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Perceived classroom disruption undermines the positive educational effects of perceived need-supportive teaching in science

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ABSTRACT

Extensive research has demonstrated the benefits of need-supportive teaching, but minimal research has examined social factors that may constrain these benefits. One factor that students experience contemporaneously to need-supportive teaching is classroom disruption. Perceived classroom disruption is a barrier to quality teaching and learning, especially in science, and may be a negative moderator of perceived need-supportive teaching. Using structural equation modelling ($N = 14{,}530$ students), this investigation examines the extent to which perceived need-supportive teaching and perceived classroom disruption uniquely predicted students' science self-efficacy, participation, and achievement; as well as the extent to which perceived classroom disruption moderates the associations between perceived need-supportive teaching and these outcomes. Findings revealed that perceived need-supportive teaching was positively associated with all outcomes. Perceived classroom disruption was negatively associated with self-efficacy and achievement and attenuated the positive association between perceived need-support and achievement. These results provide insight about the boundary conditions of need-supportive teaching.

1. Introduction

Need-supportive teaching refers to instructional approaches that seek to meet students' basic psychological needs for autonomy, competence, and relatedness by offering autonomy support, structure, and involvement (Deci & Ryan, 2000; Vansteenkiste, Aelterman, Haerens, & Soenens, 2019). Extant research has demonstrated that students academically benefit when they perceive their teacher as implementing need-supportive practices and working to meet student needs. This has been shown across multiple academic domains (e.g., Hornstra, Stroet, & Weijers, 2021; Jang, Reeve, & Deci, 2010; Mouratidis, Vansteenkiste, Sideridis, & Lens, 2011; Van den Berghe, Tallir, Cardon, Aelterman, & Haerens, 2015; for summary, see; Stroet, Opdenakker, & Minnaert, 2015), including science (e.g., Burns, Bostwick, et al., 2019, Burns, Martin, & Collie, 2019; Patall, Hooper, Vasquez, Pituch, & Steingut, 2018; Patall, Steingut, et al., 2018; Furtak & Kunter, 2012). For example, in science (the focus of the present study), students who perceive their science teachers as more need-supportive tend to report higher adaptive motivation (Beghetto, 2007), engagement (Patall, Steingut, et al., 2018), and achievement (Black & Deci, 2000). This is important considering the growing body of research that has detailed declines in student motivation, participation (both in and outside of school), and achievement in science in numerous Western countries, including Australia (the site of the present investigation; Goodrum, Druhan, & Abbs, 2012; Watt, Bucich, & Dacosta, 2019). Although self-determination theory (SDT) highlights the importance and benefits of need-supportive teaching, SDT also posits that these benefits may be constrained (or amplified) by the social context in which need-supportive teaching is provided (Deci & Ryan, 2000). Said another way, the extent to which students' science motivation, participation, and achievement are bolstered by the need-supportive teaching they experience may be limited by other concurrent social factors, such as the nature of peer behavior, and especially the level of disruptive behavior.

Researchers have often considered classroom disruption as an outcome of a lack of need-supportive teaching, such that provisions of need-support are associated with lower levels of classroom disruption and misbehavior (Vansteenkiste et al., 2012). However, in this study we are accounting for the fact that how teachers teach and how students behave are not necessarily linearly ordered, and that an individual student will experience these factors contemporaneously (Shin & Ryan,

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2016). For example, it is possible that a student may perceive their science teacher as offering autonomy-support, structure, and involvement (i.e., need-supportive teaching), *and* at the same time perceive their peers as disruptive— indeed, the reality is that these two aspects of classroom life are often co-occurring. Moreover, there is limited understanding of how students' motivation, participation, and achievement in science are impacted if students perceive their teacher as trying to implement need-supportive teaching while there is simultaneously a high level of perceived classroom disruption. Such research is needed because it can offer insight into the boundary conditions of need-supportive teaching in science and elucidate the socio-educational contexts in which the benefits of perceived need-supportive teaching may be amplified or diminished. Because students and teachers consistently identify student disruption as a barrier to quality teaching and student learning (for summary, see Duesund & Ødegård, 2018), perceived classroom disruption may be considered a negative moderator of the benefits of perceived need-support. To examine the extent to which this is the case, the present investigation examines (a) the unique associations between perceived need-supportive teaching and perceived classroom disruption and students' science motivation (via self-efficacy), participation, and achievement, and (b) the potential moderating effects of perceived classroom disruption on the positive associations between perceived need-support and outcomes in science in order to understand the extent to which the effectiveness of need-support is conditional on the concurrent level of classroom disruption.

1.1. *Perceived need-supportive teaching*

SDT is a socio-motivational theory positing that individuals have three basic psychological needs—autonomy, competence, and relatedness—and that teacher practices that seek to meet these needs are critical for student learning and development (Deci & Ryan, 2000). Need-supportive teaching is one such teaching practice that fosters students' internal motivational resources and supports students' academic involvement and achievement (Aelterman et al., 2019; Deci & Ryan, 2000; Stroet et al., 2015; Vansteenkiste et al., 2019). Need-supportive teaching occurs through teachers' provision of autonomy-support (e.g., encouraging student input), structure (e.g., clear directions), and involvement (e.g., socio-emotional support) to students (Aelterman et al., 2019). Studies across multiple academic domains have found that students who perceive their teacher as need-supportive are more likely to be adaptively motivated (e.g., higher self-efficacy) and experience more positive outcomes, such as higher achievement (Deci & Ryan, 2000; Stroet et al., 2015). In the present study, we examined students' perceptions of need-support in the science classroom.

Perceived need-supportive teaching has been particularly effective in science education, which is notable given the recent concerns about declines in students' motivation (e.g., self-efficacy), participation, and achievement in science (Watt et al., 2019). Students often consider science to be a difficult subject (Pattal, Hooper, et al., 2018; Udo, Ramsey, & Mallow, 2004). It may be that when students feel their teachers provide opportunities for input, give explanatory rationales for work (i.e., autonomy support), offer adequate scaffolding and instructional support (i.e., structure), and provide socio-emotional support (i.e., involvement) students are better positioned to cope with this perceived difficulty and succeed in science (Patall, Hooper, et al., 2018). Indeed, students who experience need-support in science are more likely to report gains in science self-efficacy, such that they have stronger beliefs in their capacity to handle challenging tasks in science (Beghetto, 2007; Jungert & Koestner, 2015); gains in participation, such that they are more likely to engage in science activities in- and out-of-school (Flick, 2000; Patall, Steingut, et al., 2018; see also; Olivier, Galand, Morin, & Hospel, 2021); and gains in achievement, such that they are likely to perform higher on assessments (Black & Deci, 2000; Furtak & Kunter, 2012).

Research examining the benefits of perceived need-support in science has not typically accounted for the role of other social factors that students may be experiencing (for exception, see Jungert & Koestner, 2015 [parent support]). This is surprising, given that SDT argues that students' need satisfaction does not only result from need-supportive teaching, but can also be derived, or thwarted, by other social factors (Vansteenkiste et al., 2019). In this way, the effectiveness of perceived need-support may be amplified or constrained by other social factors that students experience contemporaneously. Although there are numerous social dynamics that a student may experience within their classroom, the present investigation considers one social factor that students and teachers have consistently identified as an obstacle to effective teaching and learning (Blank & Shavit, 2016; Duesund & Ødegård, 2018; Hsu, Shang, & Hsiao, 2020; Nash, Schlösser, & Scarr, 2016) and that may be especially detrimental in science (Lewis, Romi, Qui, & Katz, 2005; Lin et al., 2012): perceived classroom disruption.

1.2. *Perceived classroom disruption as a negative moderator of perceived need-supportive teaching*

Classroom disruption often results from student misbehavior or is considered reflective of behavior that is off-task and distracting to others (Duesund & Ødegård, 2018; Nash et al., 2016; Tsouloupas, Carson, Matthews, Grawitch, & Barber, 2010). When students are exposed to classroom disruption, they are likely to be distracted from their work and become more frustrated and stressed (Duesund & Ødegård, 2018; Shin & Ryan, 2016). Experiences of frustration and stress resulting from perceived classroom disruption are likely to undermine students' self-efficacy (as a negative physiological/affective state; Bandura, 1997) and participation (as deactivating emotions; Pekrun, 2006; Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011). Similarly, increased distraction is likely to negatively impact student performance (Blank & Shavit, 2016; Steinmayr, Ziegler, & Träuble, 2010). To the extent that this is the case in science specifically, it is likely that students' experience of classroom disruption is negatively associated with their science self-efficacy, participation, and achievement. Indeed, these associations may be more pronounced in science given the complexity of the subject and the necessary levels of structure and scaffolding needed for safety (e.g., when using lab equipment, such as Bunsen burners, etc.) and learning (Lin et al., 2012).

By and large, researchers have considered need-supportive teaching as a negative predictor of classroom disruption (e.g., Hsu et al., 2020; Patrick, Turner, Meyer, & Midgley, 2003; Scott, Hirn, & Alter, 2014; Vansteenkiste et al., 2012; see also Jang et al., 2010 and Reeve, 2006 for broader discussion on behavioral engagement). However, as noted above, such designs have not accounted for the fact that teaching approaches and student behavior co-occur within classrooms and will be experienced by students simultaneously—that is, for example, students can experience teachers' attempts at need-supportive teaching *and* peer disruption at the same time. Indeed, given that science is often perceived as a difficult subject and students are more likely to disengage as a result (Pattal, Hooper, et al., 2018), perception of high classroom disruption may be a common occurrence in science classrooms despite the best efforts of quality teaching (Lewis et al., 2005). Because of this, students' perceptions of need-supportive teaching and classroom disruption are likely to interact. Specifically, drawing on research about negativity bias (Rozin & Royzman, 2001) and research that identifies classroom disruption as a factor that undermines effective teaching and learning (e.g., Hsu et al., 2020; Nash et al., 2016), we hypothesize that perceived classroom disruption is likely to operate as a negative moderator of perceived need-supportive teaching, such that relative increases in perceived classroom disruption are likely to attenuate the benefits of perceived need-supportive teaching in science.

According to conceptualizing around negativity bias, students are likely to place more weight on negative experiences than positive experiences (Rozin & Royzman, 2001). In this sense, students' exposure to classroom disruption (negative experience) are likely to be weighted more heavily and considered more prominent than their experiences of need-supportive teaching (positive experience; Rozin & Royzman, 2001). Because of this, when students perceive classroom disruption and need-supportive teaching concurrently, the negative consequences associated with perceived classroom disruption (e.g., stress, frustration, distraction) are likely to undercut the benefits associated with perceived need-supportive teaching. Similarly, the positive effects of perceived need-supportive teaching may become less salient as the level of perceived disruption increases. This may be because students are likely to perceive the disruptive behavior of their peers as more prominent, and there is a greater likelihood that they will be distracted from the need-supportive instruction (Blank & Shavit, 2016; Gage, MacSuga-Gage, & Crews, 2017). Indeed, researchers have found that perceived classroom disruption begets more disruptive behavior, such that students tend to respond to increases in the disruptive behavior around them by escalating it (Duesund & Ødegård, 2018); this is especially the case when students perceive low support from their teachers (Shin & Ryan, 2016). Thus, there may be a point at which the benefits of perceived need-supportive teaching are overwhelmed by the level of perceived classroom disruption. As a result, relative increases in perceived classroom disruption are likely to attenuate the positive associations between perceived need-supportive teaching and motivation, participation, and achievement in science.

In contrast, it may also be the case that low levels of perceived classroom disruption amplify the effects of perceived need-supportive teaching. SDT highlights that the effectiveness of perceived need-support is in part influenced by the other social factors that students may be experiencing (Deci & Ryan, 2000; Vansteenkiste et al., 2019). In the same way that high perceived classroom disruption may constrain the benefits of perceived need-supportive teaching in science, it may be that low classroom disruption amplifies the benefits. Low perceived classroom disruption is likely to be associated with more positive affective states (e.g., less stress, less frustration) and students' improved capacity to sustain attention and on-task behaviors (Herman, Reinke, Dong, & Bradshaw, 2020). Because of this, students' may be better placed to engage with the practices offered by need-supportive teaching (e.g., sharing their opinions, sharing in meaningful discussions, etc.), and thus reap the benefits of this teaching approach. However, questions remain about the point at which the level of perceived classroom disruption no longer amplifies but counteracts, or negates, the benefits of perceived need-support— questions the present investigation addresses through the use of moderation analysis.

1.3. Accounting for socio-demographic factors

Students' socio-demographic backgrounds have been found to be associated with their outcomes in science. As such, it is critical to account for the shared variance of these factors, namely: age, gender, language background, and socio-economic status. Doing so enables us to better identify the unique effects of perceived need-supportive teaching and classroom disruption beyond the variance attributable to background attributes. Older students typically report lower motivation and participation in science than younger students (Maltese & Tai, 2010; Vedder-Weiss & Fortus, 2011). There has been significant research on the gender differences present in science education, with girls tending to report lower self-efficacy (Britner, 2008) and participation in science, both in- and out-of-school (Burns, Martin, Kennett, Pearson, & Munro-Smith, 2021). Importantly, there is minimal support for gender differences in science achievement (Britner, 2008). Students whose home language is different from language of instruction (i.e., non-English language at home in Australia) tend to struggle in science classes and achieve at lower levels (Van Laere, Aesaert, & van Braak, 2014). Researchers have found a consistent positive association between socio-economic status and achievement across academic domains (Sirin, 2005).

1.4. Aims of the present investigation

There has been minimal research examining students' contemporaneous perceptions of need-supportive teaching and classroom disruption and their associations with students' motivation, participation, and achievement in science. Such research is needed in order to better understand the extent to which potential benefits of perceived need-supportive teaching may be dampened or amplified by the perceptions of other social dynamics and to identify potential factors for intervention that can support improved science outcomes. As such, the present investigation, via structural equation modelling, examines (a) the unique effects of perceived need-supportive teaching and classroom disruption on students' science self-efficacy, participation, and achievement; and (b) the extent to which perceived classroom disruption negatively moderates the positive associations between perceived need-supportive teaching and students' self-efficacy, participation, and achievement in science. It is hypothesized that perceived need-supportive teaching and classroom disruption will (respectively) have positive and negative associations with self-efficacy, participation, and achievement in science. It is also hypothesized that the positive effects of perceived need-supportive teaching will be attenuated with higher levels of perceived classroom disruption (and enhanced in cases of reduced disruption). These associations are presented in Fig. 1.

2. Methods

2.1. Participating and sampling procedures

The present investigation used the Australian sample of the 2015 PISA data. Of the $N = 14{,}530$ students sampled, the mean age was $M = 15.77$ ($SD = 0.29$) years old, 49% were female, and approximately 11% of the sample spoke a language other than English at home. Socio-economic status was assessed via the Index of Economic, Social, and Cultural Status (herein referred to as ESCS), which is an aggregated, standardized, and weighted measure comprised of the following factors: parent education, highest parent occupation, and home possessions. The ESCS measure is standardized across all participating PISA countries ($M = 0$, $SD = 1$). In the Australian sample of the 2015 PISA data, the average ESCS was $M = 0.19$ ($SD = 0.82$).

PISA follows a two-stage stratified sampling design to capture nationally representative samples from each of the participating countries. The first stage is school selection: PISA selects schools from a comprehensive list of national schools that are grouped by characteristics (viz., strata) and have students who are the target age of PISA sampling (viz., 15 years old). The second stage is student selection: PISA-eligible students are randomly selected within the selected schools. It is also important to note that PISA uses weighted student scores to control for the influence of variation in cluster size across schools (viz., undue influence of large or small cluster sizes). As such, PISA student data are adjusted by school as a function of cluster size (for further detail about the weighting procedure, see Chapter 8, OECD, 2017b). Although discussed in more detail below, it is important to note that the hierarchical nature of the data (i.e., students in schools) was accounted for in analysis.

2.2. Materials

All measures included in this investigation were in the 2015 PISA Student Questionnaire. The self-report measures that are the focus of the present investigation have been included in previous cycles of PISA Student Questionnaire (OECD, 2017b). These measures have demonstrated reliability and validity across these multiple data collections (OECD, 2017b). Additionally, it should be noted that the measures and rating formats align with other validated measures of perceived

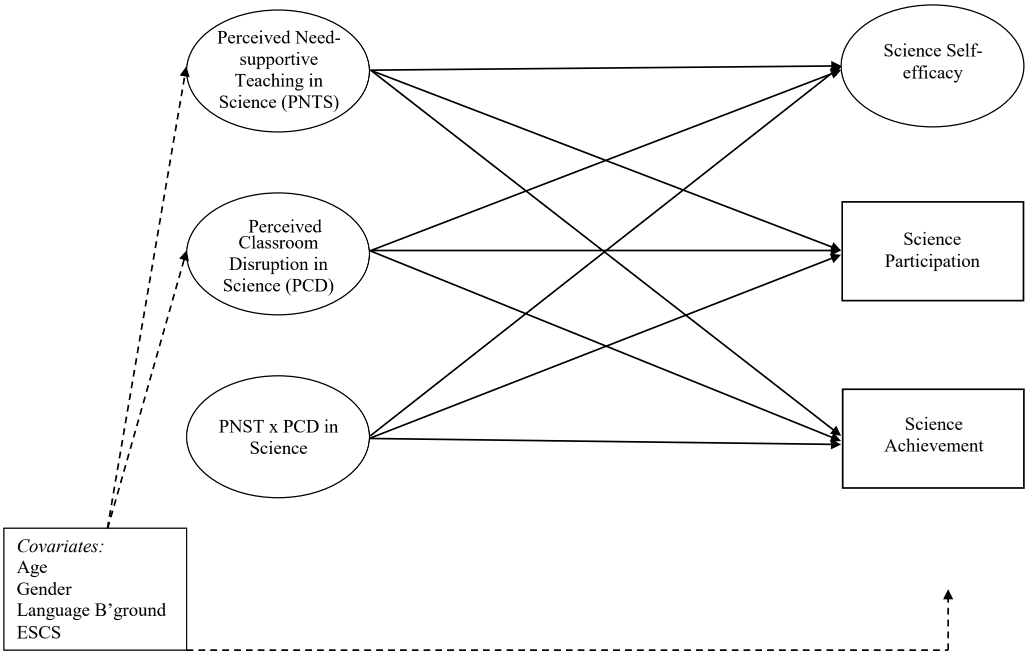

Fig. 1. Hypothesized relationships among substantive parameters and covariates.

need-supportive teaching (e.g., Mouratidis et al., 2011; Trouilloud, Sarrazin, Bressoux, & Bois, 2006), perceived classroom disruption (e.g., Duesund & Ødegård, 2018; Tsouloupas et al., 2010), self-efficacy (e.g., Chen & Usher, 2013), and participation (Dabney et al., 2012). Because of this, they are considered viable approaches to measuring our substantive constructs (please note that the limitations of self-report are discussed later). Descriptive statistics, factor loadings, and reliability scores (coefficient omega, ω_h; McNeish, 2018) for all substantive factors are reported in Table 1 (and below as appropriate).

2.2.1. *Perceived need-supportive teaching*

Perceived need-supportive teaching was assessed via the Teacher Support in Science Classes Scale. The 5 items in this scale map onto the three elements of need-supportive teaching: autonomy-support (e.g., "How often does this happen in your < school science>? The teacher continues teaching\students understand"; "How often does this happen in your < school science>? Teacher gives an opportunity to express opinions"), structure (e.g., "How often does this happen in your < school science > lessons? The teacher gives extra help"; "How often does this happen in your < school science > lessons? The teacher helps students with their learning"), and involvement (e.g., "How often does this happen in your < school science > lessons? The teacher shows interest every students' learning"). Each item was rated on a scale from 1 (*every lesson*) to 4 (*never or hardly ever*). The items were reverse coded (viz., 1 → 4, 2 → 3, 3 → 2, 4 → 1) so that a score of 1 reflected less need-support. The perceived need-supportive teaching factor was found to be reliable ($\omega_h = 0.93$).

2.2.2. *Perceived classroom disruption*

Perceived classroom disruption was assessed via the Disciplinary Climate in Science Classes Scale (5 items; e.g., "How often does this happen in your < school science > lessons? There is noise and disorder"). Each item was rated on a scale from 1 (*every lesson*) to 4 (*never or hardly ever*). The items were reverse coded (viz., 1 → 4, 2 → 3, 3 → 2, 4 → 1) so that a score of 4 reflected greater classroom disruption. This factor was found to be reliable ($\omega_h = 0.92$).

2.2.3. *Self-efficacy*

Self-efficacy was assessed via the Science Self-efficacy Scale (8 items; e.g., "How easy do you think it would be for you to perform the following tasks on your own? <specific science topic or phenomenon here>;" each item specified a different science topic or phenomenon, such as "explain why earthquakes occur more frequently in some areas than in others"). Each item was rated on a scale from 1 (*I could do this easily*) to 4 (*I couldn't do this*). The items were reverse coded (viz., 1 → 4, 2 → 3, 3 → 2, 4 → 1) so that a score of 1 reflected a lower sense of science self-efficacy. The self-efficacy factor was found to be reliable ($\omega_h = 0.91$).

2.2.4. *Participation*

Participation was assessed via the Science Activities Index. The Science Activities Index comprises 9 items assessing how often students participate in a variety of science activities both in and out of school (e.g., "Attend a <science club>"); the full index is presented in Supplementary Material. Previous research has found that students' in-class experiences, including need-supportive teaching, are significantly associated with their desire to participate in science, both in- and out-of-school (Braund & Reiss, 2006; Hagger & Hamilton, 2018). Additionally, because of growing concerns about declines in student participation in science generally, understanding classroom factors that may contribute to increased science participation and which are amenable to intervention (e.g., teacher practice, student behavior) is important for redressing these declines.

Students rated each activity on a scale of 1 (*very often*) to 4 (*never or hardly ever*). The items were reverse coded (viz., 1 → 4, 2 → 3, 3 → 2, 4 → 1) so that a score of 1 reflected less participation in that activity. The average participation score across these activities was $M = 1.46$ ($SD = 0.56$) and was found to be reliable ($\omega_h = 0.91$). For our analyses, an aggregated measure calculated from the scores related to the 9 activities was used as a single item indicator of students' science participation. This was done because the participation measure is an index of highly distinct science activities, thus an aggregated (rather than a latent) measure is considered a more appropriate calculation of students' science participation across these activities (OECD, 2017a; 2017b).

2.2.5. *Achievement*

Achievement was assessed via the Science Assessment items in PISA. PISA employs a variant matrix sampling test design, such that each

Table 1
Descriptive, reliability, and factor analytic statistics for substantive predictors.

	Mean	*SD*	Skew	Kurtosis	Factor loading mean (Range)	Coefficient omega (95% CI)
Perceived need-supportive teaching	3.16	0.79	−0.77	−0.26	.85 (.79–.90)	.93 (.92–.93)
Perceived classroom disruption	2.29	0.81	0.54	−0.48	.83 (.82–.85)	.92 (.92–.92)
Self-efficacy	2.75	0.69	−0.48	0.08	.74 (.69–.78)	.91 (.90–.91)
Participation	−0.29	1.14	0.29	−0.47	–	.91 (.91–.92)
Achievement	498.75	100.71	−0.05	−0.58	–	.99 (.99–.99)

Note: For achievement, the plausible values are calculated such that the OECD mean is 500 (*SD* = 100).

student completes different, but overlapping, sections of the Science Assessment instead of completing the entire assessment (OECD, 2017b). Because of this approach, PISA produces 10 Bayesian plausible values for each student's total Science Assessment score (OECD, 2017b). The plausible values, across all participating countries, are derived to have a mean of 500 and a standard deviation of 100, meaning that scores higher than 500 indicate science achievement scores above the PISA 2015 average (OECD, 2017b).

It is important to emphasize that individual plausible values are not equivalent to individual test scores because plausible values are randomly selected values from each student's conditional distributions. In this sense, plausible values reflect students' range of science ability (Monseur & Adams, 2009). Individual plausible values cannot be used to assess or compare students. Following OECD recommendations, all models were estimated 10 times, with each estimation using a different Bayesian plausible value of science achievement (OECD, 2017b). This was completed in a manner similar to multiple imputation via M*plus* and the resultant coefficients (viz., correlations, regressions) and *p*-values are pooled via the Rubin (1987) strategy, which is done automatically in M*plus* v8.4 (the software package used; Muthén & Muthén, 2017). This strategy allows for the calculation of unbiased parameter estimates and the result coefficients and *p*-values are reported as the final estimates. It should be noted here that this process differs from traditional multiple imputation in that only the achievement values are treated as "imputed" (e.g., the pathways are estimated 10 times, each with a different achievement value). Although the other pathways are similarly estimated ten times (e.g., perceived need-support→ self-efficacy), the values remain constant and thus do not change across the ten estimations. To assess reliability, a science achievement factor with all 10 plausible values as indicators was assessed; the science achievement factor demonstrated reliability ($\omega_h = 0.99$).

2.2.6. Covariates

The following student-level covariates were examined: age, gender, language background, and ESCS. *Age* and *ESCS* were assessed as continuous measures. *Gender* (female = 0; male = 1) and *language background* (English spoken at home = 0, language other than English spoken at home = 1) were measured as dichotomous variables.

2.3. Data analysis

There were two stages of data analysis: confirmatory factor analysis (CFA) and structural equation modelling (SEM). As noted above, the CFA and SEM were estimated 10 times (via an approach similar to multiple imputation) to accurately assess associations with students' science achievement. Tests of measurement and model invariance were also conducted; the results of these tests are reported in Supplementary Material. All data analysis was conducted in M*plus* version 8.40 (Muthén & Muthén, 2017).

Prior to running the substantive analyses, the intra-class correlations (ICC) for all substantive variables were estimated to determine if multilevel modelling[1] would be appropriate, such that it would be viable to explicitly model all substantive factors at the student- and school-level. The ICC values for perceived classroom disruption and achievement were 0.12 and 0.22 respectively, while the other two outcome variables had much smaller ICC values (self-efficacy: ICC = 0.05; participation: ICC = 0.03). Importantly, the focus of this paper was on understanding students' individual perceptions and experiences of need support and classroom disruption. Thus, data analysis proceeded with single-level modelling. This notwithstanding, the hierarchical nature of the data (i.e., students clustered within schools) was accounted for via the Huber-White sandwich estimator (i.e., "complex" and "cluster" commands) in M*plus*.

2.3.1. Confirmatory factor analysis and structural equation modeling

CFA was used to examine the factor structure and bivariate correlations among the substantive factors in the hypothesized model. SEM was used to examine the regressive pathways among the hypothesized parameters (Fig. 1). For both the CFA and SEM, all covariates and substantive factors were included within a single model, maximum likelihood with robustness to non-normality (MLR) was used for model estimation, and full information maximum likelihood (FIML) was employed to handle missing data. Importantly, student data weights (provided by PISA) were included in all analyses to appropriately adjust standard errors.

In both the CFA and SEM, need-supportive teaching, perceived classroom disruption, and self-efficacy were modelled as latent factors. Participation and achievement were modelled via single item indicators; as noted above, participation was modelled via an aggregated measure and achievement was modelled via plausible values. In the SEM, it is important to note that correlations between perceived need-supportive teaching and perceived classroom disruption were freely estimated in modelling, as were the correlations among self-efficacy, participation, and achievement, as well as among the covariates.

The latent interaction term (need-supportive teaching x classroom disruption) was calculated via the "XWITH" command with "Type = Random" in M*plus*. Although the XWITH command enables more accurate estimation of moderating effects, there are limitations to assessing model fit when the XWITH command is used in conjunction with multiple imputation (as is the case in this study for the handling of the plausible values). Specifically, traditional fit statistics and post-hoc comparison tests (e.g., loglikelihood ratio tests) are unavailable.

We rely on four indicators to circumvent these limitations and to demonstrate adequacy of model fit. First, we present the traditional fit statistics of the model without the interaction term to demonstrate the soundness of the underlying structural model. To assess the traditional fit statistics, the following indices were used (please note these were also used to assess model fit of the CFA): comparative fit index (CFI: excellent

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[1] For completeness, a multilevel model with the same paths as the hypothesized model at the student-level and the factors intercorrelated at the school-level was conducted. This model demonstrated a nearly identical pattern of findings to the hypothesized model at the student-level. As such, the single-level model was retained.

fit ≥ 0.95; adequate fit ≥ 0.90) and root mean square error of approximation (RMSEA: excellent fit ≤ 0.05; adequate fit ≤ 0.08; Hu & Bentler, 1999). Second, we compare the Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC), and Sample-size-adjusted Bayesian Information Criteria (SSA-BIC) values of the model with and without the interaction term. If the hypothesized model (i.e., model with the interaction term) had lower AIC, BIC, and SSA-BIC estimates than the model without the interaction term, then the hypothesized model could be concluded as better fitting (Kline, 2016). Third, we present the changes in R^2 for the outcome variables, such that increases in R^2 for self-efficacy, participation, achievement would indicate increased variance explained, and thus improved model fit (Kline, 2016). Lastly, we ran the model with and without the interaction term ten times, each time with a different plausible value (i.e., 20 models total). Because multiple imputation was no longer used, the information needed to run the loglikelihood ratio tests was generated. In total, 10 loglikelihood ratio tests were run, and the aggregate estimate and *p*-value was used as an indicator of improved model fit ($p < .05$ indicating improved fit; Maslowsky, Jager, & Hemken, 2015).

As discussed in more detail below, simple slopes analyses were conducted to plot the nature of the significant interaction effects. It should be noted that we recognize that in correlational research perceived need-supportive teaching could be moderating perceived classroom disruption; however, we nominate perceived classroom disruption as the moderator given the research identifying classroom disruption as a factor that undermines quality teaching and learning (Blank & Shavit, 2016; Duesund & Ødegård, 2018; Hsu et al., 2020; Nash et al., 2016).

We use Keith's (2006, 2015) guidelines for effect sizes in educational research to help interpret the meaningfulness of findings. According to these guidelines, effect sizes of $\beta < .05$ are small but not meaningful, $0.05 \leq \beta < 0.10$ are considered small but meaningful, $0.10 \leq \beta < 0.25$ are considered moderate, and $\beta \geq 0.25$ are considered large. We use these guidelines to ensure that we are not giving undue weight to effects that may be interpreted as small but not meaningful; as such we focus our interpretation and discussion on effects that are $\beta \geq 0.05$.

3. Results

The CFA demonstrated excellent fit: χ^2 (224) = 4359.21, $p < .001$; CFI = 0.953; RMSEA = 0.036. All correlations are reported in Table 2.

Given the limitations of assessing model fit when XWITH is used in conjunction with multiple imputation, we used four separate indicators to determine adequacy of model fit (outlined above). First, the traditional fit statistics of the model without the interaction term demonstrate that the underlying structural model adequately fits the data: χ^2 (239) = 4891.897, $p < .001$; CFI = 0.948; RMSEA = 0.038. Second, the AIC, BIC, and SSA-BIC estimates are lower in the hypothesized model (i.e., with interaction term) than in the model without the interaction term: ΔAIC = −72.45; ΔBIC = −46.70; ΔSSA-BIC = −59.23. Third, the R^2 estimates for self-efficacy ($\Delta R^2_{\text{self-efficacy}} = 0.004$) and achievement ($\Delta R^2_{\text{achievement}} = 0.007$) increased, albeit very slightly, with the inclusion of the interaction term; the R^2 estimate for participation remained the same. Lastly, ten loglikelihood ratio tests were conducted based on models (with and without the interaction term) run with single plausible values. The aggregate estimate and *p* value were $\chi^2(3) = 41.14, p < .001$, indicating that across these ten tests, the inclusion of the interaction term improved model fit. The full results of the loglikelihood tests are presented in Supplementary Materials. Taken together, it was concluded that the hypothesized model adequately fit the data.

Here we report all significant substantive parameters as relevant to the hypothesized pathways and their effect sizes (see also Fig. 2); Table 3 reports all significant and non-significant standardized and unstandardized parameters. Perceived need-supportive teaching significantly and positively predicted self-efficacy ($\beta = 0.14$, $p < .001$; moderate effect), participation ($\beta = 0.11$, $p < .001$; moderate effect), and achievement ($\beta = 0.05$, $p < .001$; small but meaningful effect). Perceived classroom disruption significantly and negatively predicted self-efficacy ($\beta = -0.09$, $p < .001$; small but meaningful effect) achievement ($\beta = -0.20$, $p < .001$; moderate effect).

In addition to these main effects, the interaction between perceived need-supportive teaching and perceived classroom disruption significantly predicted self-efficacy ($\beta = -0.04$, $p < .01$; small but not meaningful effect) and achievement ($\beta = -0.07$, $p < .001$; small but meaningful effect). Thus, perceived classroom disruption appeared to moderate the benefits of perceived need-supportive teaching, especially high need-supportive teaching, for both self-efficacy and achievement, such that experiences of high classroom disruption were associated with the lowest self-efficacy and achievement.

Regarding self-efficacy, students who experienced high need-supportive teaching and low classroom disruption had the highest levels of self-efficacy. In contrast when students perceived low levels of need-supportive teaching and high classroom disruption, students reported the lowest self-efficacy (see Figure S1 in Supplementary Material for interaction plot). Regarding achievement, students who experienced high need-supportive teaching and low classroom disruption had the highest levels of achievement, whereas students who perceived high need-supportive teaching and high classroom disruption had the lowest levels of achievement (see Fig. 3 for interaction plot). Importantly, students who perceived high classroom disruption, regardless of the level of need-support, experienced poorer achievement than students who perceived medium or low levels of disruption.

Simple slopes analyses were conducted to assess if the moderating effects on self-efficacy and achievement were significantly different from zero at three levels of perceived need-supportive teaching and classroom disruption: low at −1 *SD*, medium at the sample mean, and high at +1 *SD*; results are reported in Figure S1 (self-efficacy) and Fig. 3 (achievement). For self-efficacy, all of the slopes were found to be significantly different from zero (*ps* $\leq$ .001). For achievement, all three slopes were significantly different from zero: low perceived classroom

Table 2

Correlations among covariates and substantive predictors.

	Perceived need-supportive teaching	Perceived classroom disruption	Self-efficacy	Participation	Achievement
Covariates					
Age	−.01	−.04**	−.01	−.02	.05***
Gender (M)	.01	.04**	.09***	.16***	.01
Language Background	.02	−.04*	.01	.12***	−.09***
ESCS	.10***	−.13***	.25***	.10***	.34***
Substantive Factors					
Perceived need-supportive teaching	–				
Perceived classroom disruption	−.30***	–			
Self-efficacy	.19***	−.15***	–		
Participation	.12***	−.03*	.40***	–	
Achievement	.12***	−.25***	.38***	.09***	–

Note: ESCS = economic, social, and cultural status; M = Male.
*$p < .05$, **$p < .01$, ***$p < .001$.

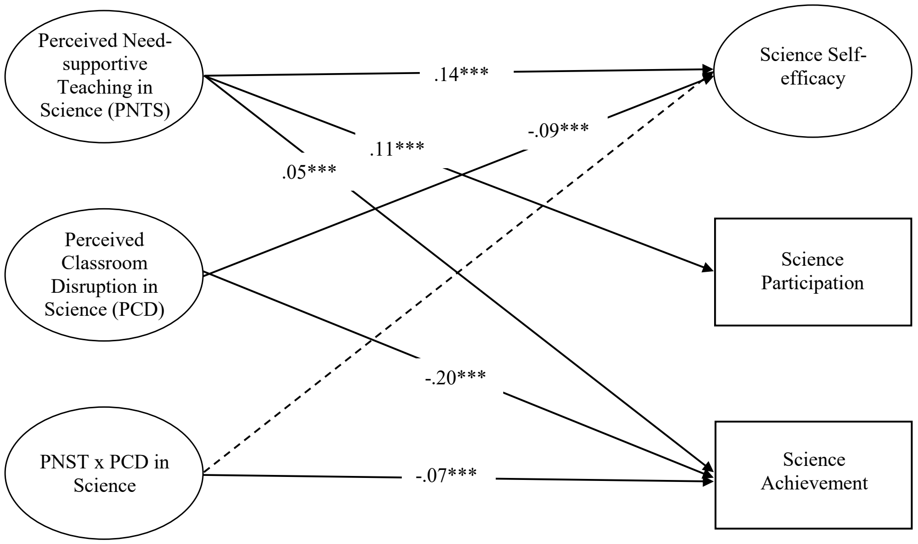

Fig. 2. Standardized results of the structural equation model. Note, that dashed line reflects an association that was significant ($p < .05$) but did not meet the benchmark for meaningful effect size ($\beta < 0.05$), as per Keith's guidelines (2006, 2015), and thus was not the focus of further interpretation. Table 3 presents all significant and non-significant estimates.

Table 3
Standardized betas, unstandardized betas, and standard errors of hypothesized pathways.

	Perceived need-supportive teaching			Perceived classroom disruption			Self-efficacy			Participation			Achievement		
	β	*b*	*S.E.*	β	*b*	*S.E.*	β	*B*	*S.E.*	β	*b*	*S.E.*	B	*b*	*S.E.*
Covariates															
Age	−.01	−0.03	0.03	−.04***	−0.10	0.03	−.02	−0.04	0.02	−.02*	−0.04	0.02	.03**	0.11	0.03
Gender (M)	.01	0.02	0.02	.04**	0.06	0.02	.09***	0.12	0.02	.16***	0.17	0.01	.02*	0.05	0.02
Language Background	.03*	0.07	0.03	−.05***	−0.11	0.03	.01	0.02	0.02	.12***	0.21	0.02	−.07***	−0.21	0.05
ESCS	.10***	0.09	0.01	−.13***	−0.12	0.01	.23***	0.18	0.01	.11***	0.08	0.01	.31***	0.39	0.02
Substantive Predictors															
Perceived Need-supportive Teaching (PNST)	–	–	–	–	–	–	.14***	0.12	0.01	.11***	0.08	0.01	.05***	0.07	0.02
Perceived Classroom Disruption (PCD)	–	–	–	–	–	–	−.09***	−0.07	0.01	.01	0.01	0.01	−.20***	−0.27	0.02
PNST x PCD	–	–	–	–	–	–	−.04**	−0.05	0.02	.01	0.01	0.01	−.07***	−0.14	0.02

Note: ESCS = economic, social, and cultural status; M = Male.
*$p < .05$, **$p < .01$, ***$p < .001$.

disruption (−1 *SD*: $b = 0.21$, $p < .001$), medium perceived classroom disruption (mean: $b = 0.07$, $p < .001$), and high perceived classroom disruption (+1 SD: $b = -0.06$, $p = .020$).

4. Discussion

Prior research has demonstrated the benefits of need-supportive teaching and the negative impacts of classroom disruption on student outcomes. Although most research has considered need-supportive teaching as a negative predictor of classroom disruption, there is a need to consider how these factors might interact given that students are likely to experience them contemporaneously (Shin & Ryan, 2016). Perceived need-supportive teaching positively predicted self-efficacy, participation, and achievement. Perceived classroom disruption negatively predicted self-efficacy and achievement. Perceived classroom disruption also negatively moderated the relationship between perceived need-support and achievement. By examining these unique and moderated effects, it is possible to come to a better understanding of the boundary conditions of perceived need-supportive teaching, and what social factors may need to be addressed in order to maximize the benefits of perceived need-supportive teaching in science.

4.1. *Unique effects of perceived need-supportive teaching and classroom disruption in science*

Perceived need-supportive teaching positively predicted students' self-efficacy (moderate effect size), participation (moderate effect size), and achievement (small effect size) in science, such that students who experienced greater need-supportive teaching experienced more positive outcomes in science. This aligns with previous research regarding self-efficacy (Jungert & Koestner, 2015; Skinner & Belmont, 1993), participation (Flick, 2000; Patall, Hooper, et al., 2018; Patall, Steingut, et al., 2018), and achievement (Black & Deci, 2000; Furtak & Kunter, 2012). For self-efficacy, need-supportive teaching offers clear directions, scaffolding, and feedback, all of which are considered vital to supporting students' sense of efficacy in the classroom (Bandura, 1997). Need-supportive practices in science also foster students' interest in science, provide students with opportunities to decide which topics to examine further, and offer students self-paced activities (Aelterman et al., 2019; Reeve & Jang, 2006). Such practices are likely to bolster students' achievement and encourage students' participation in activities both in-school and out-of-school that reinforce their interest in science.

Perceived classroom disruption negatively predicted students' science self-efficacy and achievement, such that students who experienced

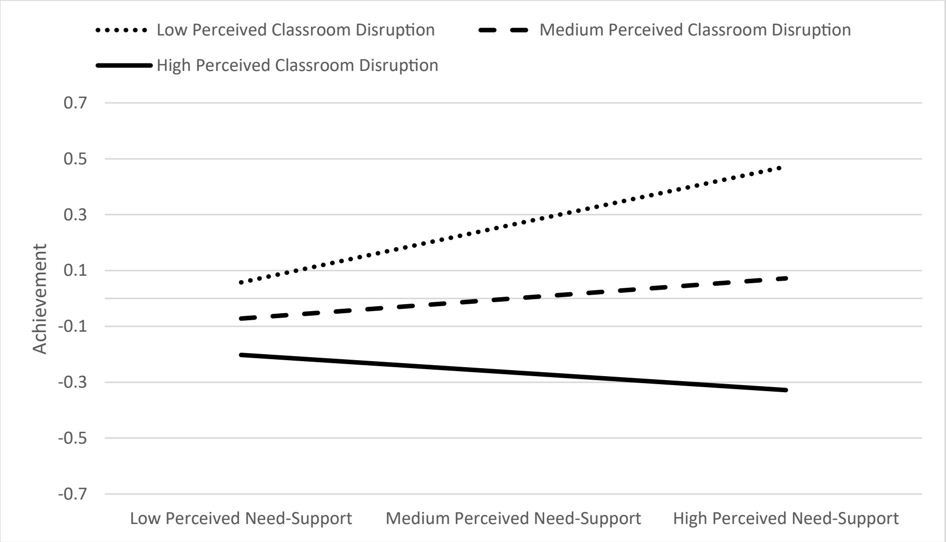

Fig. 3. Plot of perceived need-supportive teaching and perceived classroom disruption interaction effect on science achievement; Simple slopes analysis results. −1 *SD* (low perceived classroom disruption): $b = 0.21$, $p < .001$. Mean (medium perceived classroom disruption): $b = 0.07$, $p < .001$. +1 *SD* (high perceived classroom disruption): $b = -0.06$, $p = .020$.

more disruptive behaviors from peers reported lower self-efficacy and were more likely to have lower achievement (small and moderate effect sizes, respectively). Classroom disruption is a consistent source of stress and frustration for students (Duesund & Ødegård, 2018), and such negative emotions are considered negative antecedents of self-efficacy (Bandura, 1997), such that increases in stress and frustration resulting from greater perceived disruption are likely to lower students' self-efficacy. Importantly, researchers have also found that students are more likely to respond to disruptions in the learning environment with increased disruption, such that students are more likely to become off-task and inattentive themselves when they perceive their peers becoming off-task and inattentive (Duesund & Ødegård, 2018), which negatively impacts achievement (Blank & Shavit, 2016). The negative effect of perceived classroom disruption is likely to be particularly detrimental in science, given that the complexity and increasingly abstract nature of the subject in high school, as well as the fact that students often engage in laboratory practicums that involve using equipment that needs to be handled safely.

It is important to note the pattern of these unique effects. Perceived need-supportive teaching was more strongly associated with participation than achievement (moderate vs small effect size); perceived classroom disruption was significantly associated with achievement, but not participation. Although previous research has demonstrated larger positive associations between perceived need-supportive teaching and achievement in science (e.g., Black & Deci, 2000), our findings indicate that when considered alongside perceived classroom disruption, the positive impact of perceived need-supportive teaching becomes less salient. As described above, perceived classroom disruption is likely to directly interfere with students' attention, which is likely to have a more direct effect on achievement (Steinmayr et al., 2010). In contrast, the effects of perceived need-supportive teaching on science participation were still significant after accounting for the unique effects of perceived classroom disruption. Fostering students' internal motivational resources via need-supportive teaching is likely to be particularly important for participation in science given that students often report disengaging from science due to perceptions of science being difficult or uninteresting (Patall, Hooper, et al., 2018). Additionally, need-supportive teaching provides students with socio-emotional supports, such as encouragement and guidance, that are more centrally implicated in students' (non)participation in science activities in the classroom and outside of school (Hagger & Hamilton, 2018). Although increased classroom disruption may cause momentary frustrations for students, it may not significantly impact their broader interest in participating in science or outweigh the benefits of the socio-emotional support that perceived need-support offers students. These findings add to the growing of body of work that indicates the importance of accounting for the effects of co-occurring social dynamics when considering the impact of pedagogical approaches (Shin & Ryan, 2016), such as need-supportive teaching.

4.2. *Perceived classroom disruption weakens perceived need-supportive teaching in science*

In addition to the unique effects discussed above, perceived classroom disruption in science was found to negatively moderate the association between perceived need-supportive teaching and students' self-efficacy and achievement. Here we focus our discussion on the moderating effect regarding achievement (Fig. 3), given its effect size attained this study's benchmark for interpretability. When students experienced low or moderate classroom disruption, there was a positive association between perceived need-supportive teaching and achievement, such that higher levels of need-supportive teaching were associated with higher achievement. Students who experienced low classroom disruption and perceived high need-supportive teaching had the highest achievement. In contrast, when perceived classroom disruption was high, achievement was low across all levels of need-support, and lowest for students who perceived high need-support (Fig. 3). In this sense, when perceived classroom disruption is higher than average, the positive effects of perceived need-supportive teaching on achievement appear to be completely negated. This may be the result of negativity bias (Rozin & Royzman, 2001), such that the negative experiences associated with disruptive peers (e.g., stress, frustration) begin to outweigh the positive experiences associated with need-supportive teaching. It may also be the case that positive teaching practices become far less effective when students are unable to pay attention to them – students cannot benefit from teachers providing explanatory rationales, asking for opinions, and effectively scaffolding if they are too distracted by their peers' behavior to listen (Gage et al., 2017). This suggests that in order for students to experience the benefits of need-supportive teaching as relevant to achievement, the level of classroom disruption must first be attended to; this is discussed in more detail below.

4.3. Implications for theory and practice

SDT argues that students' basic psychological need satisfaction is derived from a variety of social interactions within their learning environment (Deci & Ryan, 2000). Although the majority of research has focused on how teachers can support students' need satisfaction via need-supportive teaching (for summary see, Stroet et al., 2015), SDT also argues that the impact of need-supportive teaching can be amplified or constrained by elements within the social context in which it is provided (Deci & Ryan, 2000). Our findings indicate that perceived classroom disruption is one aspect of students' social context that constrains or even negates the positive benefits of perceived need-supportive teaching on student outcomes in science. This offers important insight into the boundary conditions of perceived need-support and indicates that low levels of perceived classroom disruption may be required for students to fully experience the benefits of need-supportive teaching in science. For example, our findings indicate that the effect of perceived need-supportive teaching on achievement is to an extent conditional on the level of classroom disruption to which students are also exposed. These findings highlight the need to further examine other elements of students' social context that may amplify or constrain the benefits of perceived need-supportive teaching in order to better understand the situations in which the effects will be most salient for students.

The findings of the present investigation also have important implications for science teacher practice. The primary implication pertains to classroom disruption in science, although we feel these recommendations may extend to other academic domains as well. As noted above, our findings indicate that, in order to maximize the benefits of perceived need-support, teachers should attend to the level of disruption within the classroom. Research regarding classroom management strategies and interventions can offer guidance in this respect. Although there is a significant body of work that considers interventions of varying levels of complexity and cost (for summary, see Herman et al., 2020), we focus on common features of classroom management interventions that align with the SDT framework. Here, research highlights the importance of lesson planning and preparation in minimizing disruptive behavior (e.g., Herman et al., 2020; Regan et al., 2016). Effective planning and preparation ensure that teachers can structure their lessons and set clear expectations to ensure that students have fewer opportunities to engage in off-task behaviors. One effective planning approach is lesson study (Regan et al., 2016), which incorporates a reflective cycle of planning, testing, and improvement of lessons. Researchers also highlight the importance of positive instructional and personal interactions with students (e.g., Cook et al., 2018; Duong et al., 2019; Reinke et al., 2014), and relying on improving interactions to support student motivation rather than external motivators. External motivators, such as rewards, have been found to decrease intrinsic motivation and other desired behaviors in the long term (Deci, Koestner, & Ryan, 2001). Strategies for improving teacher-student interactions are discussed below.

Our findings also indicate that once the levels of perceived classroom disruption are moderate to low, perceived need-supportive teaching has a positive association with achievement (as well as positive main effects on self-efficacy and participation). This suggests that alongside attending to classroom disruption, teachers should also consider how they might adopt more need-supportive practices in the classroom. This can include practices that support autonomy, competence (i.e., structure), and relatedness (i.e., involvement). To support autonomy, teachers may consider offering more explanatory rationales for the work students are completing, more clearly acknowledging students' negative emotions, and incorporating students' interests into the lessons (Aelterman et al., 2019; Reeve & Jang, 2006). To provide more structure, teachers may consider using clear directions and instruction (Hospel & Galand, 2016), both of which have been found to be particularly beneficial in science (Martin, Ginns, Burns, Kennett, & Pearson, 2020). Although satisfaction of students' need for relatedness can in part be met through provisions of autonomy-support (Reeve, 2006), teachers may also consider incorporating other pedagogical approaches to support positive socio-emotional relationships with students, such as pedagogical care, which focuses on acknowledging students' individuality and using mutually respective language (Wentzel et al., 1997). Importantly, recent research has indicated that a global approach to need-supportive teaching stands to provide the most benefit to students (Olivier et al., 2021). Specifically, teachers should seek to offer students high but balanced levels of autonomy-support, structure, and involvement (Olivier et al., 2021).

4.4. Limitations

The findings of the present investigation provide vital insight regarding the boundary conditions of perceived need-supportive teaching in science; however, there are important limitations to consider when interpreting these findings and considering avenues for future research. First, the study was cross-sectional due to the nature of PISA data. Although the model investigated a theoretically grounded and well-established motivational process (Deci & Ryan, 2000), longitudinal data are required to confirm the direction of the hypothesized pathways; for example, it may be that students with lower achievement have more negative perceptions of their teacher's need-supportive practices. Second, PISA focuses on 15-year-old students. Adolescence is a period during which misbehavior and disengagement increase (Burns, Bostwick, et al., 2019). Future research should consider if the pattern of findings extends to other age ranges. Third, except for achievement, which was measured via the objective PISA Science Assessment measures, the study relied on student self-report. Although self-report is considered a valid approach to measuring students' perceptions of teacher behavior and intrapsychic phenomena, such as self-efficacy, there are known limitations to self-report (for summary, see Karabenick et al., 2007). Additionally, the current measures focused on students' perceptions, rather than teachers' perceptions of their practice. Future research may consider gathering data from other sources, such as observations of teacher practice and classroom disruption, as well as collecting self-report data from teachers. Fourth, although we accounted for the hierarchical nature of the data by adjusting standard errors as a function of the clustering of students within schools, PISA data do not provide matched classroom data. Future research may consider examining matched student and classroom data in order to examine the effects of perceived classroom disruption and need-support at the classroom-level explicitly, and how these effects may vary across classrooms. Lastly, the present investigation focused on science. Because student motivation and outcomes are domain-specific, further research is needed to examine if the associations found exist similarly in other domains, such as mathematics, English, and history.

5. Conclusion

The findings of the present investigation provide empirical evidence for the negative unique and moderating effects of perceived classroom disruption on the benefits of perceived need-supporting teaching in science. The present investigation demonstrated that perceived need-supportive teaching was positively associated with students' outcomes in science, perceived classroom disruption was associated with lower self-efficacy and achievement in science, and perceived classroom disruption appeared to negate the positive effects of perceived need-supportive teaching on students' science achievement (i.e., negative moderation). Overall, the findings provide important insights regarding the boundary conditions of perceived need-supportive teaching and the factors that teachers can target to address these boundary conditions and optimize students' outcomes.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.learninstruc.2021.101498.

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Rebecca J. Collie: Conceptualization, Writing – review & editing

Tim Mainhard: Conceptualization, Writing – review & editing

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