suggested that a positive relationship between students' perceived autonomy support from their mathematics teachers and their achievement in mathematics achievement is a general trend across the four waves, with an exception at the second time point. However, this exception did not deny the conclusion with respect to the positive influences of perceived teachers' autonomy support on achievement, as highly consistent results were reported at the three other time points. It should be noted positive correlations between perceived autonomy support and achievement scores were consistently found (see Table 3) at different time points, including T2. Therefore, the growth model's property should be considered as part of the explanation for the regression coefficients between the outcome variables and the time-varying covariates. When the average growth trajectory was evaluated, a portion of the variations in the achievement indicators were explained by the growth factors. In other words, the negative value estimated at T2 revealed a comparative relationship with respect to the general growth pattern.

Another trend from the current study that deserves discussion is the residual variances in different grades. When perceived autonomy support was modelled as time-varying covariates, the residual variances of outcome variables were reduced (expect for T4), suggesting that perceived autonomy support in mathematics class helps to explain individual differences in mathematics achievement for elementary students. However, the percentage of explained residual variances was not consistent at the 4th, 5th, and 6th grades. Perceived autonomy played stronger roles in explaining the individual differences at the first three time points compared to the last time point. The results in this study are consistent with those of Carreira et al. (2013), who found that perceived teacher autonomy support is more important in the middle grades than it is in the higher grades with respect to the learning of English among Japanese elementary school students. Furthermore, Jang et al. (2012) found unstable effects over time regarding their three hypotheses for 8th-grade Korean students. Specifically, students' grade change was found to be an important factor in predicting the effect of teacher autonomy support on student learning performance and achievement. Accordingly, it was concluded that increased attention should be paid to students in the higher grades when considering the advantages of creating a learning environment that promotes student autonomy.

The predictors of growth factors

It has been argued that the way students perceive their learning environment influences their learning. In other words, it is not the learning environment itself (e.g. Entwistle 1991). Students who are satisfied with their teachers' level of autonomy support perceive their engagement in learning as a self-chosen act that reflects their own authentic needs and values (Stroet et al. 2013). The general positive link between autonomy need satisfaction and student learning performance has been replicated in a large number of correlational studies (e.g. Carreira and Junko Matsuzaki 2012; Carreira et al. 2013; Reeve et al. 2006). The current study further discovered that autonomy need satisfaction at the initial point, rather than the average initial level, is the only significant predictor of achievement growth rate. That is, students with higher psychological need satisfaction improved their achievement more quickly, while there was no difference in the average initial scores when compared with those who reported lower psychological need satisfaction. Therefore, a concordant inference based on previous findings (Carreira and Junko Matsuzaki, 2012; Carreira et al. 2013; Reeve et al. 2006; Jang et al. 2012) is that students' satisfaction of autonomy need in the mathematics class could also contribute positively to their achievement growth in the long term.

In most of the previous studies, the positive relations between each of the three dimensions of student engagement, i.e. behavioural, emotional, and cognitive, and perceived autonomy support from teachers have been proven (e.g. Oga-Baldwin and Nakata 2015; Dupont et al. 2014; Hospel and Galand 2016). However, with respect to the effect on achievement, these forms of engagement were often integrated into one factor that exhibited a positive association with academic achievement (e.g. Jang et al. 2012; Oga-Baldwin et al. 2017). This article investigated the associations between engagement and mathematics achievement growth based on each of the three forms of engagement, and the results indicate that notable effects were found among behavioural engagement, emotional engagement, and cognitive engagement. As expected, positive behavioural engagement can predict faster mathematics achievement growth, as well as a higher average initial level of achievement. Indeed, behavioural engagement is the base of academic engagement that describes a process whereby students accomplish academic tasks, adhere to the disciplinary policies, and actively engage in the learning activities (Fredricks et al. 2004). In addition, the effects of cognitive engagement on both the intercept and slope of growth are not statistically significant when it is simultaneously modelled with other covariates, such as behavioural engagement. Furthermore, it should be noted that higher emotional engagement is related to slower growth in mathematics achievement, even when emotional engagement is modelled as a single form of engagement as in model 3. The emotional and cognitive engagements are characterized by high involvement that is closely associated with students' inner psychological states (Fredricks et al. 2004), rather than with the ability to act. However, given the exam oriented educational context, Chinese students are used to academic overburden and are bound by many course principles (Tong 2014), which implies higher efficiency of action is required to manage classroom activities or homework demands. The notable findings among emotional engagement, cognitive engagement, and behavioural engagement were also discovered in the study conducted by Zhen et al. (2018), another Chinese-based educational study.

Limitations and further research

Some limitations of the present study should be acknowledged. First, the data regarding the rates of missing participants across four time points vary. Therefore, multiple imputations were used to handle the missing data. Second, as this study focuses on the achievement in mathematics, any generalizations of its findings to other subjects must be performed with caution. Third, the nested nature of the data was not considered, and it is acknowledged that the imbalanced development of education in Chinese schools is mainly due to school location, e.g. eastern China, western China, and urban or rural areas. Since the samples used in this study are from the same district, which is located in the rural area of western Beijing, it is assumed that students from different schools in this area have no significant differences with respect to the research question in this study. Further studies should be conducted using multilevel modelling to contain the nested data structure. Finally, students' perceived autonomy support was measured using the same questionnaire on four separate occasions. The test for measurement invariance across time indicates that this instrument is invariant across time, with the only exception being one item in year 2013. Hence, it could be considered as partially invariant across time (Schimitt and Kuljanin 2008). Lai et al. (2018) determined that, from a diagnostic perspective, partial invariance had a small impact on the efficiency of the items. However, whether the partial invariance has a substantial practical impact on research findings with respect to the purpose of prediction, as in this article, requires further study.

Appendix

Table 7 Correlations among perceived autonomy support, math achievement, classroom engagement, and autonomy need satisfaction

	1	2	3	4	5	6	7	8	9	10	11	12
1. Per_T1	1.00											
2. Per_T2	0.29**	1.00										
3. Per_T3	0.27**	0.44**	1.00									
4. Per_T4	0.13**	0.24**	0.34**	1.00								
5. Math_T1	0.02	− 0.01	− 0.04	0.06*	1.00							
6. Math_T2	0.00	0.02	− 0.01	0.10**	0.60**	1.00						
7. Math_T3	0.07**	0.04	0.04	0.12**	0.60**	0.72**	1.00					
8. Math_T4	0.04	0.04	0.01	0.15**	0.55**	0.66**	0.72**	1.00				
9. Enge_B	0.37**	0.30**	0.23**	0.26**	0.16**	0.15**	0.15**	0.17**	1.00			
10. Enge_E	0.36**	0.30**	0.21**	0.16**	0.00	0.02	− 0.02	0.01	0.63**	1.00		
11. Enge_C	0.28**	0.27**	0.20**	0.20**	0.05*	0.08**	0.06*	0.06*	0.58**	0.61**	1.00	
12. Auto_need	0.70**	0.29**	0.23**	0.18**	0.03	0.05*	0.09**	0.07**	0.44**	0.40**	0.32**	1.00

Per_T1 perceived autonomy support at T1, …, *Math_T1* math achievement at T1, …, *Enge_B* behavioural engagement, *Enge_E* emotional engagement, *Enge_C* cognitive engagement, *Auto_need* autonomy need satisfaction

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

References

Alexander, K. L., Entwisle, D. R., & Dauber, S. L. (1993). First-grade classroom behavior: its short- and long-term consequences for school performance. *Child Development, 64*(3), 801–814.

Archambault, I., Janosz, M., Fallu, J.-S., & Pagani, L. S. (2009). Student engagement and its relationship with early high school dropout. *Journal of Adolescence, 32*(3), 651–670.

Assor, A., Kaplan, H., & Roth, G. (2002). Choice is good, but relevance is excellent: autonomy-enhancing and suppressing teacher behaviours predicting students' engagement in schoolwork. *British Journal of Educational Psychology, 72*(2), 261–278.

Bentler, P., Bonett, D., & Hernstein, R. J. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin, 88*(3), 588–606.

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: a self-determination theory perspective. *Science Education, 84*(6), 740–756.

Bradley, R., & Corwyn, R. (2002). Socioeconomic status and child development. *Annual Review of Psychology, 53*(1), 371–399.

Browne, M., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. Bollen & J. Long (Eds.), *Testing structural equation models* (pp. 136–162). Newbury Park, CA: Sage.

Byrne, B. M. (1998). *Structural equation modeling with LISREL, PRELIS and SIMPLIS: basic concepts, applications and programming*. Mahwah: Lawrence Erlbaum Associates.

Carreira, J. M. (2012). Motivational orienations and psychological needs in EFL learning among elementary school students in Japan. *System, 40*(2), 191–202.

Carreira, J. M., Ozaki, K., & Maeda, T. (2013). Motivational model of English learning among elementary school students in Japan. *System, 41*(3), 706–719.

Cheng, L., Dou, D., Feng, C., Qi, C. X., & Martin, V. (2013). The relationship between learning motivation and mathematics literacy of 11-year old and 15-year-old students. *Studies of Psychology and Behavior (Pin Yin: Xin Li Yu Xing Wei Yan Jiu), 11*(1), 84–89.

Chirkov, V. I., & Ryan, R. M. (2001). Parent and teacher autonomy-support in Russian and U.S. adolescents: common effects on well-being and academic motivation. *Journal of Cross-Cultural Psychology, 32*(5), 618–635.

Connell, J. P., & Wellborn, J. G. (1991). Competence, autonomy, and relatedness - a motivational analysis of self-system processes. *Minnesota Symposia on Child Psychology, 23*, 43–77.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.

Deci, E. L., & Ryan, R. M. (2000). The 'what' and 'why' of goal pursuits: human needs and the self determination of behavior. *Psychological Inquiry, 11*(4), 227–268.

Deci, E. L., Schwartz, A., Sheinman, L., & Ryan, R. M. (1981). An instrument to assess adult's orientations toward control versus autonomy in children: reflections on intrinsic motivation and perceived competence. *Journal of Educational Psychology, 73*(5), 642–650.

Deci, E., Eghrari, H., Patrick, B., & Leone, D. (1994). Facilitating internalization: the self-determination theory perspective. *Journal of Personality, 62*(1), 119–142.

Diseth, A., Breidablik, H. J., & Meland, E. (2018). Longitudinal relations between perceived autonomy support and basic need satisfaction in two student cohorts. *Educational Psychology, 38*(1), 99–115.

Dupont, S., Galand, B., Nils, F., & Hospel, V. (2014). Social context, self-perceptions and student engagement: a SEM investigation of the self-system model of motivational development (SSMMD). *Electronic Journal of Research in Educational Psychology, 12*(1), 5–32.

Entwistle, N. (1991). Approaches to learning and perceptions of the learning environment. *Higher Education, 22*(3), 201–204.

Fortus, D., & Vedder-Weiss, D. (2014). Measuring students' continuing motivation for science learning. *Journal of Research in Science Teaching, 51*(4), 497–522.

Fredricks, J. A., & McColskey, W. (2012). The measurement of student engagement: a comparative analysis of various methods and student self-report instruments. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (p. 763e782). US: Springer.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59–109.

Grimm, K. J., Kuhl, A. P., & Zhang, Z. (2013). Measurement models, estimation, and the study of change. *Structural Equation Modeling, 20*(3), 504–517.

Gagné, M. (2003). The role of autonomy support and autonomy orientation in prosocial behavior engagement. *Motivation and Emotion, 27*(3), 199–223.

Hancock, G. R., & Choi, J. (2006). A vernacular for linear latent growth models. *Structural Equation Modeling, 13*(3), 352–377.
Hardré, P. L., & Reeve, J. (2003). A motivational model of rural students' intentions to persist in, versus drop out of, high school. *Journal of Educational Psychology, 95*(2), 347–356.
Hooper, D., Coughlan, J., & Mullen, M. R. (2008). Structural equation modelling: guidelines for determining model fit. *Electronic Journal of Business Research Methods, 6*(1), 53–60.
Hospel, & Galand. (2016). Are both classroom autonomy support and structure equally important for students' engagement? A multilevel analysis. *Learning and Instruction, 41*, 1–10.
Hu, L. T., & Bentler, P. M. (1998). Fit indices in covariance structure modeling: sensitivity to underparameterized model misspecification. *Psychological Methods, 3*(4), 424–453.
Jang, H., Kim, E. J., & Reeve, J. (2012). Longitudinal test of self-determination theory's motivation mediation model in a naturally occurring classroom context. *Journal of Educational Psychology, 104*(4), 1175–1188.
Jang, H., Kim, E. J., & Reeve, J. (2016). Why students become more engaged or more disengaged during the semester: a self-determination theory dual-process model. *Learning and Instruction*, 1–12.
Jang, H., Reeve, J., & Deci, E. L. (2010). Engaging students in learning activities: it is not autonomy support or structure but autonomy support and structure. *Journal of Educational Psychology, 102*(3), 588–600.
Jang, H., Reeve, J., Ryan, R. M., & Kim, A. (2009). Can self-determination theory explain what underlies the productive, satisfying learning experiences of collectivistically oriented Korean students? *Journal of Educational Psychology, 101*(3), 644–661.
Ladd, G. W., & Dinella, L. M. (2009). Continuity and change in early school engagement: predictive of children's achievement trajectories from first to eighth grade? *Journal of Educational Psychology, 101*(1), 190–206.
Lai, M. H. C., Richardson, G. B., & Mak, H. W. (2018). Quantifying the impact of partial measurement invariance in diagnostic research: an application to addiction research. *Addictive Behaviors, 94*, 50–56.
Laursen, B., & Little, T. D. (2012). *Handbook of developmental research methods*. Guilford Press.
Lee, V. E. (2000). Using hierarchical linear modeling to study social contexts: the case of school effects. *Educational Psychologist, 35*(2), 125–141.
Masters, G. N. (1982). A rasch model for partial credit scoring. *Psychometrika, 47*(2), 149–174.
Maydeu-Olivares, A., Shi, D., & Rosseel, Y. (2018). Assessing fit in structural equation models: a Monte-Carlo evaluation of RMSEA versus SRMR confidence intervals and tests of close fit. *Structural Equation Modeling: A Multidisciplinary Journal, 25*(3), 389–402.
McArdle, J. J. (2009). Latent variable modeling of differences and changes with longitudinal data. *Annual Review of Psychology, 33*, 577–605.
Meredith, W., & Tisak, J. (1990). Latent curve analysis. *Psychometrika, 55*(1), 107–122.
Muthén, B. O. (1991). Analysis of longitudinal data using latent variable models with varying parameters. In L. M. Collins & J. L. Horn (Eds.), *Best methods for the analysis of change: recent advances, unanswered questions, future directions* (pp. 1–17). Washington DC: American Psychological Association.
Muthén, L.K. and Muthén, B.O. (1998-2007). Mplus user's guide. Seventh Edition. Los Angeles, CA: Muthén & Muthén.
Noels, K. A. (2013). Promoting the motivation of Japanese learners of English through autonomy, competence, and relatedness. In M. T. Apple, D. Da Silva, & T. Fellner (Eds.), *Language learning motivation in Japan* (pp. 15–34). Bristol: Multilingual Matters.
Noels, K. A., Pelletier, L. G., Clément, R., & Vallerand, R. J. (2000). Why are you learning a second language? Motivational orientations and self-determination theory. *Language Learning, 50*(1), 57–85.
Ntoumanis, N. (2001). A self-determination approach to the understanding of motivation in physical education. *British Journal of Educational Psychology, 71*(2), 225–242.
Oga-Baldwin, W. L. Q., & Nakata, Y. (2017). Engagement, gender, and motivation: a predictive model for Japanese young language learners. *System, 65*, 151–163.
Oga-Baldwin, W. L. Q., Nakata, Y., Parker, P., & Ryan, R. M. (2017). Motivating young language learners: a longitudinal model of self-determined motivation in elementary school foreign language classes. *Contemporary Educational Psychology, 49*(C), 140–150.
Olsen, R., Prenzel, M., & Martin, R. (2011). Interest in science: a many-faceted picture painted by data from the OECD PISA study. *International Journal of Science Education, 33*(1), 1–6.
Pintrich, P. R. (2000). Multiple goal, multiple pathways: the role of goal orientation in learning and achievement. *Journal of Educational Psychology, 92*(3), 544–555.

Pintrich, P., & Harris, K. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology, 95*(4), 667–686.
Polyhart, R. E., & Vandenberg, R. J. (2010). Longitudinal research: the theory, design, and analysis of change. *Journal of Management, 36*(1), 413–422.
Rasch, G. (1960). Probabilistic models for some intelligence and attainment tests. (Copenhagen, Danish Institute for Educational Research). Expanded edition (1980), with foreword and afterword by B. D. Wright. Chicago, The University of Chicago Press.
Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educational Psychologist, 44*(3), 159–175.
Reeve, J., Jang, H., & Harris, K. R. (2006). What teachers say and do to support students' autonomy during a learning activity. *Journal of Educational Psychology, 98*(1), 209–218.
Reeve, J., & Tseng, C. (2011). Agency as a fourth aspect of students' engagement during learning activities. *Contemporary Educational Psychology, 36*(4), 257–267.
Reeve, J., Jang, H., Carrell, D., Jeon, S., & Barch, J. (2004). Enhancing students' engagement by increasing teachers' autonomy support. Motivation and Emotion, 28(2), 147–169.
Reeve, J., Nix, G., & Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *Journal of Educational Psychology, 95*(2), 375–392.
Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: classic definitions and new directions. *Contemporary Educational Psychology, 25*(1), 54–67.
Schimitt, N., & Kuljanin, G. (2008). Measurement invariance: review of practice an implications. *Human Rescource Management Review, 8*(4), 210–222.
Schuitema, J., Peetsma, T., & Van Der Veen, I. (2016). Longitudinal relations between perceived autonomy and social support from teachers and students' self-regulated learning and achievement. *Learning and Individual Differences, 49*, 32–45.
Senécal, C., Julien, E., & Guay, F. (2003). Role conflict and academic procrastination: a self-determination perspective. *European Journal of Social Psychology, 33*(2), 135–145.
Shernoff, D. (2013). *Optimal learning environments to promote student engagement* (Vol. 8167, Advancing responsible adolescent development). New York, NY: Springer New York.
Shih, S. S. (2009). An examination of factors related to Taiwanese adolescents' reports of avoidance strategies. *Journal of Educational Research, 102*(5), 377–388.
Skinner, E. A., & Belmont, M. J. (1993). Motivation in the classroom: reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology, 85*(4), 571–581.
Skinner, E., Furrer, C., Marchand, G., & Kindermann, T. (2008). Engagement and disaffection in the classroom: part of a larger motivational dynamic? *Journal of Educational Psychology, 100*(4), 765–781.
Soenens, B., & Vansteenkiste, M. (2005). Antecedents and outcomes of selfdetermination in 3 life domains: the role of parents' and teachers' autonomy support. *Journal of Youth and Adolescence, 34*(6), 589–604.
Standage, M., & Gillison, F. (2007). Students' motivational responses toward school physical education and their relationship to general self-esteem and health-related quality of life. *Psychology of Sport and Exercise, 8*(5), 704–721.
Stroet, K., Opdenakker, M.-C., & Minnaert, A. (2013). Effects of need supportive teaching on early adolescents' motivation and engagement: a review of the literature. Educational Research Review, 9(0), 65–87.
Sun, L., (2012). Primary school students' mathematics learning motivation current situation and strategy research. Northeast Normal University, Jilin, China, 2012.
Tong, X. (2014). A review on academic overburden among Chinese primary and middle school students. *Education Science Forum, 7*, 73–75.
Vansteenkiste, M., Niemiec, C. P., & Soenens, B. (2010). The development of the five mini-theories of self-determination theory: an historical overview, emerging trends, and future directions. In T. C. Urdan & S. A. Karabenick (Eds.), *Advances in motivation and achievement* (The decade ahead: theoretical perspectives on motivation and achievement) (Vol. 16, pp. 105–167). Bingley: Emerald Group.
Vansteenkiste, M., Sierens, E., Soenens, B., Luyckx, K., & Lens, W. (2009). Motivational profiles from a self-determination perspective: the quality of motivation matters. *Journal of Educational Psychology, 101*(3), 671–688.
Vansteenkiste, M., Zhou, M., Lens, W., & Soenens, B. (2005). Experiences of autonomy and control among Chinese learners: vitalizing or immobilizing? Journal of Educational Psychology, 97(3), 468–483.

White, R. W. (1959). Motivation reconsidered: the concept of competence. *Psychological Review, 66*(5), 297–333.

Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: a test of self-determination theory. *Journal of Personality and Social Psychology, 70*(4), 767–779.

Wu, W., & Wu, X. (2007). Zhong Xiao Xue Sheng Xue Xi Dong Ji De Fa Zhan Qu Shi Ji Qi Dui Xue Ye Cheng Ji De Ying Xiang (Pin Yin). *Chinese Psychological Society (Abstract)*.

Zhang, D., Bobis, J., Wu, X., & Cui, Y. (2018). *Research in Science Education*, https://doi.org/10.1007/s11165-018-9706-y

Zhang, D. H., Fu, D. M., Liu, H. Y., & Liu, L. M. (2018). Effect of Perceived Teacher's Autonomy Support on Students' Achievement: The mediating Role of Autonomy Psychological Need and Intrinsic Motivation. *Teacher Education Research (Pin Yin:Jiao Shi Jiao Yu Yan Jiu), 30*(1):79-86.

Zhen, R., Liu, R.-D., Ding, Y., Liu, Y., Wang, J., & Xu, L. (2018). The moderating role of intrinsic value in the relation between psychological needs support and academic engagement in mathematics among Chinese adolescent students. *International Journal of Psychology, 53*(4), 313–320.

Zhou, M. M., Ma, W. J., & Deci, E. (2009). The importance of autonomy for rural Chinese children's motivation for learning. *Learning and Individual Differences, 19*(4), 492–498.

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Wei, D., Zhang, D.H., Liu, H.Y. The Exploration and Application of Multidimensional Testlets Response Model in DIF Detecting. *Journal of Psychological Science* (Xin Li KeXue), in press.

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Zhang, D., Bobis, J., Wu X., & Cui, Y. (2018). The Effects of an Autonomy-Supportive Teaching Intervention on Chinese Physics Students and their Teacher. *Research in Science Education*, published online 12 April, 2018. https://doi.org/10.1007/s11165-018-9706-y.

Zhang, D., Cui, Y., Zhou, Y., & Liu, H. (2018). The role of school adaptation and self-concept in influencing Chinese high school students' Growth in math achievement. *Frontiers in Psychology, 9*:2356. https://doi.org/10.3389/fpsyg.2018.02356.

Guo, S., Li, L., & Zhang, D. (2018). A multilevel analysis of the effects of disciplinary climate strength on student reading performance. *Asia Pacific Education Review, 19*, 1–15.

Zhang, D* & Tang, X. (2017). The Role of Extracurricular Activities in Influencing Middle School Students' Science Learning in China. *International Journal of Science Education, V39*(10), 1381-1402.

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Most relevant publications in the field of Education:

Jiang F. & He J. (2017). Analysis on the Types of STEM Education Activities in China and Abroad. Information technology education in primary and secondary schools (Pin Yin: ZhongxiaoxueXinxiJishuJiaoyu),(11):64-70.

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Most relevant publications in the field of Psychology of Education::

Collie, R., Martin, A., Bobis, J., Way, J., & Anderson, J. (2019). How students switch on and switch off in mathematics: Exploring patterns and predictors of (dis)engagement across middle years and high school. *Educational Psychology, 39*(4), 489-509. https://doi.org/10.1080/01443410.2018.1537480.

Durksen, T., Way, J., Bobis, J., Anderson, J., Skilling, K., & Martin, A. (2017). Motivation and engagement in mathematics: A qualitative framework for teacher-student interactions. *Mathematics Education Research Journal, 29*, 163-181. https://doi.org/10.1007/s13394-017-0199-1.

Martin, A., Way, J., Bobis, J., & Anderson, J. (2015). Exploring the ups and downs of mathematics engagement in the middle years. *The Journal of Early Adolescence, 35*(2), 199-244. https://doi.org/10.1177/0272431614529365.

Martin, A., Anderson, J., Bobis, J., Way, J., &Vellar, R. (2012). Switching on and switching off in mathematics: An ecological study of future intent and disengagement amongst middle school students. *Journal of Educational Psychology, 104*(1), 1-18. https://doi.org/10.1037/a0025988.

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