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What students need from their teacher: Need satisfaction as mediator of the association between perceived cognitive adaptive support, and student outcomes

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Abstract

In this study, it was examined whether teachers' cognitive adaptive support (i.e., support that is tailored to students' understanding), as perceived by students, was associated with students' intrinsic motivation and academic achievement, and whether satisfaction of students' needs for autonomy, competence, and relatedness explain these associations. Multilevel analyses in a sample of $n = 692$ secondary education students from 35 classes revealed positive relations between cognitive adaptive support and students' need satisfaction and motivation, and mixed findings regarding academic achievement. Feeling competent mediated the association between cognitive adaptive support and achievement; feeling autonomous and connected to the teacher explained increases in intrinsic motivation. Although there was significant between-class variation for most adaptivity scales, within-classroom variation was larger, indicating substantial differences in perceived adaptivity within classes. Overall, the findings suggest that cognitive adaptive support is important for supporting students' psychological needs and motivation.

Educational relevance and implications statement

The current study stresses the importance for educators of tailoring their support to students' level of understanding, as cognitive adaptive support is positively related to students' need satisfaction, their intrinsic motivation, and to some extent, their academic achievement. Especially, when students do not understand an exercise, it is crucial for teacher to increase their degree of support. Failure to do so might lead to students feeling a diminished sense of autonomy, competence, and connection to their teacher, which could in turn result in reduced intrinsic motivation and achievement.

Keywords Cognitive adaptive support · Self-determination theory · Students' perceptions · Multilevel structural equation modeling

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1 Introduction

Cognitive adaptive support, also commonly referred to as adaptive teaching, can be understood as the extent to which teachers adapt their support to individual students' understanding. It is widely believed to be a cornerstone of effective instruction (Parsons et al., 2018). Nevertheless, existing evidence on the effectiveness of cognitive adaptive support is limited (e.g., Van de Pol et al., 2010). Moreover, little is known about the underlying psychological mechanisms within students that can explain *why* cognitive adaptive support might enhance student outcomes (Parsons et al., 2018; Van de Pol et al., 2010). Self-determination theory (SDT; Deci & Ryan, 1985; Ryan & Deci, 2020) states that through their interactions with students, teachers can fulfill students' needs for autonomy, competence, and relatedness, and thereby foster students' motivation and learning (Bureau et al., 2022; Stroet et al., 2013; Cerasoli et al., 2016; Ryan & Deci, 2017). Cognitive adaptive support by definition entails an approach tailored to individual students' needs. It could help students to feel competent in their learning, as teacher adapt their instruction and feedback to students' understanding, it could also help them feel autonomous because teachers reduce their support when students show greater understanding, and attuning to students' needs may support a sense of relatedness with the teacher. Hence, need satisfaction may explain the potential positive associations between cognitive adaptive support and students' motivation and achievement.

The aim of the current study is to examine whether cognitive adaptive support, as perceived by students, is predictive of students' intrinsic motivation and academic achievement, and whether these associations may be explained by students' need satisfaction. The current study integrates the scientific fields of adaptive support (Hardy et al., 2019; Parsons et al., 2018; Van de Pol et al., 2023) and SDT (Bureau et al., 2022; Ryan & Deci, 2020; Vansteenkiste et al., 2020). An understanding of the underlying psychological mechanisms (e.g. need satisfaction) of cognitive adaptive support will contribute to shaping current theoretical models of cognitive adaptive support and might help in designing effective teacher interventions aimed at promoting cognitive adaptive support in the classroom. In addition, this study could offer valuable insights into ways in which teachers might apply need-supportive teaching, by addressing individual differences in an adaptive manner (Vansteenkiste et al., 2020).

1.1 Adaptive support

The construct of adaptive support has roots in social-constructivism and in the field of teacher metacognition (Parsons et al., 2018). Adaptivity can be viewed as a key feature of scaffolding (Hardy et al., 2019; Van de Pol et al., 2023), which describes a process of support that enables a child or novice to complete a task, solve a problem, or achieve a goal beyond their abilities (Wood et al., 1976). Although adaptive support can have different aims, such as support of students' metacognitive activities or affect (see Parsons et al., 2018; Van de Pol et al., 2010), in most research, the focus is on how teachers adapt their support of the student's learning process to a student's understanding (Van de Pol et al., 2023). The present study will therefore use the term *cognitive* adaptive support. In order to provide cognitive adaptive support, teachers

need to diagnose a student's current level of understanding and subsequently adapt their degree of support to this level (Van de Pol & Elbers, 2013; Bakker et al., 2015a, b; Puntambekar, 2022). When students encounter difficulties, teachers might increase their degree of support by providing explanatory structures that organize the learning activity, or they can reduce the degrees of freedom by taking over parts of a task that the student is not yet able to perform. These interventions simplify the task for the student (Van de Pol et al., 2010; Puntambekar, 2022), which in turn can lead to a reduced cognitive load in students, as well as to higher motivation and improved learning (Evans et al., 2024; Heitmann et al., 2021; Obergassel et al., 2024). When students demonstrate high levels of understanding, teachers can decrease their degree of support, for example by asking open questions which are less structured or by giving the student more degrees of freedom in their way of answering (Van de Pol & Elbers, 2013). Thus, in order to provide cognitive adaptive support, the teacher either has to increase the degree of support when students are not yet able to deal with the task demands or decrease the degree of support when students show a high level of understanding (Van de Pol & Elbers, 2013).

A previous study into students' perceptions of levels of teachers' cognitive adaptive support revealed that cognitive adaptive support can be conceptualized as a four-facet construct (1) increased support upon low student understanding (Adaptive+/A+), (2) decreased support upon high understanding (Adaptive-/A-), (3) increased support upon high understanding (Non-Adaptive+/NA+), and (4) decreased support upon low understanding (Non-Adaptive-/NA-), see also Tabel 1 (Van de Pol et al., 2023). Non-adaptive support (NA+and NA-) can be seen as a failure to adapt. Although non-adaptive support might be seen as the opposite of adaptive support, a previous study showed that these types of adaptivity are not necessarily mutually exclusive (Van de Pol et al., 2023).

1.1.1 Effects of cognitive adaptive support

Over the past few decades, researchers have recognized cognitive adaptive support as a crucial component of effective instruction (Hardy et al., 2019; Parsons et al., 2018). However, it has also been argued that it is hard to measure due to its complex and dynamic nature (Hardy et al., 2019). As a result, researchers have studied this phenomenon using various methods across different disciplines, yielding varied outcomes (Parsons et al., 2018). Most studies were small-scaled and qualitatively analyzed individual teacher-student interactions within a specific task. This approach allowed researchers to capture the dynamic nature and complexity of adaptive support in the classroom (Parsons et al., 2018; Van de Pol et al., 2010). Two recent review studies summarized the existing evidence and found that cognitive adaptive support increased the instructional quality at a classroom level across different domains and had a positive effect on students' academic achievement (cf. Hardy et al., 2019; Parsons et al., 2018). In these reviews, no studies on the effect on students' motivation were included.

However, when zooming in on the facets of cognitive adaptive support from Table 1, it was found that adaptive support is not unequivocally effective (Van de Pol & Elbers, 2013). Findings from an observational study indicated that adaptive sup-

Table 1 Facets of cognitive adaptive support

Adaptivity facet	Student's level of understanding	Teacher response	Explanation
A+	Low	High degree of support	Adaptive support by providing much support upon low student understanding
A-	High	Low degree of support	Adaptive support by providing little support upon high student understanding
NA+	High	High degree of support	Non-adaptive support by providing much support upon high student understanding
NA-	Low	Low degree of support	Non-adaptive support by providing little support upon low student understanding

Note. A = Adaptive, NA = Non-adaptive. Derived and adjusted from Van de Pol et al. (2023, p. 3)

port was mostly effective due to decreasing the degree of support upon high understanding (A-) rather than increasing the degree of support upon low understanding (A+; Kupers et al., 2015). Another observational study by Van de Pol and Elbers (2013), using a similar coding scheme, showed that only an increase of support upon low student understanding (A+) was effective for students' learning. Furthermore, it was found that teachers did not often decrease their degree of support upon high level of student understanding (A-), which might explain why no learning effect was found for this facet of cognitive adaptive support. In addition, teachers usually did not increase their degree of support when students had a high understanding (NA+), while they did decrease the degree of their support when students had a low level of understanding (NA-). A possible explanation might be that teachers tend to use their own – more developed – knowledge as a reference point (Van de Pol & Elbers, 2013).

Thus, mainly observational research is available on the effects of the different facets of cognitive adaptive support for individual students with a focus on the nature of teacher-student interactions in a specific task (e.g., Kupers et al., 2015; Van de Pol & Elbers, 2013). However, research on the effects of cognitive adaptive support on students' motivation and achievement at a more general level is scarce. As such, it is unclear what happens with students' motivation and achievement when their teacher frequently provides adaptive or non-adaptive support. Students are often regarded as experts for many aspects of teachers' instructional quality since they encounter different teachers and spend considerable time in class with them (Lüdtke et al., 2009). Moreover, it is commonly assumed that a student's personal perception of the classroom context, such as the teacher-student interaction, may play a critical role in their academic performance (Kunter & Baumert, 2007). Therefore, the current study uses a large dataset in which the four facets of cognitive adaptive support are investigated from a student-perspective, and related to students' intrinsic motivation and academic achievement within a specific subject domain. Insight into students' perceptions of their teacher's overall degree of adaptive support could give more detailed informa-

tion about differences between students, and how adaptive support may affect their motivation and learning (Van de Pol et al., 2023).

1.2 Basic psychological need satisfaction

Self-determination theory (SDT; Deci & Ryan, 1985; Ryan & Deci, 2020) is a theoretical framework that could offer an important lens through which we might elucidate why cognitive adaptive support can be effective, as SDT connects teacher-student interactions to students' intrinsic motivation and achievement (Deci & Ryan, 1985; Ryan & Deci, 2020; Stroet et al., 2013). Intrinsic motivation occurs when students engage in learning, because they experience enjoyment and interest in doing tasks (Deci & Ryan, 1985; Ryan & Deci, 2020). SDT posits that all people have three basic psychological needs: the need to experience volition in and a self-endorsement of activities they undertake (autonomy), to feel effective (competence), and to feel connected to those they care about (relatedness; Deci & Ryan, 1985). When students' psychological needs are met, they undergo an internalization process in which their motivations for participating in tasks shift from externally imposed (e.g., mandatory) to self-generated (e.g., enjoyment; Deci et al., 1994; Ryan & Deci, 2017). This internalization process explains why satisfaction of these psychological needs leads to greater appreciation for the learning activity and a higher level of interest in it (Ryan & Deci, 2020).

In an educational context, teachers play a crucial role in guiding students in their learning process (Stroet et al., 2013). Indeed, research has shown that teacher-student interactions affect satisfaction of students' psychological needs (Bureau et al., 2022), intrinsic motivation (Stroet et al., 2013), and academic achievement (Cerasoli et al., 2016; Ryan & Deci, 2017). Although much research focused on autonomy-supportive teaching (Ryan & Deci, 2020), recent meta-analyses have shown that not autonomy, but competence satisfaction appears to be the most important predictor of students' intrinsic motivation (Bureau et al., 2022; Vasconcellos et al., 2020) and students' performance (Cerasoli et al., 2016). Hence, when teachers want to effectively support their students it is especially important for them to adopt behaviors that enhance their students' satisfaction of competence, in addition to promoting autonomy and relatedness (Bureau et al., 2022; Cerasoli et al., 2016).

1.3 Adaptive support and differences in students' need satisfaction

To better understand which specific teacher behaviors are supporting students' psychological needs, Ahmadi et al. (2022) used a Delphi method to create a classification of need-supportive teaching behaviors. The most important teacher behavior they identified in supporting students' sense of competence, is to provide optimal challenge to students. They described this as providing students with tasks that are more challenging if they find them too easy or less challenging if they find them too difficult (Ahmadi et al., 2022). Although not made explicit in SDT, providing optimal challenge to students implies that teachers should differentiate their support between students based on students' levels of understanding. This bears strong resemblance to the construct of cognitive adaptive support (Van de Pol et al., 2023). If teachers

succeed in making the match between their degree of support and students' level of understanding, students will experience optimal, yet attainable challenge and will feel that they can stretch and improve their abilities, which leads to satisfaction of competence (Yu et al., 2022). This will stimulate and maintain students' intrinsic motivation, as well as increase the likelihood of success in learning (Kim et al., 2018).

However, if the teacher increases their degree of support when the student already understands it (NA+), the student might feel bored or underestimated, experience a lack of interest (Tozman et al., 2015), or perceive the exercises as non-effective (Yu et al., 2022). According to SDT, this could decrease students' sense of competence (Ryan & Deci, 2020). In addition, if the student has a low level of understanding, but the teacher does not offer any help (NA-), the student keeps struggling with the exercise and could become anxious and disengaged (Willingham, 2009). This might cause the student to feel less competent and possibly also less connected with the teacher (Ahmadi et al., 2022).

Additionally, when teachers provide adaptive support, they may also stimulate students' need for autonomy, as adaptive support implies that teachers reduce their support upon high understanding, providing students with a greater sense of control over their own learning. Similarly, adaptive support may contribute to students' need for relatedness as students may experience their teacher to be attuned to their needs.

In SDT, the claim is made that need satisfaction is inherently beneficial for all individuals (Ryan & Deci, 2020). Research on need-supportive teaching has traditionally focused mostly on universal principles to support the needs of all students in class, while focusing less on how teachers can tailor their support to adapt to differences between students. Nevertheless, Vansteenkiste et al. (2020) emphasize there is a variation in the way how individuals' needs can be supported. That means that the pathways to fulfil their needs may differ across individuals (Vansteenkiste et al., 2019, 2020). Combining the four facets of cognitive adaptive support (Van de Pol et al., 2023) with SDT could help to create a better understanding of how teachers can tailor their need support to individual students.

To our knowledge, only one study examined the relationship between cognitive adaptive support (described as scaffolding), need satisfaction, and intrinsic motivation (Pat-El et al., 2012). Students from secondary vocational education ('MBO' in Dutch) were asked about their perceptions of their teacher's adaptive support with a focus on the provision of feedback and clear support for learning. They found that when students experienced a higher level of adaptive support, they reported more autonomy and competence satisfaction, and somewhat more relatedness satisfaction. In addition, it appeared that especially competence satisfaction, and to a lesser extent relatedness satisfaction, were predictive of intrinsic motivation. Although Pat-El et al. (2012) did not test whether this indirect effect was indeed significant, these results suggest that competence satisfaction seems to be the main mediating factor between cognitive adaptive support and intrinsic motivation. Moreover, in this study, the effect of adaptive support on achievement was not investigated and adaptive support was only examined as a single construct without distinguishing the different facets. Looking deeper into the four facets of cognitive adaptive support and how these relate to students' needs satisfaction, intrinsic motivation, and achievement could give more

detailed insights into the effectiveness of adaptive support and its underlying mechanisms (Van de Pol et al., 2023).

1.4 Present study

The overall aim of the current study is to get a better understanding of the effectiveness of cognitive adaptive support by analyzing students' perceptions of their teachers' cognitive adaptive support in relation to students' intrinsic motivation and academic achievement. Secondly, this study aims to make a connection between the scientific fields of adaptive support and SDT by examining whether need satisfaction could be the underlying psychological mechanism to explain the potential associations between cognitive adaptive support and student's intrinsic motivation and achievement.

In contrast to prior observational studies on adaptive support which primarily examined the interactional dynamics during specific tasks or lessons, this study investigates students' overall perceptions of their teacher's cognitive adaptive support. This approach helps us better understand what happens with students' motivation and achievement when a teacher frequently provides adaptive or non-adaptive support. Research has shown that student ratings are an efficient and valid way of assessing students' perceptions of individualized instruction, especially with regard to assessing individual differences between students (Tetzlaff et al., 2022).

In Fig. 1, the conceptual model of the relations between cognitive adaptive support, need satisfaction, intrinsic motivation, and academic achievement is presented. Previous research has shown that intrinsic motivation and achievement are strongly reciprocally related to each other (e.g., Deci & Ryan, 2020). The relationship between students' intrinsic motivation and their academic achievement is beyond the scope of the current study. Therefore, two separate models will be tested. First, it will be examined whether there is a relationship between the four facets of cognitive adaptive support, and students' intrinsic motivation, and achievement. Second, it will be examined whether need satisfaction is the underlying psychological mechanism that

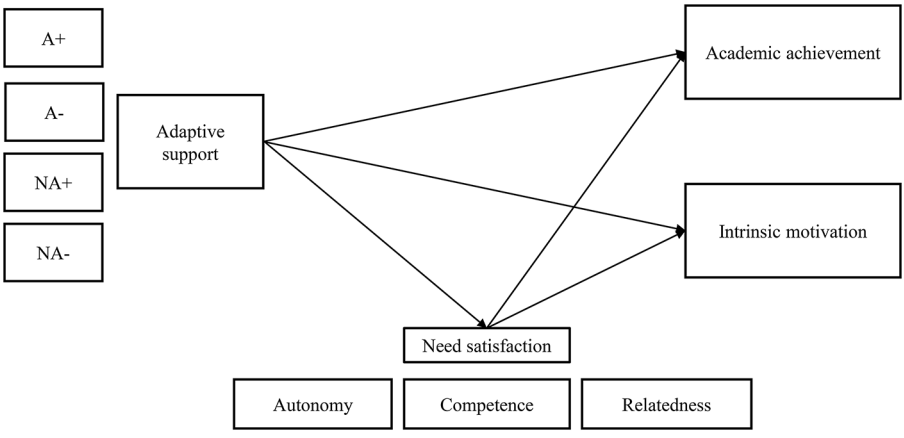

Fig. 1 Conceptual model

might explain why cognitive adaptive support is positively, and non-adaptive support is negatively related to students' intrinsic motivation, and achievement. To examine these relations, the present study adopts a multilevel approach. The aim is to gauge the extent to which students within the same class have similar perceptions of their teacher's adaptive support, and how this might relate to students' need satisfaction, motivation, and achievement. The following hypotheses will be investigated at student and classroom levels:

1. Adaptive support (A+and A-) is positively related to students' intrinsic motivation and achievement (Hardy et al., 2019; Parsons et al., 2018; Van de Pol & Elbers, 2013), whereas there is no or a negative relationship with non-adaptive support (NA+and NA-).
2. Students' psychological need satisfaction for competence, and to a lesser extent for autonomy and relatedness, can partially explain the positive relationship between the facets of support adaptivity (A+and A-) and student outcomes, and the negative relationship between the facets of non-adaptive support (NA+and NA-) and student outcomes (Ahmadi et al., 2022; Pat-El et al., 2012).

2 Methods

2.1 Participants

Data were collected at thirteen secondary schools in the Netherlands. Participating teachers were recruited via the network of the researchers. These data were part of a larger project (Van de Pol et al., 2023). In total, 35 teachers (M_{age} = 42.71 years, range: 26–64, 37.1% male, 88.6% with Dutch ethnic background) participated in the study. The subjects the teachers taught were Dutch (n=12), English (n=12), or mathematics (n=11). On average, they had 16.81 years of teaching experience (range: 1–43), had known their class for 10 months (range: 6–27), and taught their class 3.3 h per week (range: 2–4).

Each teacher participated with one class, resulting in a sample of 692 students (M_{age} = 14.44 years, SD=1.41, range: 12–18), of which 337 were boys (48.7%), 350 girls (50.1%), and five students did not report their gender. The majority of the students were born in the Netherlands (94.1%) and had a Dutch ethnic background (88.2%). All grades and grade levels from Dutch secondary education were represented, which is equal to US Grade 7 to Grade 12. Most students were enrolled in the prevocational education track (n=593), but also students from general secondary education (n=25), pre-university education (n=56), and a combination of the former two types of education (n=6) were included. In addition, eight students attended a different educational track, and four students did not report their educational track.

2.2 Instruments

To measure the constructs cognitive adaptive support, need satisfaction, and intrinsic motivation, several existing scales were used (see below).

2.2.1 Cognitive adaptive support

The Questionnaire on Teacher Support Adaptivity (QTSA; Van de Pol et al., 2023), consisting of 21 items, was used to measure students' perceptions of their teacher's cognitive adaptive support. This questionnaire consists of four subscales: the subscales A+and NA- each consist of six items, the subscale A- of five items, and the subscale NA+of four items. Students answered on a five-point scale (1=totally disagree, 5=totally agree). Confirmatory factor analyses confirmed the four-factor structure. See online supplemental materials for a full description of the CFA's. Table 2 shows the internal consistencies and example items. Three out of four scales showed acceptable internal consistencies (Nunnally & Bernstein, 1994). Only for the subscale NA+, the internal consistency would preferably be a bit higher (α=0.69), which was also the case in the study of Van de Pol et al. (2023). They explained that possibly a higher degree of support upon good student understanding rarely occurs in the perception of students, and is therefore hard to judge. Thus, outcomes related to the subscale NA+need to be interpreted with caution.

2.2.2 Need satisfaction

Autonomy and competence satisfaction were assessed by a Dutch version of the *Basic Psychological Need Satisfaction and Frustration Scale* (BPNSFS; Haerens et al., 2015). Questions related to physical education (e.g., "During the past PE lesson…") were replaced by the subjects of interest in the current study. Both scales consisted of eight items, and students answered on a five-point scale (1=not true, 5=true). Because the Relatedness scale of the BPNSFS pertains to students' relation-

Table 2 Internal consistencies and example items for subscales

Subscale	Cronbach's α	Example item
A+	0.82	When I don't know how to continue, this teacher helps me to find the correct answer.
A-	0.81	When I understand something well, this teacher makes it a little bit harder for me.
NA+	0.69	This teacher helps me with things that I already understand.
NA-	0.76	When I find an exercise very difficult, this teacher still lets me do it on my own.
Autonomy*	0.77	During the past Dutch/English/math lesson, I felt a sense of choice and freedom in the things I undertake.
Competence**	0.82	During the Dutch/English/math lesson, I feel capable at what I do.
Relatedness***	0.91	I feel at ease with my Dutch/English/math teacher.
Intrinsic motivation	0.87	I would describe the Dutch/English/math exercises as very interesting.

Note. Correlated residuals added for

* items 3&5, items 7&8;

** items 3&5, items 5&7, items 5&8, items 7&8;

ship with classmates, rather than their teacher, we used a 7-item scale on students' well-being in relation to the teacher (Peetsma et al., 2001). The scales showed acceptable internal consistencies (see Table 2).

2.2.3 Intrinsic motivation

The scale 'Interest/Enjoyment' of the Intrinsic Motivation Inventory was used to measure students' intrinsic motivation (Deci et al., 1994; Ryan, 1982). The subject of interest (Dutch, English, or mathematics) was included to make the questionnaire domain-specific. The scale consisted of six items, and students answered on a five-point scale (1 = not true, 5 = true). Because of the low factor loading of item 6 ("The exercises for Dutch/English/math do not hold my attention at all"; factor loading = 0.31), this item was excluded. A CFA indicated that a single-factor model with the remaining five items had good model fit ($\chi^2(5) = 28.24$, $p < .001$, CFI = 0.98, RMSEA = 0.08, SRMR = 0.02), and good internal consistency (see Table 2).

2.2.4 Academic achievement

Academic achievement was operationalized as students' most recent average report grade and measured by asking "What was your last report grade for Dutch, English, or mathematics?" If students did not have a report grade, their average grade for the subject was reported. Previous research has suggested that report grades can be a reliable and valid measure of achievement (e.g., Bowers, 2009; Südkamp et al., 2012), especially when they are based on at least eight grades (Van der Lans et al., 2015). In the current study, teachers indicated that the report grade for each student was on average based on 7.8 grades ($SD = 3.4$).

2.3 Procedure

The local Ethics Committee approved the study protocol (22–0490). Before data collection took place, parents were asked for assent. Furthermore, teachers and students were asked for their active written consent. Students filled out the questionnaires during a lesson at school. At the start of the lesson, the researcher (1) explained the aim and duration of the survey, (2) emphasized the voluntary nature of participation, and the students' right to quit the survey at any moment, and (3) instructed the students on how to fill out the surveys. Afterward, the students completed the survey on paper. The duration of the data collection ranged between thirty and forty minutes.

2.4 Data analyses

Missing data analyses showed that for each item only maximum 3.47% of the data were missing. Means for each subscale were computed when a student filled out at least half of the items, resulting in a maximum of 2.00% missing data on a subscale. Researchers suggest that less than 5% missing data is inconsequential for further subsequent analyses (Schafer, 1999; Scheffer, 2002). In the current study, missing data was accounted for by the full information maximum likelihood (FIML) method.

Multilevel Structural Equation Modeling (MSEM) in Mplus 8.8 (Muthén & Muthén, 2017) was used to test the analytic model specifying paths from cognitive adaptive support via need satisfaction towards intrinsic motivation in the first model, and academic achievement in the second model. As the data had a hierarchical structure (students nested within classes), the data were analyzed on both the individual student (within) level and the class (between) level (Geiser, 2012). For multilevel analyses, at least thirty units at the between level have been recommended (Maas & Hox, 2005), which indicates that the present study has sufficient power ($n=35$ classes). At the student-level, student-specific perceptions of the four facets of adaptive support were included as predictors, and students' perceived sense of autonomy, competence, and relatedness were included as mediating variables. At the class-level, the aggregated class means of the four facets of adaptive support were included as predictors, and aggregated class means of perceived sense of autonomy, competence, and relatedness were included as mediating variables. The independent and mediating variables were group-mean-centered at the within-level to assess differences between students within the same classroom, and grand-mean-centered at the between-level to assess differences between classes (Lüdtke et al., 2009).

First, the multiple-mediator model from the four facets of adaptive support to intrinsic motivation through need satisfaction was fitted without including correlated residuals among the mediators. The fit indices were not acceptable yet ($\chi^2(6)=82.09$, $p<.001$, CFI=0.93, RMSEA=0.14, SRMR for within =0.05, SRMR for between =0.04; Shi et al., 2019). The modification indices suggested to allow the residuals of autonomy and relatedness satisfaction at the within-level to correlate with each other. After adding this correlated residual to the model, the model showed acceptable fit ($\chi^2(5)=23.76$, $p<.001$, CFI=0.98, RMSEA=0.07, SRMR for within =0.03, SRMR for between =0.04). The same steps were followed for the model with academic achievement as outcome variable. Again, the model without correlated residuals among the mediators did not fit the data well yet ($\chi^2(6)=81.60$, $p<.001$, CFI=0.93, RMSEA=0.14, SRMR for within =0.04, SRMR for between =0.04). The same correlated residual of autonomy and relatedness satisfaction at the within-level was suggested, and added to the model, resulting in an acceptable model fit ($\chi^2(5)=23.56$, $p<.001$, CFI=0.98, RMSEA=0.07, SRMR for within =0.03, SRMR for between =0.04).

To test the first hypothesis regarding the relationship between cognitive adaptive support and student outcomes, total effects were estimated through a structural model with paths from the four facets of adaptive support to students' intrinsic motivation and achievement. For the second hypothesis, the indirect effects of adaptive support on student outcomes via need satisfaction were examined. To test whether these indirect effects were significant, the product-of-coefficients test of mediation through the MODEL INDIRECT procedure was used (Muthén & Muthén, 2017). Standardized beta's were used as a measure for effect size. A value of 0.1 corresponds to a weak effect, 0.3 to a moderate effect, and 0.5 to a strong effect (Cohen, 1988).

3 Results

3.1 Descriptive statistics

In Table 3, means, standard deviations, and intra-class correlations (ICC's) of the study variables are presented. The mean of A+ is relatively higher compared to the other facets of (non-)adaptive support, which suggests that teachers mainly provide adaptive support by increasing their support upon low student understanding. Moreover, the mean of NA- is somewhat lower than the other facets, indicating that students perceive this facet as occurring infrequently. As the data are hierarchically structured (students nested within classes), the variance at the class-level was estimated for each study variable, indicated by the ICC's. All class-level variances were statistically significant, except for NA+, meaning that for all other variables, there were significant between-class differences. Especially the ICCs of relatedness satisfaction, intrinsic motivation, and academic achievement were relatively high (with 16–24% of the variance situated at the class-level), suggesting stronger between classroom differences for those variables than for the other study variables. In contrast, it appeared that the ICC's for the facets of adaptive support were smaller (with 1–13% of the variance situated at the class-level), suggesting substantial differences in how students within the same class perceive their teacher's cognitive adaptive support. Table 4 shows the correlations between the study variables at the student- and class-level.

3.2 Cognitive adaptive support and intrinsic motivation

Standardized path coefficients between cognitive adaptive support (i.e., A+, A-, NA+, NA-) and the mediators (i.e., autonomy, competence, and relatedness satisfaction), and between the mediators and students' intrinsic motivation are respectively represented by α and β in Table 5, and are displayed graphically in Fig. 2. Table 5 also presents the standardized point estimates for the indirect effects (α*β).

The results of the model with intrinsic motivation as outcome variable showed that Hypothesis 1, which assumed positive relations between adaptive support and intrinsic motivation, and negative relations between non-adaptive support and intrinsic motivation, could be partly confirmed. When looking at the total effects at the student-level, both facets of adaptive support (A+ and A-) were positively related

Table 3 Descriptive statistics and intraclass correlations

Subscale	*n*	M	SD	Range	ICC
A+	690	3.95	0.70	1.00–5.00	0.13**
A-	688	2.69	0.82	1.00–5.00	0.10**
NA+	688	2.75	0.73	1.00–5.00	0.08
NA-	689	2.23	0.70	1.00–5.00	0.09**
Autonomy	691	3.34	0.70	1.00–5.00	0.12**
Competence	682	3.68	0.71	1.00–5.00	0.05*
Relatedness	678	3.48	0.95	1.00–5.00	0.24**
Intrinsic motivation	680	2.53	0.87	1.00–5.00	0.16**
Academic achievement	687	6.74	1.14	1.00-9.20	0.21**

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

Table 4 Correlations at the Student-Level (above the diagonal; $n = 680$) and Class-Level (under the diagonal; $n = 35$)

	1	2	3	4	5	6	7	8	9
1. A+	-	0.32**	−0.08*	−0.58**	0.53**	0.29**	0.68**	0.36**	0.16**
2. A-	0.43**	-	0.03	−0.10*	0.36**	0.04	0.34**	0.38**	0.02
3. NA+	0.23**	0.06	-	0.26**	−0.14**	0.00	−0.06	−0.04	0.08*
4. NA-	−0.69**	−0.30**	−0.01	-	−0.44**	−0.31**	−0.48**	−0.25**	−0.19**
5. Autonomy	0.76**	0.56**	−0.02	−0.71**	-	0.26**	0.59**	0.52**	0.20**
6. Competence	0.19**	−0.04	−0.02	−0.17**	−0.18**	-	0.29**	0.13**	0.42**
7. Relatedness	0.76**	0.54**	0.25**	−0.53**	0.76**	0.27**	-	0.51**	0.16**
8. Intrinsic motivation	0.19**	0.23**	0.01	−0.18**	0.34**	−0.01	0.27**	-	0.15**
9. Academic achievement	0.18**	0.03	0.08*	−0.20**	0.25**	0.18**	0.17**	0.15**	-

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

to intrinsic motivation, meaning that students who experienced more adaptive support from their teacher reported higher levels of intrinsic motivation. These effects were small to moderate (Cohen, 1998). Moreover, as expected, NA- was negatively related to intrinsic motivation, meaning that students who experienced less support from their teacher when they did not understand an exercise reported lower levels of intrinsic motivation. This was a small effect. No significant relationship was found between NA+ and intrinsic motivation. When looking at the total effects at the class-level, only A- was positively related to intrinsic motivation, which was a strong effect. This means that in classes where students on average reported a decrease in support when there was a high level of understanding, students' intrinsic motivation was higher. No relationships were found between A+, NA+, NA-, and intrinsic motivation at the class-level.

To test Hypothesis 2, it was examined whether need satisfaction could mediate the relationship between adaptive support and intrinsic motivation. Therefore, the indirect effects (α*β) were evaluated (see Table 5). At the student-level, autonomy and relatedness satisfaction mediated the relationship between the facets A+, A-, and NA-, and intrinsic motivation. These effects were small. The relationship between NA+ and intrinsic motivation was only mediated by autonomy satisfaction. Contrary to the hypothesis, no significant indirect effects via competence satisfaction were found. To ensure that these results were not due to suppression by the other mediators, we ran the model with competence as the only mediator. In this model, we found that even after excluding autonomy and relatedness satisfaction, competence satisfaction was still not predictive of intrinsic motivation (b* = 0.08, p=.150).

The relationship between the facets A+, NA+, and NA-, and intrinsic motivation were fully mediated, as the direct effects from adaptive support to intrinsic motivation were not significant. Only for the facet A-, there was a significant direct positive relationship with intrinsic motivation, suggesting that there was only partial media-

Table 5 Standardized path coefficients from adaptive support to student outcomes through need satisfaction

	Total Effect	Direct Effect	Autonomy			Competence			Relatedness		
Intrinsic motivation			α	β	α*β	α	β	α*β	α	β	α*β
Student-level											
A+	0.21**	−0.04	0.31**	0.28**	0.09**	0.19**	0.02	0.00	0.53**	0.30**	0.16**
A-	0.27**	0.18**	0.21**	0.28**	0.06**	−0.03	0.02	0.00	0.12**	0.30**	0.04**
NA+	−0.02	0.01	−0.08*	0.28**	−0.02*	0.01*	0.02	0.00	−0.01	0.30**	−0.00
NA-	−0.07**	0.04	−0.20**	0.28**	−0.05**	−0.26**	0.02	−0.00	−0.16**	0.30**	−0.05**
Class-level											
A+	0.21	−0.49	0.51**	1.01**	0.52**	0.24	−0.19	−0.05	0.59**	0.39*	0.23
A-	0.51**	0.06	0.29**	1.01**	0.29**	−0.19	−0.19	0.04	0.33**	0.39*	0.13
NA+	−0.01	0.04	−0.11	1.01**	−0.11	−0.15	−0.19	0.03	0.11	0.39*	0.04
NA-	−0.09	0.12	−0.23	1.01**	−0.23	−0.14	−0.19	0.03	−0.00	0.39*	0.00
Academic achievement											
Student-level											
A+	0.03	−0.05	0.31**	0.04	0.01	0.19**	0.43**	0.08**	0.53**	−0.02	−0.01
A-	−0.01	−0.00	0.21**	0.04	0.01	−0.03	0.43**	−0.01	0.12**	−0.02	−0.00
NA+	0.12*	0.08	−0.08*	0.04	−0.00	0.01*	0.43**	0.04**	−0.01	−0.02	0.00
NA-	−0.15**	−0.04	−0.20**	0.04	−0.00	−0.26**	0.43**	−0.11**	−0.16**	−0.02	0.00
Class-level											
A+	0.20	−0.17	0.51**	0.83**	0.42*	0.24	0.32*	0.08	0.59**	−0.22	−0.13
A-	−0.19	−0.30	0.29**	0.83**	0.24*	−0.19	0.32*	−0.06	0.33**	−0.22	−0.07
NA+	0.11	0.28*	−0.11	0.83**	−0.10	−0.15	0.32*	−0.05	0.11	−0.22	−0.02
NA-	−0.35	−0.11	−0.23	0.83**	−0.19	−0.14	0.32*	−0.04	−0.00	−0.22	0.00

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

tion for this facet. In total, 31% of the variance in intrinsic motivation was explained by the predictors in the model at the student-level (see Fig. 2).

At the class-level, the relationships between both A+ and A-, and intrinsic motivation were significantly mediated by autonomy satisfaction, meaning that students in classes that on average experienced more adaptive support from their teacher, reported more autonomy satisfaction, which in turn was associated with higher levels of intrinsic motivation. The effect sizes were moderate to strong. All other indirect paths were insignificant. At the class-level, 82% of the variance in intrinsic motivation was explained by the predictors in the model.

3.3 Adaptive support and academic achievement

Table 5; Fig. 3 present the results from the multilevel mediation model with academic achievement as outcome variable. The results suggested that Hypothesis 1, regarding the total relationship between adaptive support and academic achievement, could be partially confirmed. In line with the hypothesis, a significant negative relationship between NA- and academic achievement was found, which implies that students who experienced less support when they did not understand an exercise scored lower on academic achievement. However, in contrast to the hypothesis, a significant positive relationship between NA+ and academic achievement was found at the student-level, meaning that students who experienced more support when they already understood the exercise scored higher on academic achievement. Both effect sizes were small. Moreover, no significant relationships between A+ and A- and academic achievement were found. Finally, at the class-level, all class averages of the facets of adaptive support were not significantly related to students' academic achievement.

When looking at Hypothesis 2, regarding the mediating effect of need satisfaction, most indirect paths were not statistically significant. There was an exception for competence satisfaction at the student-level, as competence satisfaction significantly mediated the relationship between A+, NA+, and NA-, and academic achievement. Although there was no significant total effect from A+ to academic achievement, the indirect effect via competence satisfaction was significant. This is likely due to the negative but non-significant direct relationship between A+ and academic achievement. So, in line with the hypothesis, students who experienced more support upon a low level of understanding (A+), scored higher on academic achievement which was explained by an increase in their sense of competence. Moreover, students who reported less support upon a low level of understanding (NA-), reported a lower sense of competence, and in addition scored lower on academic achievement. However, in contrast to the hypothesis, students who experienced more support upon a higher level of understanding (NA+), reported more competence satisfaction, which was related to higher levels of academic achievement. The effect sizes for these indirect effects were small. At the student-level, 19% of the variance in academic achievement was explained by the predictors in the model (see Fig. 3).

At the class-level, autonomy satisfaction significantly mediated both the relationship between A+ and academic achievement, and A- and academic achievement, meaning that students in classes that on average perceived their teacher to be more adaptive, reported more autonomy satisfaction, which in turn was associated with

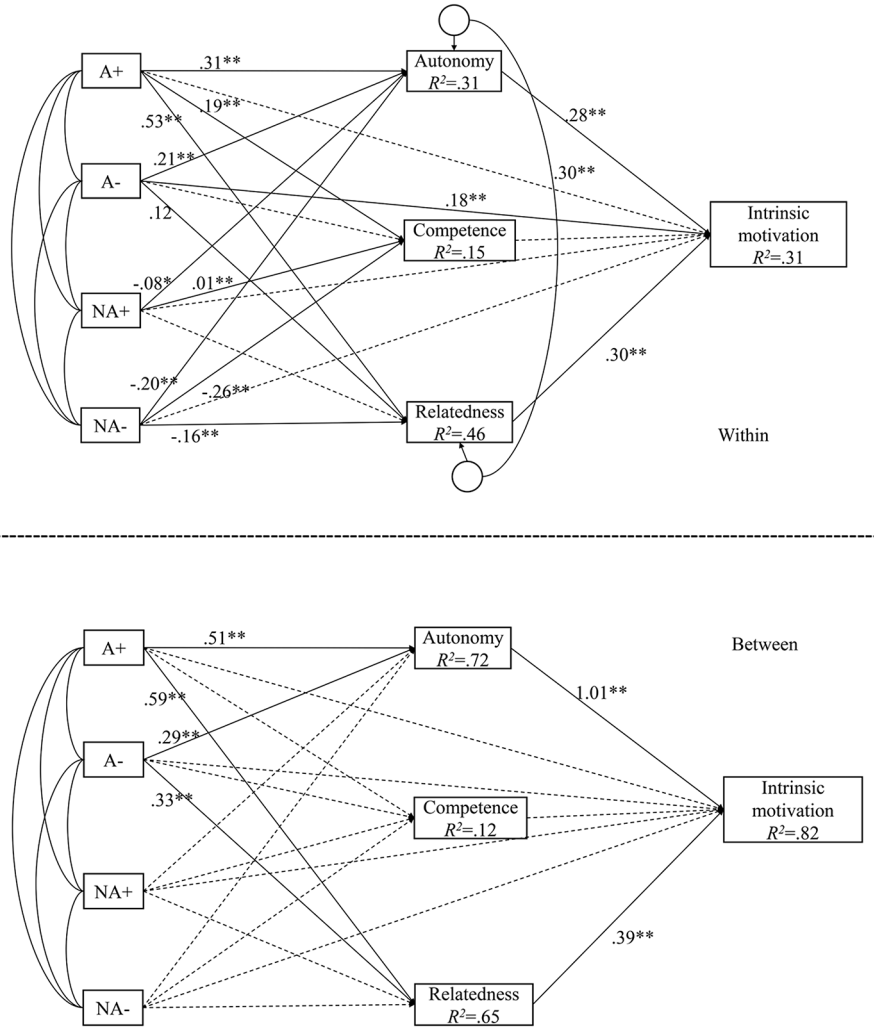

Fig. 2 Standardized Regression Coefficients for Relationships between Perceived Adaptive Support and Intrinsic Motivation Mediated by Perceived Need Satisfaction *Note.* *p<.05, **p<.01

higher scores on academic achievement. The effect sizes were moderate. In total, 53% of the variance in academic achievement at the class-level was explained by the predictors in the model.

4 Discussion

Previous research suggested that cognitive adaptive support by teachers has the potential to enhance students' motivation and academic achievement. However, research on the underlying psychological mechanisms is scarce. The aim of the cur-

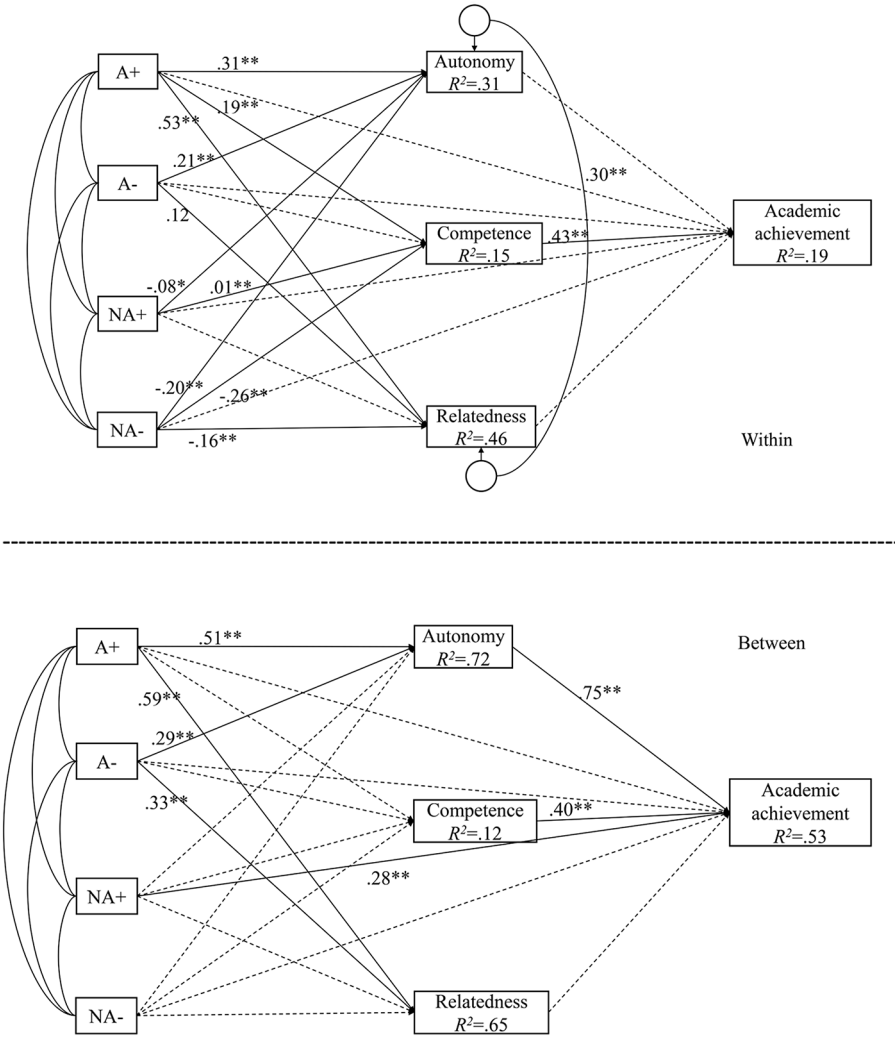

Fig. 3 Stadardized Regression Coefficients for Relationships between Perceived Adaptive Support and Academic Achievement Mediated by Perceived Need Satisfaction. n*Note.* *p<.05, **p<.01

rent study was to get a better understanding of the effectiveness of cognitive adaptive support by studying students' perceptions of their teacher's cognitive adaptive support in relation to their intrinsic motivation and academic achievement. Moreover, it was examined whether need satisfaction may explain the associations between cognitive adaptive support and student's intrinsic motivation and achievement. Overall, the results indicated that when students perceived more cognitive adaptive support from their teacher, they experienced higher levels of need satisfaction and intrinsic motivation. The results were mixed with regard to academic achievement, as especially perceived non-adaptive support, rather than adaptive support, was related to academic achievement.

4.1 Cognitive adaptive support and intrinsic motivation and achievement

The findings of the current study cautiously indicate that students who experienced more adaptive support from their teacher and less non-adaptive support reported higher levels of intrinsic motivation. Within the framework of SDT, extensive research has been conducted on factors that foster students' intrinsic motivation, including research on specific teacher behaviors than can promote students' motivation (Ahmadi et al., 2022; Ryan & Deci, 2017, 2020). Most of this research, however, has focused on universal principles for supporting students, without making explicit how teachers can adapt their support to individual students (e.g., Ahmadi et al., 2022). The current findings highlight that increasing or decreasing support based on students' current understanding can be regarded as a teacher behavior that enhances satisfaction of students' needs and thereby students' intrinsic motivation (Vansteenkiste et al., 2020). These findings suggest that focusing on how teachers adapt their support to individual students may be a fruitful direction for future work on need-supportive teaching.

Previous research has shown that cognitive adaptive support has a positive effect on a student's academic achievement (Kupers et al., 2015; Van de Pol & Elbers, 2013), although it has to be emphasized that these empirical studies studied one-on-one teacher-student interactions, and evaluated students' achievement immediately after a specific task, rather than measuring students' overall perception of adaptive support. In the current study, only perceived non-adaptive support was predictive of students' academic achievement. As expected, students who reported to receive less support from their teacher when they did not understand an exercise (NA-), scored lower on academic achievement. This finding is in line with previous research suggesting that students who receive additional support when they are struggling, rather than less support, are more likely to persist in their efforts, engage with the material, and eventually achieve better academic outcomes (Vansteenkiste et al., 2012). Contrary to the hypothesis, students who reported more support when they understood an exercise (NA+), scored higher, instead of lower, on academic achievement. This finding suggests that additional support from teachers may have a positive impact on student performance, also among students who already master the exercise. It is possible that this additional support helps students to consolidate or extend their knowledge, contributing to improved achievement. Finally, contrary to the hypotheses, perceived adaptive support (A+and A-) was not related to students' academic achievement. It may be that the effectiveness of adaptive support depends on other factors, such as the amount of independent work time given to students and their level of task effort (Van de Pol & Elbers, 2013).

4.2 Mediating role of need satisfaction

Based on SDT, it was expected that cognitive adaptive support would provide students with optimal challenge, and therefore particularly enhance students' competence satisfaction (Ahmadi et al., 2022; Pat-El et al., 2012). Indeed, it was found that students who experienced more adaptive support, felt more competent, whereas students who experienced less adaptive support (NA-), reported lower levels of competence satis-

faction. Moreover, the current study obtained evidence that adaptive support was also positively associated with students' sense of autonomy and relatedness satisfaction. Hence, when students perceive their teacher's support as adaptive, students may feel that the teacher takes their perspective, and feel more connected to the teacher, implying an increase in their sense of autonomy (Reeve & Cheon, 2021), and relatedness satisfaction (Ahmadi et al., 2022). Surprisingly, cognitive adaptive support was more strongly associated with autonomy and relatedness satisfaction than with competence satisfaction. This difference may be attributed to the fact that through cognitive adaptive support teachers may stimulate student' thinking and challenge them, rather than making tasks easier (Van de Pol et al., 2010). Although students may feel capable of achieving their goals with their teacher's support, students are still required to invest effort into the task, which could explain the comparatively smaller effect for competence satisfaction.

Previous SDT research has often found that teachers struggle to support students' learning in autonomy-supportive ways (e.g., Domen et al., 2020). That is, some strategies, such as reducing degrees of freedom for the student or taking over parts of the learning activity (Van de Pol et al., 2010), are usually related to a decrease in students' sense of autonomy (Ahmadi et al., 2022; Reeve & Cheon, 2021). However, the results of the current study indicate that not only A- (decrease of support upon a high level of understanding) was positively associated with students' sense of autonomy, this was also the case for A+ (increased support upon low understanding). Hence, this highlights that as long as students perceive their teacher's support as adaptive and tailored to their needs, cognitive adaptive support – even when the amount of support is increased – can foster students' sense of autonomy and thereby their intrinsic motivation.

Additionally, feeling competent mediated the association between cognitive adaptive support and achievement, whereas autonomy and relatedness satisfaction, but not competence satisfaction, mediated the association between cognitive adaptive support and intrinsic motivation. Competence satisfaction did not mediate the association between cognitive adaptive support and intrinsic motivation, as competence satisfaction was not predictive of intrinsic motivation. This is surprising as previous research on need satisfaction and intrinsic motivation (Bureau et al., 2022; Stroet et al., 2013), suggested competence satisfaction to be the strongest predictor of intrinsic motivation compared to the other two needs. This finding may possibly be explained by the tracked educational system in the Dutch secondary education, which clusters students in groups of a rather homogeneous ability level. This might potentially limit the variability in competence satisfaction compared to more heterogenous settings, and thereby lower the strength of the association with intrinsic motivation. Future research could further test this assumption.

4.3 Untangling between-classroom and within-classroom findings

By incorporating a multilevel approach, we were able to distinguish the findings at the between-classroom and within-classroom level. The ICCs for the adaptivity scales, except for the NA+ scale, were significant, meaning that there were significant between-class differences. Still, the within-classroom variation in adaptive support

was considerably larger than the between-classroom variation, suggesting that students within the class differed from one another in how they perceived their teacher's adaptivity. It could be that different students perceive the same teaching behaviors differently (Pat-El et al., 2012; Wubbels et al., 2022). Another explanation is that teachers may not be equally adaptive to all students. That is, it could be that they are more adaptive to some students than to others. Perhaps some teachers are most adaptive to the needs of lower achieving students, whereas others are better able to adapt their support for high-achieving students. Future research could further unravel the underlying reasons for within classroom variation in perceived adaptivity.Nevertheless, these findings suggest that it is important to be careful when making general claims about a teacher's adaptiveness, as teachers' adaptiveness may differ across students and potentially also across situations (Kupers et al., 2015).

Additionally, fewer relationships were found between the class-averages of perceived adaptive support, need satisfaction, and students' intrinsic motivation, and achievement than on the individual student level. Classes who perceived more adaptive support (A+ & A-) experienced, on average, a greater sense of autonomy satisfaction, and in turn, more intrinsic motivation and higher academic achievement. Due to the cross-sectional nature of the present study, however, this finding should be cautiously interpreted as the relationship might also be the other way around (i.e., students in high performing classes received on average more autonomy from their teacher).

The findings indicated that perceived adaptive support appears to be mainly specific to individual students, and different relationships between perceived adaptive support and student outcomes were observed both within and between classrooms. Therefore, it is crucial to consider both within-classroom and between-classroom differences in perceived adaptive support to gain a more comprehensive understanding of its associations with student outcomes.

Furthermore, although there were fewer significant relations at the between-classroom level compared to the within-classroom level, the explained variance of intrinsic motivation and achievement at the between-classroom level was substantially larger than the explained variance at the within-classroom level. Similar findings have been obtained in other studies (e.g., Domen et al., 2020; Hospel & Galand, 2016). Interestingly, the present study suggests that the shared perceptions of adaptive teaching and need satisfaction of students within the same classroom were highly predictive of the average level of intrinsic motivation and achievement within a class. Nevertheless, this does not imply that these effects have a large impact in practice. We also found that the ICCs are rather small, which indicates that there is relatively little variance at the between-classroom level. Hence, even though the predictors and mediating variables explain a lot of the variance at the class level, they still explain a rather small amount of the total variance. This was also noticeable when it came to the correlations. Correlations at both levels differed substantially between both levels. For example, the relationship between competence satisfaction and academic achievement was considerably smaller at the between-classroom level than at the within-classroom level. This could be because students within a class may use their classmates as frame of reference on which they base their competence satisfaction (e.g. Marsh et al., 2008). They may compare their achievement to their classmates'

achievement, which may affect their competence beliefs, while the class-average achievement may not necessarily impact their competence beliefs.

4.4 Strengths and limitations

This study has several strengths. Whereas many studies focused on the nature of teacher-student interactions in a specific task (Kupers et al., 2015; Van de Pol & Elbers, 2013), this study assessed cognitive adaptive support from the perspective of students, which allowed us to study the associations between teachers' overall level of adaptive support and student outcomes among a large and diverse sample of students from secondary education. Moreover, distinguishing between the four facets of adaptive support helped in getting a more differentiated picture of adaptive support, and its relation with student outcomes (Van de Pol et al., 2023). Finally, by using a multilevel approach, it was possible to analyze the variation in perceived adaptive support on the student- and class-level, and examine the relations between variables at both levels.

However, it is important to acknowledge some limitations of the current study. While the observed effect sizes indicate that cognitive adaptive support has moderate to strong associations with motivation and small associations with achievement (Cohen, 1988), and even more substantial effects according to other more nuanced interpretations of effect size (Gignac & Szodorai, 2016; Funder & Ozer, 2019), these findings should be interpreted with caution. First of all, because the current study had a cross-sectional design, no causal claims about the effect of adaptive support on students' motivation and achievement can be made. Moreover, our measure of achievement was based on students' achievement throughout the school year, and students' perceptions of their teachers' adaptivity may be mostly based on more recent interactions in class. Longitudinal designs could give more insights into the directions of the relationships between adaptive support, need satisfaction, and students' intrinsic motivation and achievement. Secondly, caution in interpreting the findings is warranted because cognitive adaptive support, need satisfaction, and the outcome variable intrinsic motivation, were all assessed with student questionnaires. This approach potentially introduced common method bias, which may cause an overestimation of the associations among these variables (see Podsakoff et al., 2003).

Additionally, report grades may not be a suitable measure of the impact of adaptive support on academic achievement (Allen, 2005). Grades could reflect different types of assignments across classes, and not all assignments might be related to the teacher's support in class (e.g., writing a argumentative text is different than memorizing words).

Lastly, the questionnaire on cognitive adaptive support does not zoom in on different ways in which teachers provide support. In the questionnaire, the main focus was on the match between a student's understanding and the degree of support which was provided by teachers. However, there are various approaches available to teachers for providing adaptive support to students, such as providing explanatory structures that organize the learning activity (e.g. worked examples) or take over parts of the task in reaction to students' failure (A+; for instance explicit direct instruction), or give the student more degrees of freedom in their next steps in their learning process upon stu-

dents' success (A-; Van de Pol & Elbers, 2013). In terms of future research, it would be useful to extend the current findings by examining which specific strategies teachers use to provide adaptive support, and link these behaviors to students' intrinsic motivation and achievement. This could provide teachers with valuable guidelines on how to effectively provide adaptive support.

4.5 Implications

Despite the limitations, the findings suggest some practical implications. The current study stresses the importance for educators of tailoring their support to students' level of understanding, as it is related to students' need satisfaction, their intrinsic motivation, and to some extent, their academic achievement. In practice, this might imply that it could be beneficial for student learning when teachers increase support in instances in which students do not understand an exercise. Not having their needs for support met by a teacher (NA-) might negatively affect intrinsic motivation and achievement in students. There was one exception for the facet NA+, as there was no relationship found with intrinsic motivation, but there was an unexpected positive relationship with achievement. This implies that a higher degree of support, even when students (think they) already master the exercise, is beneficial for their academic achievement, and not demotivating (possibly due to tasks that might be executed better and might be perceived as easier due to (unnecessarily) high levels of teacher support).[1] Previous research proposed that teachers could facilitate students' cognitive activities by implementing cognitive structuring and reducing the degrees of freedom (Van de Pol et al., 2010). However, in order to provide cognitive adaptive support, teachers must first diagnose students' level of understanding, which is often challenging (Van de Pol et al., 2021). Hence, adaptive teaching may be enhanced by helping teachers to acquire the skills necessary to diagnose students' level of understanding.

Moreover, previous SDT interventions have primarily focused on universal principles for promoting need support, such as offering choices and activities that engage students' interests (Ryan & Deci, 2020). This study highlights the importance of adjusting the level of support to students' psychological needs. Therefore, interventions are needed that focus on how to effectively apply the principles of need-supportive teaching, while simultaneously considering and addressing individual differences between students in an adaptive manner. The current findings can guide researchers and practitioners in designing or modifying this type of interventions.

5 Conclusion

To conclude, the current study has shown that students' perceptions of their teacher's adaptive support are associated with students' intrinsic motivation, and to some extent with their academic achievement. In addition, the findings of the current study

[1] Possibly due to tasks that might be executed better and might be perceived as easier due to (unnecessarily) high levels of teacher support.

suggest that integrating the research fields on adaptive support and SDT seems promising: It offers more understanding of how teachers can use need-supportive teaching effectively in their classrooms (by applying the different aspects of adaptive teaching) and shows how 'need satisfaction' explains why adaptive teaching can boost motivation and learning. Educators and researchers might use this information to design effective learning environments and interventions that support individual students.

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Data availability Data, materials, and/or code are available upon request from the authors.

Declarations

Ethical approval The study has been approved by the Ethics Committee of the Faculty of Social and Behavioural Sciences of Utrecht University (22–0490).

Informed consent Informed consent was obtained from all adult individual participants included in the study. Passive consent was obtained from parents or legal guardians for minor participants. These procedures were in accordance with the institutional regulations at the time of data collection and approved by the local IRB.

Competing interests The authors declare that they have no known competing interests that could have appeared to influence the work reported in this paper.

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