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Connecting teacher and student motivation: Student-perceived teacher need-supportive practices and student need satisfaction

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ABSTRACT

According to Self-Determination Theory (SDT), teacher motivation affects student motivation indirectly via teaching practices that support the satisfaction of students' basic psychological needs, but studies have not shown evidence of this entire sequence. We tested the complete model: teacher motivation (autonomous, controlled, and amotivation) → perceived need-supportive practices (autonomy support, structure, and involvement) → student need satisfaction (autonomy, competence, and relatedness) → student motivation (autonomous, controlled, and amotivation) → student academic achievement. South Korean 5th and 6th graders ($N = 697$) and their 35 teachers participated in this study. A multi-level structural equation model showed evidence supporting: 1) a positive link between teacher and student autonomous motivation, and, 2) its mediation by student perceived need-supportive practices and student autonomy and competence. We discussed further conceptual and empirical consideration with the results.

1. Introduction

Teachers' motivations can influence their students' motivations (Reeve, 2002; Roth, 2014; Ryan & Deci, 2016). According to Self-Determination Theory (SDT; Ryan & Deci, 2000, 2016, 2017), teachers' motivation affects their teaching practices, especially practices that support students' sense of autonomy (i.e., autonomy support), provide structure (i.e., competence support), or communicate involvement (i.e., relatedness support). These practices help meet students' basic psychological needs for autonomy, competence, and relatedness, which in turn support their autonomous (i.e., self-directed) motivation. By contrast, insufficient need support undermines students' needs, which results in controlled motivation or amotivation (i.e., absence of motivation). Autonomously motivated students, and those whose psychological needs are satisfied, tend to learn more compared to students with controlled motivation or unsatisfied needs; amotivated students tend to learn the least of all (Reeve, 2002; Ryan & Deci, 2000, 2017).

Myriad studies provide evidence for many of the theorized processes connecting teacher and student motivation, however some links remain untested, particularly those involving amotivation, teacher involvement, and student relatedness. Examining relations among only some of these constructs involved may mask inherent complexity in applying the underlying theory (e.g., constructs may be theoretically but not empirically distinct), and thus provide an inaccurate or simplistic view of the processes it seeks to explain. Testing the empirical soundness of the complete theoretical model is therefore important. These results suggest areas for theoretical refinement (e.g., when autonomy support, structure, and involvement are perceived separately vs. holistically—in situations in which multiple types of need satisfaction interact), and implications for educators, particularly if results that the relative importance of practices differ across contexts (e.g., content areas, grade levels). To our knowledge, no published study has statistically connected teacher motivation and their need-supportive practices to student need satisfaction, motivation, and academic achievement, as proposed by SDT. Therefore, our study tested this complete model with: (a) teacher motivation (autonomous, controlled, amotivation), (b) student-perceived need-supportive practices (autonomy support, structure, involvement), (c) student satisfaction of their basic needs (autonomy, competence, relatedness), (d) student motivation (autonomous, controlled, amotivation), and (e) student academic achievement (see Fig. 1). We also tested whether student perceptions of teacher need-supportive practices and student need satisfaction mediate the links

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between teacher and student motivations.

1.1. Self-determination theory and education

SDT is a universal theory of motivation, claiming that autonomous motivation is always optimal. Central premises are that motivation is sensitive to one's context, and that theoretical tenets apply to people of all ages and cultures, in all aspects of life (Ryan & Deci, 2017). A few studies indicate variability in peoples' motivation across contexts. For example, children's reports of autonomy support from both teachers and parents vary from day-to-day (van der Kaap-Deeder, Vansteenkiste, Soenens, & Mabbe, 2017). Additionally, elementary school students' motivation varies by school subject (Guay et al., 2010), college students' motivation varies across courses relative to the support perceived from instructors (Yu & Levesque-Bristol, 2020), and relations between adolescents' autonomous motivation and achievement are content-area specific (Guay & Bureau, 2018).

Although the predominance of SDT-based studies were conducted with high school and college students, data from the elementary grades also provide considerable empirical support (e.g., Assor, Kaplan, & Roth, 2002; Domen, Hornstra, Weijers, van derVeen, & Peetsma, 2020; Guay, Roy, & Valois, 2017; Kurdi, Archambault, Brière, & Turgeon, 2018; Oga-Baldwin, Nakata, Parker, & Ryan, 2017; Roth, Assor, Kanat-Maymon, & Kaplan, 2007; Skinner & Belmont, 1993; Skinner, Furrer, Marchand, & Kindermann, 2008; van der Kaap-Deeder et al., 2017; Wang, Tian, & Huebner, 2019; Wei, Zhang, He, & Bobis, 2019). Nevertheless, studies with elementary grade students do not address all aspects of the theorized process. More research about possible developmental differences is needed.

The theoretical premise receiving most attention in the past decade involves the cultural universality of SDT. In particular, given the central role that SDT ascribes to perceived autonomy and autonomy support, researchers have questioned whether these constructs are crucial to the motivation of students not only in individualistic cultures but also in collectivist cultures. Ryan and Deci (2020) note that autonomy support encompasses students' perceptions that the unique challenges they face are appreciated, their perspectives are respected, and that they and their learning are supported, therefore feeling autonomous and that one's autonomy is encouraged is crucial for everyone. However, cultural norms and beliefs influence how specific behaviors are perceived (e.g., as autonomy-supporting or controlling) (Jang, Reeve, Ryan, & Kim, 2009; Ryan & Deci, 2020; Zhou, Lam, & Chan, 2012). For example, teaching practices that Western students tend to perceive as controlling and negative are typically viewed by Chinese students as less controlling and indicating teacher caring (Zhou et al., 2012). In short, SDT can be characterized as "universalism without uniformity" (Soenens, Vansteenkiste, & Petegem, 2015).

Motivation. SDT posits five qualitatively different types of motivation along a continuum from self-determined (i.e., autonomous) to non-self-determined (i.e., controlled) (Ryan & Deci, 2000). Although these types differ depending on the source of the motivation and the amount of control it imposes, "the most central distinction in SDT is between autonomous motivation and controlled motivation" (Deci & Ryan, 2008, p. 182). *Autonomous motivation* comprises intrinsic motivation, where inherent interest and enjoyment drive engagement, and integrated and identified regulation—types of autonomous extrinsic motivation arising from the activity being consistent with one's identity or one's own values and goals, respectively (Deci & Ryan, 2008; Ryan & Deci, 2020). *Controlled motivation* comprises introjected regulation, in which activity is motivated by feelings of guilt or a desire for approval, and external regulation, arising from a desire to gain reward or avoid punishment. Motivation may also be absent (i.e., amotivation) (Ryan & Deci, 2016).

Consistent with Deci and Ryan (2008; Ryan & Deci, 2017) conceptual distinction, SDT researchers typically conduct analyses with separate summary measures of autonomous (i.e., intrinsic motivation and identified regulation) and controlled (i.e., introjected and external regulation) motivation (e.g., Garn et al., 2019; Stroet, Opdenakker, & Minnaert, 2015; Vansteenkiste et al., 2012). Integrated regulation is usually not measured, because it is not operationally distinct from identified regulation, and is not salient to students (Roth et al., 2007; Vallerand et al., 1992). Researchers also sometimes further collapse subscales by subtracting controlled motivation from autonomous motivation scores (e.g., Katz & Shahar, 2015), or aggregating weighted subscale scores to create a composite self-determination index or measure of overall relative autonomy (Ryan & Deci, 2020; e.g., Pelletier, Séguin-Lévesque, & Legault, 2002; Yu & Levesque-Bristol, 2020).

Basic psychological needs. According to SDT, students are autonomously motivated when their basic psychological needs for autonomy (i.e., feeling psychologically free and self-determined), competence (i.e., feeling efficacious), and relatedness (i.e., feeling connected with others)

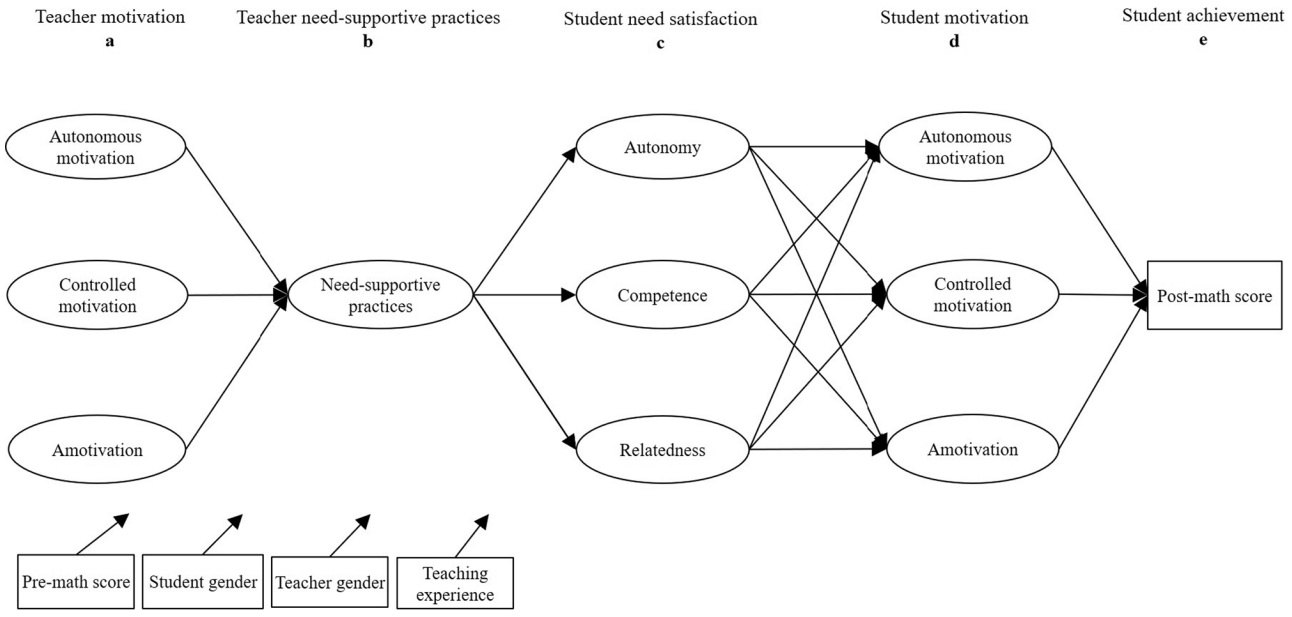

Fig. 1. Hypothesized model for the relations among teacher motivation, student perceptions of teacher need-supportive practices, student need satisfaction, student motivation, and student achievement.

are met. In contrast, when these needs are not satisfied, students' motivation tends to be controlled or even absent (amotivation) (Ryan & Deci, 2000, 2017).

Instruction that supports students' needs. SDT theory posits that teachers contribute to satisfying students' needs through the instructional practices they use (Reeve, 2002; Ryan & Deci, 2000, 2016). Specifically, teachers can promote student autonomy, competence, and relatedness by supporting autonomy, providing structure, and communicating involvement. *Autonomy supportive* practices include giving students meaningful choices; showing the relevance and value of the lessons' content; listening to students; using non-controlling language; and providing rationales for activities (Assor et al., 2002; Reeve & Jang, 2006). Practices that build and maintain organized, predictable learning environments provide *structure* and help students focus on learning. Examples include giving clear directions; expressing high but attainable expectations; providing guidance when students need help; and offering informative feedback (Haerens et al., 2013; Jang, Reeve, & Deci, 2010; Reeve, 2006). Teachers' *involvement* promotes their students' positive interpersonal relationships and sense of belonging to their class and school (Connell & Wellborn, 1991; Niemiec & Ryan, 2009). Teachers communicate involvement by interacting with students warmly and respectfully, being fair, showing trust, caring about students' learning, and investing time and effort to help them learn (Haerens et al., 2013; Stornes, Bru, & Idsoe, 2008).

Teachers' practices are interpreted by students and hence indirectly influence their need-satisfaction (Skinner et al., 2008). Students' perceptions are affected by their previous experiences and current thoughts and feelings, so students in the same class can perceive teacher practices differently. Moreover, some teachers provide differential instruction, such as autonomy support and structure (Domen et al., 2020), to students in the same class. For these reasons, student perceptions of teacher need-supportive practices are most relevant for student motivation. Consistent with this theoretical premise, a meta-analysis indicates that student reports are related significantly to their engagement and motivation, but the associations of teacher and observer reports are more modest or not statistically significant (Stroet, Opdenakker, & Minnaert, 2013). Accordingly, most studies examine student reports of their teachers' need-supportive practices (Stroet et al., 2013).

Although each type of need-supportive practice corresponds conceptually to a psychological need (e.g., autonomy support with the need for autonomy), types of support may satisfy multiple student needs. For example, perceived teacher autonomy support is associated positively with student competence and relatedness, in addition to autonomy (Jang et al., 2009).

Although conceptually different in theory, it is not clear that the three types of perceived need-supportive practices are empirically distinct in practice, especially for elementary grade students. Across studies that measured perceived teacher autonomy support, structure, and involvement, some results indicated three factors (e.g., Leenknecht, Wijnia, Loyens, & Rikers, 2017; Stornes et al., 2008), but others indicated one (Katz, Kaplan, & Gueta, 2009) or four (Haerens et al., 2013). Notably, the non has shown that elementary school students perceived three distinct types of teacher need-supporting practices, and one study provides some evidence suggesting they do not. Specifically, Katz and her colleagues' (2009) showed that fourth and eighth grade students viewed all teacher need-supporting practices as one factor. Additionally, third through sixth graders viewed teacher autonomy support and structure as a single construct (Domen et al., 2020; Oga-Baldwin et al., 2017). Identifying the perceived distinctiveness of types of need supports, and perhaps whether there are grade level differences in students' perceptions, is hampered by two research tendencies. First, SDT researchers tend to focus predominantly on autonomy support and pay less attention to structure and, especially, teacher involvement (Leenknecht et al., 2017). To understand how uniquely salient autonomy support, structure, and involvement are to students, all three types should be examined together. Second, researchers create a composite measure of perceived need-supportive practices but do not report the underlying factor analysis (e.g., Baeten, Dochy, & Struyven, 2013; Skinner et al., 2008; Taylor et al., 2014). Accordingly, we consider the factor structure of elementary students' perceived autonomy support, structure, and involvement scores in the present study.

In most studies, researchers analyzed the construct of need-supportive practices with *single-level factor analysis*, ignoring the *nested data* structure of students within classrooms, which can bias results (Huang & Cornell, 2016). Addressing this issue, Authors (2019) used *multilevel factor analysis* (Jöreskog & Sörbom, 2015) on students' perceived need support scores, and found that students perceived teacher need-supportive practices as a single construct, not three. In line with this finding, and given the mixed results noted in the previous paragraph, we used a multilevel, single-factor construct of perceived teacher need-supportive practice in this study.

1.2. Hypothesized sequence connecting teacher and student motivation

1.2.1. Teacher motivation and subsequent constructs

Teacher motivation and need-supportive practices. Teachers' motivation for teaching is associated with the extent to which their instruction supports their students' psychological needs. For example, autonomously motivated teachers tend to be perceived by students as using practices that foster student autonomy (Roth et al., 2007; Taylor et al., 2014; Van den Berghe, Tallir, Cardon, Aelterman, & Haerens, 2015), and report a preference for such practices (Abós, Haerens, Sevil, Aelterman, & García-González, 2018; Katz & Shahar, 2015; Pelletier et al., 2002). They are also generally perceived by students as supporting relatedness (Abós et al., 2018; Taylor & Ntoumanis, 2007) and providing structure (Taylor & Ntoumanis, 2007). By contrast, teachers whose motivation is controlled are perceived as providing less autonomy support, structure, and involvement than are autonomously motivated teachers (Van den Berghe et al., 2014). Amotivated teachers are viewed by students as providing little support for student autonomy or relatedness (Abós et al., 2018). Researchers have not simultaneously tested all critical links between the three teacher motivation types and three groups of need-supportive practices in a single study; therefore, we do so in this study.

Teacher motivation and student need satisfaction. Teacher motivation is presumed to influence student autonomy, competence, and relatedness, however it has received little empirical attention. We found only one somewhat related study; an analysis of data from the United States Early Childhood Longitudinal Study found that teachers' satisfactions of needs at work (perceived self-competence and relatedness), which theoretically undergird autonomous motivation, were not related to their students' perceptions of competence or relatedness, respectively (Marshik, Ashton, & Algina, 2017). In the present study, we tested the links between teacher motivation and student need satisfaction.

Teacher motivation and student motivation. Autonomously motivated teachers tend to have students who also express autonomous motivation (Lam, Cheng, & Ma, 2009; Roth et al., 2007). Similarly, student perceptions of their teacher's intrinsic motivation is related positively to their own intrinsic motivation, persistence, and interest (Radel, Sarrazin, Legrain, & Wild, 2010). In contrast, however, Taylor and Ntoumanis (2007) found no significant link between self-reported motivations of teachers and their students (both in aggregate and for each subscale). Hence, our study provides further evidence regarding the relation between teachers' and their students' motivations.

1.2.2. Need-supportive practices and subsequent constructs

Need-supportive practices and student need satisfaction. Myriad studies have confirmed the theoretical positive links between perceived teacher need-supportive practices and student need satisfaction. For example, autonomy support is related positively to student-reported autonomy, structure, and involvement (Jang et al., 2009; Taylor &

Ntoumanis, 2007). Similarly, perceived autonomy-supportive structure (combined autonomy support and structure) is related to aggregated autonomy, competence, and relatedness (Oga-Baldwin et al., 2017). Teacher structure is associated with student-perceived competence (Guay et al., 2017; Kurdi et al., 2018; Mouratidis, Vansteenkiste, Michou, & Lens, 2013) and relatedness (Kurdi et al., 2018); teacher involvement is also associated with student relatedness (Kurdi et al., 2018; Taylor & Ntoumanis, 2007).

Need-supportive practices and student motivation. Teacher need-supportive practices are linked to student motivation. Students tend to report feeling autonomously motivated or self-determined when they perceive their teacher as supporting student autonomy (Gillet, Vallerand, & Lafrenière, 2012; Roth et al., 2007; Taylor & Ntoumanis, 2007), providing structure (Roth et al., 2007; Taylor & Ntoumanis, 2007), or being involved (Taylor & Ntoumanis, 2007). Furthermore, perceived structure is related negatively to controlled motivation (Guay et al., 2017). When student-perceived need-supportive teaching is considered as a composite (i.e., two or three types aggregated), it is related positively to autonomous motivation and negatively to controlled motivation (Baeten et al., 2013; Domen et al., 2020; Katz et al., 2009; Leenknecht et al., 2017). Student perceptions of each of the three types of need-supportive practices, and their aggregate, are related negatively to student disaffection or amotivation (Skinner et al., 2008).

Teaching practices that support students' psychological needs mediate the link between teacher and student motivation. For example, perceived teacher support for student autonomy mediated the link between teacher and student autonomous: (Roth et al., 2007) or intrinsic (Radel et al., 2010) motivation. Similarly, perceived need-supportive instruction (comprised of teacher-provided challenge, relevance, choice, recognition, care, and warmth) mediated the link between teacher intrinsic motivation to teach and student intrinsic motivation to learn (Lam et al., 2009).

Need-supportive practices and student achievement. Instruction that supports student needs is linked to superior academic achievement (e.g., Jang, Kim, & Reeve, 2012; Leenknecht et al., 2017; Wei et al., 2019). Compared to other students, those who perceive more autonomy support from their teacher often have higher grade point averages (GPA; Black & Deci, 2000), higher test scores, deeper learning (Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004), and, in a sample of Chinese students, greater English proficiency (Hu & Zhang, 2017). Likewise, students who perceive greater teacher-provided structure (van Loon, Ros, & Martens, 2012) or involvement (Joe, Hiver, & Al-Hoorie, 2017) than other students do, tend to have higher academic achievement.

1.2.3. Student need satisfaction and subsequent constructs

Student need satisfaction and motivation. Students who report greater satisfaction of their needs than other students do, are often more autonomously motivated. Specifically, student-reported autonomy (Jang et al., 2009; Taylor & Ntoumanis, 2007), competence (Guay et al., 2017; Jang et al., 2009; Taylor & Ntoumanis, 2007; Xiang, Ağbuğa, Liu, & McBride, 2017), and relatedness (Furrer & Skinner, 2003; Zhou et al., 2012) are related positively to autonomous motivation and self-determination. Furthermore, aggregated need satisfaction (i.e., autonomy, competence, and relatedness composite) is related positively to autonomous and self-determined motivation (Garn, Morin, & Lonsdale, 2019; Joe et al., 2017; Kaplan, 2018), and negatively to controlled motivation (Garn et al., 2019) and amotivation (Standage, Duda, & Ntoumanis, 2005).

According to SDT, student need satisfaction should mediate the links between teacher and student motivation. To the best of our knowledge, no published study tested for this mediation; therefore, we do so in this study.

Student need satisfaction and achievement. Students who perceive greater satisfaction of their psychological needs than other students do often have higher academic achievement (Hu & Zhang, 2017; Oga-Baldwin et al., 2017; Wang et al., 2019). Measured separately, student autonomy (Jang et al., 2009, 2012; Soenens, Sierens, Vansteenkiste, Dochy, & Goossens, 2012), competence (Jang et al., 2009; Joe et al., 2017; Marshik et al., 2017; van Loon et al., 2012), and relatedness (King, 2015) are linked positively to their academic achievement.

1.2.4. Student motivation and achievement

Student motivation is linked to achievement. Specifically, students who are more autonomously motivated than others tend to have higher achievement, including grades and test scores (Baeten et al., 2013; Froiland, Davison, & Worrell, 2016; Guay & Bureau, 2018; Soenens & Vansteenkiste, 2005; Taylor et al., 2014; Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009). By contrast, amotivated students typically have the lowest test scores (Taylor et al., 2014).

Unlike these consistent findings for autonomous motivation and amotivation, results regarding the relation between controlled motivation and achievement are mixed. Some studies show a negative relation (e.g., Boiché, Sarrazin, Grouzet, Pelletier, & Chanal, 2008; Boiché & Stephan, 2014; Wang & Guthrie, 2004), whereas others show a positive relation (e.g., Datu, King, & Valdez, 2018; Taylor et al., 2014).

1.3. Summary of research

SDT posits the following causal sequence: teacher motivation → teacher need-supportive practices → student need satisfaction → student motivation → student academic achievement. Specifically, teacher motivation (autonomous [positively, +], controlled [negatively, −], and amotivation [negatively, −]) affects student perceptions of the teachers' use of need-supportive practice (combined autonomy support, structure, and involvement), which positively influences student need satisfaction. Student need satisfaction (autonomy, competence, and relatedness) positively affects their motivation (autonomous [+], controlled [−], or amotivation [−]), which influences their academic achievement. We test this complete model. Because studies show that student gender (Flunger, Mayer, & Umbach, 2019), teacher gender (Klassen & Chiu, 2010) and teaching experience (Louws, Meirink, van Veen, & van Driel, 2017) are linked to our outcomes, we add them to our statistical model to reduce *omitted variable bias* (Kennedy, 2008).

2. Method

2.1. Participants

Of the 697 participating students from 35 classrooms (M = 19.9 students per class) in three elementary schools in Seoul, South Korea, 385 were fifth graders and 312 were sixth graders, with slightly more girls (n = 368; 53%) than boys (n = 329; 47%). All participants were Korean, and between 10 and 12 years old (M = 11.09, SD = 0.96). All students had active parental consent. The 35 teachers comprised 6 males (17%) and 29 females. Their years of teaching experience varied substantially (M = 10.92 years, SD = 9.37 years).

2.2. Procedure

We surveyed students and teachers at the end of May, approximately three months into the school year. The teachers left their classrooms before we administered the student surveys. We assured students that we would keep their responses confidential. Teachers were asked to answer the survey by the end of the day and then seal it in the envelope provided for collection. We collected students' completed surveys at the end of class and teachers' completed surveys at the end of the day. Students' math test scores were collected from their school records. IRB approval was granted before data collection.

2.3. Measures

All questionnaire items had a 5-point Likert-scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). All items were in Korean and specific to mathematics lessons. As the two measures of teacher motivation and student perceived need-supportive practices were not available in Korean, we translated them from English, and a Korean-English bilingual colleague backward-translated them. The original and the backward-translated version were identical. All items are shown in the Appendix.

2.3.1. Teacher motivation

We measured teacher motivation with the 20-item teacher self-determination (Taylor & Ntoumanis, 2007); each of its five subscales (Intrinsic Motivation, Identified Regulation, Introjected Regulation, External Regulation, Amotivation) has 4 items. Each question begins with this stem: "I teach my class math because…" Here are sample items for *Intrinsic Motivation* (I think that teaching this class is interesting), *Identified Regulation* (I think teaching this class is good for me), *Introjected Regulation* (I want my colleagues to think I'm a good teacher), *External Regulation* (I am supposed to do it), and *Amotivation* (There may be good reasons for teaching this class, but personally I don't see any).

Following other researchers (e.g., Abós et al., 2018; Ratelle, Guay, Vallerand, Larose, & Senécal, 2007; Stroet et al., 2015), we combined the correlated Intrinsic Motivation and Identified Regulation scores (r = 0.72) to form *Autonomous Motivation* and combined the correlated Introjected Regulation and External Regulation scores (r = 0.63) to create *Controlled Motivation*. To increase convergent validity, we removed items with low factor loadings (i.e., <0.45; Jöreskog & Sörbom, 2015). The internal consistencies of the final three subscales were acceptable: 5 *Autonomous Motivation* items (Intrinsic Motivation and Identified Regulation; α = 0.88), 7 *Controlled Motivation* items (Introjected Regulation and External Regulation; α = 0.82), and 4 *Amotivation* items (α = 0.79).

2.3.2. Perceived need-supportive practices

We used the *Teacher as Social Context Questionnaire* (*TASCQ*; Belmont, Skinner, Wellborn, & Connell, 1992) to measure student perceptions of teacher need-supportive practices. The 24-item short form comprises three scales, each with eight items: *Autonomy Support* (e.g., My teacher gives me a lot of choices about how I do my schoolwork), *Structure* (e.g., My teacher makes sure I understand before he or she goes on), and *Involvement* (e.g., My teacher likes me). A multilevel factor analysis showed that after removing 6 items with low loadings (<0.45) or substantial cross-loadings (>0.45), a single factor with 18 items fit the data best ($\chi^2[304] = 557$, $p < .001$; CFI = 0.968; TLI = 0.951; SRMR = 0.056 (within) & 0.061 (between); RMSEA = 0.068 (for more details see Authors, 2019). The final scale comprised 18 items (7 Autonomy Support, 4 Structure, and 7 Involvement) and had good internal consistency (α = 0.89).

2.3.3. Student need satisfaction

The Korean Basic Psychological Needs Scale (K-BPNS; Lee & Kim, 2008) was adapted for Korean students from the English language Basic Psychological Needs Scale (BPNS; Center for Self-Determination Theory, 2019) and is used widely in South Korea. Its scores have shown good internal consistency reliability and validity (e.g., Heo & Kim, 2012). For example, autonomy, competence, and relatedness are related positively, as expected, to student engagement (Kim & Kim, 2011) and school satisfaction (Sung & Kim, 2017). Each K-BPNS subscale originally comprised five items, but in the present study two Autonomy items with factor loadings less than 0.45 were removed. This resulted in three *Autonomy* items (e.g., In math class I feel that I am free to decide for myself how to work, α = 0.65), five *Competence* items (e.g., … I feel that I am very effective, α = 0.79), and five *Relatedness* items (e.g., … I feel that people care about me, α = 0.75). Although the alpha of the autonomy scale was less than ideal, it resembles that attained by Jang and her colleagues (2012) with South Korean middle school students (i.e., 0.67). Nevertheless, results involving students' autonomy must be interpreted cautiously.

2.3.4. Student motivation

The Korean Academic Self-Regulation Questionnaire (K-SQR-A; Kim, 2002) measures student motivation with five subscales comprising 25 items. Kim (2002) created the K-SQR-A by adapting and translating four subscales (Intrinsic Motivation, Identified Regulation, Introjected Regulation, and External Regulation) of the Academic Self-Regulation Questionnaire (SRQ-A; Ryan & Connell, 1989) into Korean, and developing the Amotivation subscale. Scores have shown good internal consistency reliability and validity (e.g., Institute, 2007). For example, autonomous motivation is related, as expected, to student engagement and achievement (Kim & Kim, 2014). All items begin with the stem "I study math because…." Each subscale has 5 items: *Intrinsic Motivation* (e.g., "I enjoy studying math"), *Identified Regulation* (e.g., "I believe accumulating knowledge is valuable"), *Introjected Regulation* (e.g., "I want the teacher to think I'm a good student"), *External Regulation* (e.g., "My parents will be angry if I don't do it"), and *Amotivation* (e.g., "I don't know what to do in class"). As with teacher motivation scores, we combined students' correlated Intrinsic Motivation and Identified Regulation scores (r = 0.71) to form Autonomous Motivation and combined the Introjected Regulation and External Regulation scores (r = 0.68) to create Controlled Motivation. These items formed three subscales, with five items removed because of low (i.e., < 0.45) factor loadings, yielding: 9 *Autonomous Motivation* items (α = 0.90), 7 Controlled motivation items (α = 0.80), and 4 *Amotivation* items (α = 0.76).

2.3.5. Student achievement

The Korea Education and Research Information Service (KERIS) provides a test bank of statistically-validated test questions for teachers in South Korea to use in their students' exams. Test bank questions correspond to the learning goals of the national curriculum.

At the beginning of the school year, teachers administered diagnostic tests to assess achievement of the previous year's learning goals (*pre-math* score). Students' math test scores at the end of the first semester served as the *post-math* score. Both pre- and post-math achievement tests were pencil-and-paper tests with maximum scores of 100 points.

2.4. Plan of analyses

We properly address missing data, analyze nested data, and simultaneously test for multiple mediation effects with *Markov Chain Monte Carlo multiple imputation, multilevel analysis*, and a *multilevel structural equation model*, respectively. As missing data can bias results, reduce estimation efficiency, or complicate data analyses, we used *Markov Chain Monte Carlo multiple imputation* to estimate the values of the missing data; this method outperforms deletion, mean substitution, and simple imputation, according to computer simulations (Peugh & Enders, 2004). Only 1% of our data was missing, and we could not determine any clear pattern of its missingness (e.g., whether it was missing at random or not at random). As students taught by the same teacher in the same school likely resemble one another more than those taught by different teachers in different schools (*nested data*), an ordinary least squares regression underestimates the *standard errors*, so we use a *multilevel analysis* to estimate them with greater precision (Goldstein, 2011; also known as *hierarchical linear modeling*, Bryk & Raudenbush, 1992). Separate, single-level mediation tests on nested data can bias results, so we test for simultaneous, multi-level mediation effects with a *multi-level structural equation model* (Crandall, Preacher, Bovaird, Card, & Little, 2012).

2.4.1. Explanatory model

We entered the variables according to time constraints, expected causal relationships, and likely importance.

$$Post-Math_{ijk} = \beta + g_k + f_{jk} + e_{ijk} \quad (1)$$

The *post-math* score of student *i* in class *j* in school *k* has grand mean intercept β and unexplained components (*residuals*) at the school-, class- and student-levels: g_k, f_{jk} and e_{ijk}. If a *variance components* model did not show significant variance at any of these levels, we removed those levels from the multilevel analysis (Goldstein, 2011).

To control for past achievement, we first entered *Pre-math* score. Then we added a **vector** of student and teacher demographics variables: student gender, teacher gender, and years of teaching experience (**Demography**). Next, we entered teacher motivation variables regarding autonomous, controlled, and amotivation (**Teacher_Motivation**). Then, we added perceived *Need-supportive practices*. Next, we entered student need satisfaction variables regarding autonomy, competence, and relatedness (**Student_Satisfaction**). Lastly, we added student motivation variables regarding autonomous, controlled, and amotivation (**Student_Motivation**).

To assess the fit of the final ML-SEM, we used the comparative fit index (CFI), Tucker–Lewis index (TLI), standardized root mean square residual (SRMR) and root mean square error approximation (RMSEA), which often minimizes Type I and Type II errors as shown in Hu and Bentler (1999) simulations. Fit thresholds are as follows: good (CFI & TLI > 0.95; SRMR < 0.08; RMSEA < 0.06), moderate (0.90 < CFI & TLI < 0.95; 0.08 < SRMR < 0.10; 0.06 < RMSEA < 0.10), and poor (CFI & TLI < 0.90; SRMR & RMSEA > 0.10). The *total effect* (TE) of an explanatory variable on the outcome is the sum of its direct effects and indirect effects.

The statistical power of our sample differs for the teacher and student levels (Konstantopoulos, 2008). We used α = 0.05. With 697 students, statistical power exceeded 0.99 for an effect size of 0.2. With only 35 teachers, statistical power is only 0.68 for an effect size of 0.4. As low statistical power raises the likelihood of *false negatives* at the teacher level, we retain confidence in our significant results but not in our non-significant results at that level (Kennedy, 2008). Because most of our variables are the student level (e.g., student perceptions of teacher need-supportive practices), only interpretations involving teacher-level data and results (e.g., teacher gender) are especially vulnerable to false negatives.

$$\begin{aligned} Post-Math_{ijk} = {} & \beta_{000} + \boldsymbol{g}_k + \boldsymbol{f}_{jk} + \boldsymbol{e}_{ijk} + \beta_{pjk} Pre-Math_{ijk} + \beta_{djk} \boldsymbol{Demography}_{ijk} + \beta_{tk} \boldsymbol{Teacher\_Motivation}_{ijk} + \beta_{nk} Need-supportive\_practices_{ijk} \\ & + \beta_{sjk} \boldsymbol{Student\_Satisfaction}_{ijk} + \beta_{djk} \boldsymbol{Student\_Motivation}_{ijk} \end{aligned} \quad (2)$$

Because testing many hypotheses increases the likelihood of a *false positive*, we controlled for the *false discovery rate* (FDR) via the *two-stage linear step-up procedure*, which outperformed 13 other methods in computer simulations (Benjamini, Krieger, & Yekutieli, 2006). As removing non-significant explanatory variables does not cause *omitted variable bias*, we safely removed them to increase accuracy and reduce *multicollinearity* (Kennedy, 2008).

We used multi-level mediation tests across the above vectors (MacKinnon, Lockwood, & Williams, 2004). Then, the final regression model with significant mediators served as the initial ML-SEM candidate. We removed non-significant parameters to obtain the final ML-SEM.

3. Results

3.1. ICC and summary Statistics

Most variables did not vary much across classes; student perceived teacher need-supportive practices is a notable exception (intra-class correlation [ICC] = 19%). See Table 1 for ICCs, means, standard deviations, skewness, kurtosis, and reliability coefficients. See Table 2 for correlations. The correlations showed the patterns expected by SDT among variables. Teachers' and students' autonomous motivation were related positively to perceived need-supportive practices and student need satisfaction, whereas teachers' and students' amotivation were related negatively to these variables. Of note, teachers' and students'

Table 1
Descriptive Statistics for Student and Teacher Variables and Intra Class Coefficients (ICC).

Variable	No. of items	*M*	*SD*	Skewness	Kurtosis	α	ICC
Teacher Report (*N* = 35)							
Female		0.85	0.36	−1.94	4.75		
Years teaching		10.95	8.48	0.72	2.58		
Motivation							
Autonomous	5	3.81	0.75	−0.29	−0.56	0.88	—
Controlled	7	3.57	0.80	−0.89	1.20	0.82	—
Amotivation	4	2.07	0.76	0.06	−1.06	0.79	—
Student Report (*N* = 697)							
Girl		0.53	0.50	−0.11	1.01		
Teacher Need-Supportive Practices	18	3.51	0.64	−0.26	0.25	0.89	0.19
Need Satisfaction							
Autonomy	3	3.87	0.80	−0.81	1.09	0.65	0.05
Competence	5	3.33	0.80	−0.11	0.03	0.79	0.02
Relatedness	5	3.54	0.77	−0.23	0.06	0.75	0.02
Motivation							
Autonomous	9	3.44	0.86	−0.25	−0.22	0.90	0.06
Controlled	7	2.49	0.84	0.17	−0.56	0.80	0.04
Amotivation	4	2.23	0.90	0.64	0.13	0.76	0.05
School Report (*N* = 697)							
Pre-test score		82.28	16.01	−1.15	4.06		
Post-test score		83.29	15.52	−1.56	5.99		

Table 2
Zero-Order Correlations for All Student and Teacher Variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Teacher ($N = 35$)															
1. Gender	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2. Teaching Experience	−0.28	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3. Autonomous Motivation	−0.04	0.40*	—	—	—	—	—	—	—	—	—	—	—	—	—
4. Controlled Motivation	−0.02	0.25	−0.07	—	—	—	—	—	—	—	—	—	—	—	—
5. Amotivation	−0.19	−0.34*	−0.70**	−0.02	—	—	—	—	—	—	—	—	—	—	—
Student ($N = 697$)															
6. Gender	−0.03	0.01	−0.02	0.00	0.02	—	—	—	—	—	—	—	—	—	—
7. Pre-math score	0.00	0.06	0.05	0.01	−0.03	0.03	—	—	—	—	—	—	—	—	—
8. Perceived Teacher Need-Support	0.23**	−0.21**	0.09*	0.00	−0.14**	0.01	0.18**	—	—	—	—	—	—	—	—
9. Autonomy	0.10**	−0.04	0.11**	0.06	−0.10*	−0.09*	0.21**	0.40**	—	—	—	—	—	—	—
10. Competence	0.02	0.04	0.08*	0.07	−0.09*	0.00	0.39**	0.36**	0.42**	—	—	—	—	—	—
11. Relatedness	0.09*	0.00	0.08*	0.02	−0.07	0.06	0.24**	0.42**	0.44**	0.63**	—	—	—	—	—
12. Autonomous Motivation	0.04	−0.02	0.07	0.06	−0.06	−0.07	0.35**	0.37**	0.45**	0.69**	0.47**	—	—	—	—
13. Controlled Motivation	−0.03	0.09*	−0.01	0.03	−0.01	0.09*	0.10*	−0.07	−0.18**	0.18**	0.09*	0.14**	—	—	—
14. Amotivation	−0.09*	0.04	−0.07	−0.08*	0.07	0.14**	−0.27**	−0.32**	−0.57**	−0.47**	−0.37**	−0.64**	0.07	—	—
15. Post-math score	0.09*	0.05	0.07	0.04	−0.10*	0.05	0.75**	0.20**	0.24**	0.41**	0.23**	0.36**	0.06	−0.31**	—

[a]Gender was coded 0 = male and 1 = female. * $p < .05$. ** $p < .01$.

controlled motivation were weakly or not significantly related to those variables.

3.2. Explanatory model

Pre-math scores, demographics, teacher motivation, student perceived need-supportive practices, student need satisfaction, and student motivation were all linked to post-math scores, and the final ML-SEM showed a good fit (SRMR = 0.059; CFI = 0.960; TLI = 0.957; RMSEA = 0.058; $\chi^2[928] = 2.798$, $p < .001$; see Fig. 2). This SEM accounted for over 40% of the differences in students' post-math scores (squared multiple correlation = 0.408). All significant explanatory variables are described below; all $p < .001$ except for girl ($p < .01$). All coefficients are standardized.

3.2.1. Theoretical premises

We confirmed several fundamental premises of SDT: Teacher need-supportive practices satisfy student basic needs, which facilitate student autonomous motivation, which in turn aids achievement. Students who perceived greater need-supportive practices than other students reported more autonomy (+0.490 [direct effect]) and competence (+0.383). Students who perceived more autonomy or competence than other students had more autonomous motivation (+0.187 or +0.777, respectively). Students with more autonomous motivation than other students had higher achievement (+0.226).

3.2.2. Teacher and student motivation

Teacher motivation was positively linked to student motivation. Specifically, teachers with more autonomous motivation had students with more autonomous motivation (TE = +0.191). In contrast, neither teachers' controlled motivation nor amotivation were significantly linked to those of their students.

3.2.3. Mediation by teacher need-supportive practice and student need satisfaction

Together, perceived need-supportive practices and student need satisfaction fully mediated the relations between teacher and student motivation. Teachers with greater autonomous motivation than other teachers were perceived by their students to use more need-supportive practices (+0.174); students in turn had more autonomy (+0.490) and competence (+0.383), so teacher autonomous motivation was linked to both student autonomy and competence (TEs = +0.085 and +0.067, respectively). In addition to their links with need-supportive practices, students with more autonomy or more competence than other students had more autonomous motivation (+0.187 and +0.777, respectively); hence, students with more perceived need-supportive practices than other students had more autonomous motivation (TE = 0.389).

Significant control variables included the following. Students with higher pre-test scores perceived greater levels of teacher need-supportive practices (TE = 0.010), autonomy (TE = 0.009) and competence (TE = 0.020), and post-test scores (TE = 0.033). Also, girls reported lower autonomy than boys (TE = −0.243). Female teachers reported higher autonomous motivation (TE = 0.760) and were perceived as more need-supportive (TE = 0.640), compared to male teachers. Also, teachers with more years of experience than other teachers reported greater autonomous motivation (TE = 0.038) but were perceived lower levels of need-supportive practices (TE = −0.019). All other explanatory variables were not significantly linked to the outcomes (e.g., student gender was not linked to student-reported competence). Furthermore, all significant links were at the student level. None of the classroom links were significant.

4. Discussion

In this SDT-based study, we tested a model of teacher motivation and student perceived teacher need-supportive practices, need satisfaction,

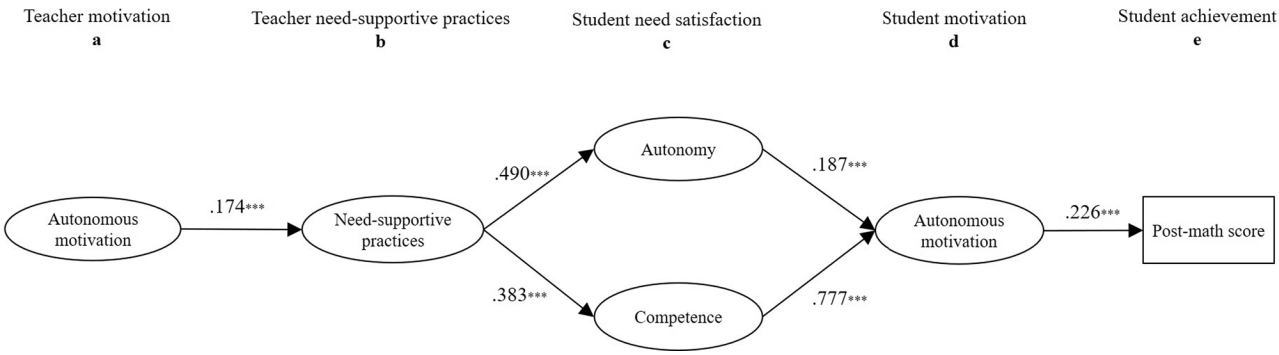

Fig. 2. Path diagram of standardized final SEM model predicting students' post-test scores. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$. (SRMR = 0.059; IFI = 0.960; TLI = 0.957; RMSEA = 0.058; $\chi^2[928] = 2798$). *Note*. Control variables - Students with higher pre-test achievement perceived greater levels of perceived teacher need-supportive practices (TE = 0.010), autonomy (TE = 0.009) and competence (TE = 0.020), and post-test achievement (TE = 0.033). Also, girls reported lower autonomy than boys (TE = −0.243). Regarding teachers, female teachers tend to have higher autonomous motivation (TE = 0.760) and be perceived as more need-supportive (TE = 0.640), compared to male teachers. Also, teachers with more years of experience had higher autonomous motivation (TE = 0.08) but fewer need-supportive practices (TE = −0.019).

motivation, and achievement, unlike past studies that tested only parts of it. To the best of our knowledge, this is the first study to do so. Furthermore, we focused on teachers and students in upper elementary school, in contrast to the majority of research with middle school through university students. As we expected, more autonomously motivated teachers were perceived by students to engage in more need-supportive practices (perceived as a single construct), which correlated positively with student-reported autonomy, competence, and relatedness. With the full model, however, only autonomy and competence were related significantly to perceived need-supportive teaching. Both self-reported autonomy and competence accompanied student autonomous motivation, which in turn was linked to achievement; student relatedness was not uniquely related to autonomous motivation.

Our findings are consistent with many of those from past studies, but not all of them. Hence, they raise questions for further conceptual and empirical consideration. First, students did not perceive teacher autonomy support, structure, and involvement practices as distinct, thereby raising the question of developmental differences in student perceptions. Second, the non-significant associations of student relatedness with need-supportive practices and with autonomous motivation show the utility of considering all constructs together rather than only a few constructs in isolation. And third, our finding of the strong negative correlation between autonomous motivation and amotivation raises questions about their distinctiveness, at least in elementary school.

4.1. Student perceptions of teacher need-supportive practices

One important result was that students did not perceive teacher autonomy support, structure, and involvement as separate constructs. This finding contributes to the discussion about the inconsistency in factor structure of student-perceived need-supportive practices (Authors, 2019; Leenknecht et al., 2017). It also indicates that further research is needed to consider *when* students perceive teacher need-supports holistically. Of note, our result is consistent with those of other studies with elementary grade students in several countries that also found a single need-supportive factor (Domen et al., 2020; Katz et al., 2009; Oga-Baldwin et al., 2017). Therefore, differences across studies may reflect developmental variability in students' perceptions of teacher instructional practices. The issue of developmental differences is a crucial one that few SDT researchers have considered. An exception is Assor and his colleagues (2002), who found that both 3rd-5th graders and 6th-8th graders differentiated between the autonomy-enhancing and autonomy-suppressing practices of their teachers in similar ways.

Developmental differences in students' perceptions of teachers' need-supportive practices are likely. Our study contributes strong evidence for the argument that young children attend to teachers' practices for autonomy support, structure, and involvement, together, when perceiving the extent to which their teacher supports their psychological needs. This is important information that has not been emphasized to date, and it has implications for both the nature of researchers' studies and their recommendations for educators.

4.2. Role of student relatedness

Interestingly, despite moderate correlations among them, perceived need-supportive practices were not uniquely linked to students' feelings of relatedness when competence and autonomy were also included in the model. The non-significant link between perceived need-supportive teaching and student relatedness contrasts with findings from other studies showing significant associations with relatedness. For example, Taylor and Ntoumanis (2007) found that student relatedness is associated significantly with perceived teacher autonomy support, structure, and involvement. However, in contrast with our study, they conducted three separate analyses (one for each type of practice) and therefore did not consider the correlations among outcomes and among explanatory variables, which can yield biased results (Kennedy, 2008).

Our results also differ from findings that student relatedness is associated with student perceptions of autonomy support (Jang et al., 2009) and with teacher-reported involvement (Kurdi et al., 2018), and that combined student-perceived autonomy support and structure is related to an aggregate of student autonomy, competence, and relatedness (Oga-Baldwin et al., 2017). However, we found no other study comparable to ours, whereby student reports of autonomy support, structure, involvement, autonomy, competence, and relatedness were included in a single model.

Similar to past studies (Jang et al., 2009; Taylor & Ntoumanis, 2007), our results show that when the three student needs were included in the same model, autonomy and competence were significantly related to autonomous motivation and self-determination. However, relatedness was not significantly related to autonomous motivation or self-determination, despite its significant correlation with autonomous motivation ($r = 0.47$). Few studies include student reports of autonomy, competence, relatedness, autonomous and controlled motivation, and amotivation as separate constructs in a single model, which limits comparisons with our findings. Furthermore, researchers sometimes aggregate autonomy, competence and relatedness (e.g., Garn et al., 2019), which also limits comparisons. Nevertheless, our results are consistent with the contention that relatedness is less central than autonomy and competence to autonomous motivation (Ryan & Deci, 2016). That said, it may be fruitful to investigate whether student relatedness is differentially significant (i.e., moderated).

Although researchers often focus on main effects, recent studies

showed how relatedness moderates other associations. Kurdi and her colleagues (2018) found that both student achievement and anxiety moderated the link between teacher involvement and student relatedness. Specifically, elementary grade students who were both highly anxious and high achieving reported similar perceptions of relatedness regardless of the extent of teacher involvement, whereas the relatedness of highly anxious, low achieving students differed by teacher involvement. And in challenging undergraduate STEM courses, perceived relatedness both with the instructor and with classmates significantly and independently moderated how perceived autonomy and competence were associated with adaptive and maladaptive help seeking (Oh, 2020). Further research may identify other situations where perceived relatedness plays a significant role in concert with other factors.

Like past international studies showing that relatedness is higher and has less variance in collectivist countries than individualist ones (Chiu, Chow, McBride, & Mol, 2016), our South Korean data show high student-reported relatedness with low variance (see Table 1). The low variance in collectivist countries (Chiu et al., 2016) reduces the statistical likelihood of its significant links with other variables (Kennedy, 2008). This might help explain why relatedness showed a significant bivariate correlation with controlled motivation (see Table 2), but no significant link after controlling for other variables (see Fig. 2). Because student competence and relatedness were highly correlated ($r = 0.63$), another possible explanation is multicollinearity. Thus, our result does not necessarily indicate that student relatedness is unimportant for their academic motivation and achievement; future studies with larger samples can test this possible link more precisely.

4.3. Associations between autonomous motivation and amotivation

Because amotivation and autonomous motivation were strongly and negatively correlated among both students and teachers in our study (see Table 2), they cause multicollinearity; the variable with weaker links to other outcomes (amotivation) is no longer significant in statistical models (Kennedy, 2008). This multicollinearity and non-significant result are consistent with past studies (Gillet et al., 2012), and raise the issue of whether amotivation and the lack of autonomous motivation are empirically distinct. If not, it might explain why most studies that include autonomous, controlled, and amotivation either (a) use a single composite score rather than three separate motivation scores (e.g., Lavigne, Vallerand, & Miquelon, 2007; Taylor & Ntoumanis, 2007), or (b) model each motivation type separately (e.g., De Meyer et al., 2014; Stroet et al., 2015). If studies consistently show that teachers, or students, with high autonomous motivation also report low amotivation, and those with low autonomous motivation have high amotivation, it may be that amotivation is not an empirically-useful, independent construct, and researchers can stop using it. Note that this relation might change across time; autonomous and amotivation might be more independent in earlier or later grades; as few studies have examined autonomous, controlled, and amotivation in elementary school, future studies can consider this issue.

The correlations between autonomous motivation and controlled motivation for both teachers and students in our South Korean data are consistent with past studies in collectivist countries and help explain these non-significant effects of controlled motivation. Unlike individualistic countries (e.g., United States), collectivist ones (e.g., South Korea) value group goals over individual ones. Students in collectivist cultures attend closely to one another's concerns, so they tend to interpret external influences as caring (Chiu & Chow, 2010). In contrast, students who value autonomy in individualistic societies often view external influences as intrusive (Chiu, Chow, & Mcbride-Chang, 2007). Consistent with past studies (e.g., D'Ailly, 2003; You & Dörnyei, 2016), autonomous motivation and controlled motivation are not significantly negatively correlated in collectivist countries like South Korea for both teachers and students (see Table 2), which can help explain these non-significant effects of controlled motivation. These results show the importance of both research studies in diverse countries and inclusion of cultural values as moderators in multi-country meta-analyses.

4.4. Relations between teacher and student motivation and their mediators

We found that autonomously motivated teachers tended to also have autonomously motivated students, consistent with past studies (e.g., Lam et al., 2009; Radel et al., 2010; Roth et al., 2007). This finding raises the interesting question of whether having autonomously motivated teachers teach amotivated students would increase those students' autonomous motivation. If so, further research can (a) identify school policies that increase teacher autonomous motivation (e.g., giving teachers autonomy over teaching materials, curriculum design, and classroom management [Pelletier et al., 2002]) or (b) develop suitable interventions to improve teacher autonomous motivation by satisfying teacher needs. Such school policies might include reducing administrative pressures (fulfilling the need for autonomy; Pogodzinski, 2015; Ryan & Deci, 2016), encouraging shared analysis of lesson videos to improve instruction (fulfilling the need for competence; Christ, Arya, & Chiu, 2014), or providing a teacher mentoring program for novice teachers (fulfilling the need for relatedness; Pogodzinski, 2015).

The link between teacher and student autonomous motivation was fully mediated by perceived need-supportive practices and student need satisfaction, consistent with past studies supporting parts of this model (e.g., Jang et al., 2012; Katz & Shahar, 2015; Lam et al., 2009; Roth et al., 2007; van Loon et al., 2012). Our finding also accords with the theoretical premise that teachers with more autonomous motivation use more need-supportive practices that help satisfy their students' needs for autonomy and competence, which fosters students' autonomous motivation to learn more mathematics (Roth, 2014).

It is arguably worthwhile to test whether pre-service or in-service teacher development programs designed to enhance teachers' capacity to improve their students' motivation and learning outcomes are effective because of the practices they use and the extent to which they support and satisfy students' psychological needs (e.g., Cheon, Reeve, Lee, & Lee, 2018; Cheon & Reeve, 2015). Our results support these studies by providing evidence of the full process from teacher motivation to student motivation and achievement.

4.5. Practical implications, limitations, and future directions

This study shows that teachers' autonomous motivation has positive implications for their students' learning and motivation. Accordingly, educators must consider how to promote teachers' autonomous motivation via fostering greater teacher autonomy (e.g., by including teachers in decision-making processes, providing freedom to create/modify curricula/materials and determine their classroom management practices), competence (e.g., attending professional development to update teaching practices, mentoring), and relatedness (e.g., ensuring a supportive working environment, respectful communication with administrators). Both districts and schools can enact these steps via their respective policies, procedures and practices.

By showing the link between teacher motivation and students' learning and motivation, our study suggests that policies that undermine teachers' autonomous motivation are unlikely to benefit students. For example, policies intended to increase teacher accountability can be highly controlling and prescriptive, and have unintended negative consequences of loss of autonomous motivation for teachers and students (e.g., Olsen & Sexton, 2009; Ryan & Brown, 2005). Our study suggests that policies that support teachers' psychological needs and motivation might be more effective in raising student achievement.

Limitations of our study include its convenience sample, limited measures, and cross-sectional data. The convenience sample included data from only fifth- and sixth-graders, mostly female teachers, and from three schools in one country, so future studies can include representative

samples of students and teachers in more grade levels and from multiple countries. In many countries, however, elementary school teachers are predominantly female (Organisation for Economic Co-operation and Development, 2017), so it may be difficult to include comparable numbers of male and female teachers.

We used only student reports of their teacher's need-supportive practices. Future studies can include reports from others (e.g., teachers, school administrators, researcher observers) about these practices; doing so would further test the validity of the model. However, given the central role of student perceptions in interpreting teacher behaviors, and the finding that teacher and observer reports have low or no associations with student motivation, at least for early adolescent students (Stroet et al., 2013), it is important to understand how students interpret their teachers' behavior and the reasons for why the same practices are interpreted differently by students in the same class. In one such study, Wallace and Sung (2017) questioned students about specific teacher practices after showing them video clips from their classroom; more studies like this are crucial in bridging theory and empirical findings with practical suggestions for educators.

Because we, like others (e.g., Jang et al., 2012), found borderline internal consistency in measuring South Korean student autonomy, researchers can develop an alternate instrument with greater reliability for these students. We note, however, that researchers in other countries have also found low internal consistency for student self-reported autonomy (Leenknecht et al., 2017).

In future studies with different populations, researchers can further examine whether Intrinsic Motivation and Identified Regulation subscale scores constitute a single index of autonomous motivation, and whether Integrated Regulation and External Regulation scores cohere to measure controlled motivation. Although combining subscales in this fashion is a well-established convention, researchers often do not report the factor analysis needed to validate this process (Guay et al., 2017; Stroet et al., 2015). Furthermore, reported factor analyses showed inconsistent empirical support. Some studies show support for the aggregated measures (e.g., Garn et al., 2018; Vansteenkiste et al., 2009) but others show support for separate scales (e.g., Guay & Bureau, 2018; Roth et al., 2007). Therefore, further studies can help discern reasons for the varying results, such as whether the factor structure of motivation types differ developmentally or across content areas.

As our data were cross-sectional, we could not test inferences about temporal precedence or directions of causality; future studies can use longitudinal data to do so. Longitudinal research can include examining the extent to which associations between student and teacher motivation are reciprocal, and possible moderators (e.g., student gender).

Within SDT, attention to cross-cultural similarities and differences is increasing (Ryan & Deci, 2020). Although important, culture in these studies has tended to involve dichotomization (e.g., individualistic vs. collectivist, independent vs. interdependent), and has primarily been inferred from the country in which the research was conducted. Cultural nuances and differences within countries have received less attention but warrant further investigation.

We have already noted the importance of considering possible developmental factors in terms of how students perceive teachers' need-supportive practices. This will necessitate more research that includes all three types of practices, in contrast to the tendency to focus on autonomy support. Furthermore, many instructional practices are content area-specific, so future studies can examine whether students perceive the same teacher's need-supportive practices vary across content areas. Both possible developmental and content area differences have tremendous implications for practice, and yet have received minimal attention by SDT researchers to date.

5. Conclusions

Although SDT posits that teacher motivation influences student motivation, no published study has statistically modeled data to show the full sequence of these mechanisms. In this study, we theoretically proposed and empirically showed the adjacent sequential links of teacher motivation to perceived need-supportive practices to satisfaction of students' needs to their motivation to their academic achievement. Furthermore, the link between teacher autonomous motivation and student autonomous motivation was fully mediated by perceived need-supportive practices and student need satisfaction. Hence, these findings are consistent with the theoretical mechanisms that teacher autonomous motivation affects student autonomous motivation and academic achievement via teacher practices that support satisfaction of student needs for autonomy and competence.

Appendix. Scale items used in the current research

* All items scored on a 5-point scale

(1 = strongly disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = strongly agree)

[+] Item deleted after factor analysis

Teacher Motivation:

Teacher self-determination (Taylor & Ntoumanis, 2007)

I teach my class math because…

Autonomous Motivation

1. teaching this class is fun.
2. I feel good when I am teaching this class.
3. I think that teaching this class is pleasurable.
4. I think that teaching this class is interesting.
5. I am doing it for my own good. [+]
6. I believe teaching this class is important for me.
7. I think teaching this class is good for me. [+]
8. it is my personal decision. [+]

Controlled Motivation

1. it would bother me if I was asked not to teach this class.
2. I want my colleagues to think I'm a good teacher
3. I would feel bad if I was asked not to teach this class.
4. I want the other teachers to think I am skillful at teaching.
5. I am supposed to do it.
6. I feel that I have to do it.
7. I don't have the choice.
8. it is something that I have to do. [+]

Amotivation

How do you feel about teaching this class math?

1. I don't know. I don't see what teaching this class gives me.
2. I teach this class, but I am not sure if it is worth it for me.
3. There may be good reasons for teaching this class, but personally I don't see any.
4. I teach this class, but I am not sure it is a good thing for me that I carry on.

Student Perceptions of Teacher Need Support:

Teacher as Social Context Questionnaire (TASCQ-S)

In my math class…

1. It seems like my teacher is always telling me what to do (R).
2. My teacher doesn't listen to my opinion (R).
3. My teacher doesn't give me much choice about how I do my schoolwork (R).
4. My teacher is always getting on my case about schoolwork (R). [+]
5. My teacher doesn't explain why what I do in school is important to me (R).
6. My teacher gives me a lot of choices about how I do my schoolwork.

7. My teacher listens to my ideas.
8. My teacher talks about how I can use the things we learn in school.
9. Every time I do something wrong, my teacher acts differently (R). +
10. My teacher shows me how to solve problems for myself. +
11. My teacher keeps changing how he/she acts towards me (R). +
12. My teacher doesn't make it clear what he/she expects of me in class (R).
13. My teacher doesn't tell me what he/she expects of me in class (R). +
14. My teacher makes sure I understand before he/she goes on.
15. If I can't solve a problem, my teacher shows me different ways to try to.
16. My teacher checks to see if I'm ready before he/she starts a new topic.
17. My teacher likes me.
18. My teacher knows me well. +
19. My teacher really cares about me.
20. My teacher just doesn't understand me (R).
21. My teacher spends time with me.
22. My teacher talks with me.
23. I can't depend on my teacher for important things (R).
24. I can't count on my teacher when I need him/her (R).

Student Perceptions of Basic Psychological Need Satisfaction: Korean Basic Psychological Needs Scale (K-BPNS)

In my math class …

Autonomy

1. I feel pressured from others (R).
2. I frequently have to do what I am told (R).
3. I'm not allowed to choose the way to do activities (R). +
4. I feel that I am free to decide for myself how to work in math class. +
5. I generally feel free to express my ideas and opinions.

Competence

1. I feel that I am very effective.
2. People I know tell me I am good at math.
3. Most days I feel a sense of accomplishment from what I do.
4. I feel like I am capable more than others are.
5. I feel like I can teach what I know to others well.

Relatedness

1. I feel that people care about me.
2. I really like the people I interact with.
3. People around me and I generally help each other.
4. The people I interact with do not seem to like me much (R).
5. People around me and I generally share our feelings with each other.

Student Motivation:
Korean Academic Self-Regulation Questionnaire (K-SRQ-A)

I study math because …

Autonomous Motivation

1. I enjoy answering challenging questions.
2. It's fun.
3. I like to think about new questions.
4. I enjoy studying math.
5. I enjoy working out the answers to math problems.
6. I want to learn about new things.
7. It helps me to understand difficult concepts.
8. I believe it is valuable to accumulate knowledge.
9. I find out if I'm right or wrong. +
10. It helps me to understand the lesson contents.

Controlled Motivation

1. I don't want the teacher to ignore me.
2. I don't want to be ashamed of myself if it didn't do well.
3. I want to get better grades that the other students.
4. I want the teacher to think I'm a good student.
5. I want the other students to think I'm smart.
6. I might get a reward (money, gift, praise etc.) from my parents if I do well.
7. My parents will be angry if I don't do it.
8. I want the teacher to say nice things about me. +
9. My teacher will punish if I don't do it. +
10. My teacher says that I'm supposed to do it. +

Amotivation

In my math class …

1. I don't know what I do in the class.
2. I am not interested in math.
3. I think math is not important for my life.
4. I don't know why I study math. +
5. I feel that I waste a lot of time in math class.

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