Learning and Instruction 58 (2018) 220–231

Contents lists available at ScienceDirect

Learning and Instruction

journal homepage: www.elsevier.com/locate/learninstruc

Science class is too hard: Perceived difficulty, disengagement, and the role of teacher autonomy support from a daily diary perspective[☆]

Erika A. Patall[a,*], Sophia Hooper[b], Ariana C. Vasquez[b], Keenan A. Pituch[b], Rebecca R. Steingut[c]

[a] Rossier School Rossier School of Education, University of Southern California, Los Angeles, CA, 90089, USA
[b] Department of Educational Psychology, Department of Educational Psychology, The University of Texas at Austin, Austin, TX, 78712, USA
[c] Teacher's College, Columbia University, New York, NY, 10027, USA

ARTICLE INFO

Keywords:
Perceived difficulty
Perceived competence
Autonomy support
Disengagement
Daily diary method

ABSTRACT

The current research aimed to investigate students' daily experiences in high school classes by answering the following questions: to what extent does daily perceived difficulty of science classwork predict daily feelings of competence and disengagement? Are autonomy-supportive teaching strategies useful when work in science class is perceived to be more difficult than the average day? Two-hundred and eighteen high school students in 43 science classes participated in the daily diary study across a six-week instructional unit. Results of multilevel modeling revealed that on days when students perceived their science classwork to be more difficult than usual, they experienced a decrease in perceived competence, which was in turn associated with an increase in disengagement. In addition, the current research suggested that the decrease in perceived competence and subsequent decrease in engagement as a function of perceived difficulty was minimized when students perceived their teachers to provide autonomy support. Discussion centers on the theoretical and practical implications.

1. Introduction

Why do some high school students experience a low sense of competence in their science classes and what are the consequences of those feelings? One likely answer is that when students perceive task demands to exceed their skills in science class, their perceptions of competence suffer and they disengage from class activities. In fact, a great deal of research demonstrates that students are more likely to disengage from a task when it is perceived to be too hard (e.g., Fong, Zaleski, & Leach, 2015; Moneta & Csikszentmihalyi, 1996). While past research has examined the consequences of task difficulty by manipulating the difficulty of a task (e.g., Fulmer & Frijters, 2011), this research provides no information about students' daily experience of difficult course work within an authentic science classroom. Moreover, given evidence suggesting that disengagement is a critical predictor of academic struggles during adolescence (e.g., Balfanz, Herzog, & Mac Iver, 2007), it is surprising that little is known about how students' daily experiences in the classroom predict changes in their classroom disengagement. Thus, one of the main purposes of the current study was to examine the extent to which perceptions that classwork was more difficult than average predicted changes in students' perceptions of competence and disengagement in high school science classrooms on a daily basis.

Due to the diversity of students and their experiences of course work in a given science classroom, it is rarely possible for teachers to adjust the class content for each and every student in the classroom context every day. Thus, it becomes critical to ask whether there are strategies that can mitigate the potentially negative correlates of students experiencing science classwork as more difficult than typical. One potential answer lies in the motivational power of autonomy-supportive strategies in the classroom. Autonomy-supportive strategies, which encourage students to relate their interests and preferences to learning activities, seem likely to facilitate the inner motivational resources and competence students need to tackle difficult tasks (e.g., Reeve, 2009; Reeve, Jang, Carrell, Jeon, & Barch, 2004). Thus, the second purpose of this study was to explore the extent to which autonomy-supportive practices buffer undesirable correlates of students' perceiving that

☆ This research was supported by a grant from the William T. Grant Foundation (Project #180042) to Erika A. Patall.
* Corresponding author. Rossier School of Education, University of Southern California, 3470 Trousdale Parkway, Waite Phillips Hall, Los Angeles, CA, 90089, USA.
E-mail address: patall@rossier.usc.edu (E.A. Patall).

https://doi.org/10.1016/j.learninstruc.2018.07.004
Received 14 August 2017; Received in revised form 9 July 2018; Accepted 11 July 2018
0959-4752/

science course work is too hard on any given day.

2. Literature review

2.1. The dangers of disengagement

Engagement refers to active involvement in a task or activities, while disengagement, the focus of this investigation, reflects not merely low engagement, but the active and sometimes intentional detachment from such tasks (Furrer & Skinner, 2003; Skinner & Belmont, 1993; Skinner, Furrer, Marchand, & Kindermann, 2008). Engagement and disengagement have both behavioral and emotional components, with behavioral disengagement including behaviors such as giving up, passivity, or lack of initiation of the activities and emotional disengagement including experiences of frustration, discouragement, or dejection. Recent research has increasingly suggested that maximizing students' engagement and minimizing disengagement in class is critical to their learning and achievement (e.g., Carini, Kuh, & Klein, 2006; Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008; Strambler & Weinstein, 2010; Wang & Holcombe, 2010). Disengagement is associated with lower grades (e.g., De Castella, Byrne, & Covington, 2013), and higher rates of school dropout (Henry, Knight, & Thornberry, 2012). Given the risks associated with disengagement, the current study examines its relationship with an understudied, though potentially important contributor to students' disengagement in high school classrooms, namely, students' perceptions that class activities are difficult.

2.2. The role of perceived difficulty in perceived competence and disengagement

Self-determination theory (SDT) provides a framework for understanding why students' perceptions of coursework being experienced as difficult may have consequences for their perceptions of competence and disengagement. According to SDT, experiencing a sense of competence, along with autonomy and relatedness, is an essential need that underlies students' adaptive motivation and psychological functioning, including their engagement (Deci & Ryan, 2000). Importantly, the environment, and students' perceptions of it, has a great deal of power for supporting or thwarting students' experiences of competence and their subsequent motivation and engagement (Deci & Ryan, 2000). While tasks that are perceived to provide an *optimal challenge*, that is, tasks that demand a high but attainable level of skill (Ryan & Deci, 2017), are likely to be the best at promoting competence need satisfaction, intrinsic motivation, and engagement, tasks that are perceived to be more difficult than current skills are likely to diminish students' sense of competence and lead to disengagement (e.g., Deci, 1975; Reeve, 2012). Tasks that are perceived to be too easy may, similarly, do little to promote a sense of competence and may even lead to disengagement in the form of boredom (e.g., Nakamura & Csikszentmihalyi, 2014, pp. 239–263), though the threat to perceptions of competence is less with easy compared to difficult tasks.

Empirical research largely supports SDT's theoretical predictions. Most research on perceived difficulty suggests that perceived difficulty leads to diminished motivation and disengagement, though a great deal of this research has been conducted by providing students with a difficult task (or not) outside of the classroom environment (e.g., Fulmer & Frijters, 2011; Keller & Bless, 2008). For example, Fulmer and Frijters (2011) found that 10–14 years old students reported lower levels of enjoyment, perceived competence, and effort for reading a text that was well beyond their reading abilities compared to their reports of enjoyment, perceived competence, and effort for reading in general. In another study with 6th and 7th grade students who were given a challenging math and reading task, ratings of the perceived difficulty of the task was associated with less situational interest, increased negative affect, and less perceived competence (Tulis & Fulmer, 2013).

Though less research on actual or perceived task difficulty has focused on students' experience in an authentic classroom, past field research has also supported the predictions of SDT. For example, in one qualitative study (Aschbacher, Li, & Roth, 2010) involving interviews with high school science students, some students reflected on their struggles in science class and suggested that not being able to understand the class content really undermined confidence and interest. Quantitative studies investigating the relationships between students' *daily* experience of class difficulty and their experiences of perceived competence and disengagement are also limited, though several studies provide some support for our prediction that perceptions that classwork is difficult on a given day predicts lowered perceived competence and disengagement in the classroom. For example, a repeated-measures study by Schweinle, Meyer, and Turner (2006) in which 42 elementary students were surveyed for 8 consecutive days revealed that perceived challenge in math class was positively associated with social affect (e.g., feeling cooperative, open, and involved) and negatively associated with self-efficacy (a construct similar to perceived competence). However, although this study assessed students' daily perceptions of their math classes, it only examined average classroom-level math class challenges and did not examine students' daily experiences. Similarly, Malmberg, Walls, Martin, Little, and Lim (2013) conducted a one-week intensive longitudinal study with 292 elementary school students and found that on average, students experienced a significant decrease in perceived competence for lessons that students perceived to be difficult, with some individual differences in this within-person association.

While prior research has made it clear that extensive variance in students' experiences exists within students rather than between students (e.g., Malmberg et al., 2013; Pöysä et al., 2018; Tolvanen et al., 2011; Vasalampi et al., 2016), few studies have focused on the role of perceived difficulty at the day level and disengagement has not been examined as an outcome. As such, the extent to which students' daily perception of task difficulty in class plays a role in their daily perceived competence and disengagement during class remains unclear. Moreover, although previous work has been informative, it falls on future research to explore whether this pattern will extend to high school students' experiences of perceived competence and disengagement in science class. Taken together, these findings suggest a need to examine the daily association between high school students' perceptions of difficult classwork and their perceptions of competence and disengagement in authentic classrooms *within* students rather than between students. The current study seeks to fill these gaps in the existing literature.

2.3. The potential of autonomy support for mitigating risks associated with difficult classwork

Given the likelihood of detrimental correlates of students perceiving classwork to be difficult, finding strategies that teachers can use to mitigate the risks associated with perceived difficulty is important. One straightforward solution is to adjust the task demands or the level of the challenge of classwork to make sure it matches students' skills (e.g., Nakamura & Csikszentmihalyi, 2014, pp. 239–263) or to guide and scaffold students interaction with a task so that they can handle the challenge with assistance, in line with the idea of a zone of proximal development (Vygotsky, 1978). However, the reality of the classroom is that there is often a great deal of variation in students' perceptions of classwork both across students, and even within students, that often make creating optimal challenge and scaffolding every students' experience with each task difficult. It is often not possible for teachers to assess and adapt class content to each student and even to one student across multiple days.

An alternative motivation-focused approach that may not require as much individualization for each student is for teachers to adopt an autonomy-supportive orientation. SDT emphasizes the importance of autonomy support for students' engagement (e.g., see Reeve, 2012; Reeve et al., 2004). Broadly, autonomy support in the classroom context reflects a motivational approach in which teachers identify, nurture, and develop students' inner motivational resources so that students perceive themselves as the initiator of their actions (Reeve, 2009). While many teacher behaviors can be involved in creating an autonomy-supportive classroom environment, autonomy-supportive teachers consider their students' perspectives, offer choices, and encourage students to take initiative in their work, and to work in their own way at their own pace. Autonomy-supportive teachers rely on non-controlling language, acknowledge and accept students' negative feelings about course work, and provide time for students to express their opinions and ask questions. Although they attempt to structure activities around students' interests or include fun elements in lessons whenever possible, they also provide meaningful and personally relevant rationales to explain the usefulness of "boring" course activities, and give encouraging and informational feedback when students become frustrated or struggle (Reeve & Jang, 2006; Reeve, 2009; Su & Reeve, 2011). A substantial body of research has suggested that teachers who engage in practices that are supportive of students' experiences of autonomy facilitate students' need satisfaction, motivation, and engagement (e.g., Assor, Kaplan, & Roth, 2002; Patall, Dent, Oyer, & Wynn, 2013; Reeve & Jang, 2006; Reeve et al., 2004).

Despite the known benefits of autonomy support, guidance from prior research as to whether autonomy support can mitigate the detriments of perceived difficulty of classwork on a given day is limited. Research on the synergistic benefits of classroom support for competence in the form of structure (e.g., clear expectations and guidance) and autonomy support suggests that each has independent effects on students' engagement (e.g., Jang, Reeve, & Deci, 2010) and that the greatest motivational and self-regulatory benefits emerge when both are high (e.g., Sierens, Vansteenkiste, Goossens, Soenens, & Dochy, 2009; Vansteenkiste et al., 2012). Although critical to understanding how autonomy support and structure function, this previous work says little about whether autonomy support can compensate for the competence thwarting experience of perceiving coursework to be very difficult. However, building on this work, we anticipate that in the context of difficult science classwork, autonomy-supportive practices (a) nurture students' inner resources that support engagement, even in a context of challenging tasks, and (b) restore some sense of competence by either revealing the consistency of tasks with their personal skills and preferences or providing opportunities to make tasks more consistent with student skills and preferences. That is, autonomy support provides a means for students to see how even very difficult work may be aligned with their current skills and ways of working.

It is also worth noting that some of these practices encourage more individualization, direction, and emotional support than others and thus, may vary in the extent to which they serve as effective moderators. In line with recent conceptualizations of autonomy support (Aelterman, Vansteenkiste, Soenens; Haerens, & Reeve, in press), while some strategies place greater emphasis on teachers inviting students' input and can thus be conceptualized as *participative* (e.g., choice provision and question opportunities), other practices place greater emphasis on teachers' attempts to align and connect activities with students' needs and interests and can be conceptualized as *attuning* (e.g., creating interesting activities, accepting negative affect, providing rationales, and encouraging, informational feedback). While all forms of autonomy support may help to minimize the negative correlates of perceiving classwork to be very difficult, attuning (rather than participative) strategies may be particularly effective at protecting students from experiencing a drop in perceived competence when encountering difficulty as such practices emphasize providing information and expressing understanding as teachers try to align their instruction with students' ways of seeing things. Along these lines, prior between-subject correlational and experimental research evidence has suggested that the provision of choices in particular, may have few, if any, benefits for perceived competence, motivation, or engagement if for example, middle students are low achievers (e.g., Wang & Eccles, 2013) or college students' competence is challenged with low ability feedback or difficult tasks (e.g., Patall, Sylvester, & Han, 2014). Said a different way, while participating in creating the learning activities may support an experience of autonomy, the extent to which it may protect feelings of competence when faced with very difficult tasks may be limited. This may be because participating has the potential to be threatening as well as supportive in the context of tasks that seem very difficult. In contrast, perceiving the teacher as attuning to student needs by trying to understand student perspectives and create a teacher-guided context for students to feel they are learning in ways they want to be learning reduces the threat that difficult tasks pose for students' perceptions of competence.

With this background in mind, we attempted to examine the extent to which perceived teacher autonomy support may mitigate the undesirable relationship between perceptions of classwork being difficult on a given day and high school students' perceived competence, and, in turn, disengagement that day within authentic classrooms. We hypothesized that, on average, teacher autonomy-supportive practices would be beneficial even when students have difficulties in their classes and would mitigate the negative correlates of daily perceived difficulty. We focused on a broad set of autonomy-supportive practices, acknowledging SDT's Gestalt view of autonomy support which suggests that autonomy-supportive practices are most effective when administered in a cluster of practices (e.g., Deci, Eghrari, Patrick, & Leone, 1994). However, we also explored the role of various practices separately, expecting that attuning strategies may better mitigate the negative relationship between perceived difficulty and perceived competence than participative strategies.

3. Present study

The current study used daily diary data collected from high school students over the course of a six-week instructional unit in science classrooms. Using a daily diary approach has a number of benefits. First, it allows us to not only examine within-subject variation, but also completely separate within- and between-subject variation. Second, it allows psychological processes to be examined more proximally to the day-to-day events that occur in authentic settings. Experimental and correlational studies (even traditional longitudinal designs) are often not well-equipped to capture those day-to-day events and experiences as they naturally occur in authentic settings. By conducting a daily diary study, our research aimed to investigate students' every day experiences in science classes, specifically those times when students perceive their science classwork to be more difficult than the average day. The links between challenge, perceived competence, and engagement have been tested in other studies (e.g., Schweinle et al., 2006). However, the diary design of the current study provided a unique opportunity to test variation within individuals and conduct correlational analyses examining the extent to which daily perceptions of difficulty in science class predict a change in same day experiences of competence and disengagement after controlling for perceived competence and disengagement reported during the previous class session.

We focused on students' daily experiences in science classes for several reasons. First, technology has dramatically transformed the labor market (OECD, 2017). In May 2015, there were about 8.6 million science, technology, engineering, and mathematics (STEM) jobs (Fayer, Lacey, & Watson, 2017). This points to increasing STEM opportunities and a large demand for more students to be trained in STEM fields. Despite these market demands, perceptions of course work difficulty may be particularly prevalent and may be of particular concern in high school science courses given research suggesting that a large number of students who report interest in pursuing a science career early in high school no longer wish to pursue a STEM career by 12th grade (Aschbacher et al., 2010). This suggests that understanding the correlates of students' perceptions of difficult coursework in the science classroom and factors that may minimize any negative correlates of difficulty may be particularly critical in the context of science coursework.

With this in mind, in the current study we examined the extent to which students' daily perceptions of difficult classwork predicted changes in daily feelings of competence and in turn, daily behavioral and emotional disengagement during science. We also examined the extent to which students' perceptions that their teachers provided autonomy support across a variety of practices (choice provision, opportunities for questions, consideration for student interests, rationales for the value of activities, openness to students' negative affect, and encouraging, informational feedback) might buffer the associations between perceived difficulty, perceived competence, and disengagement. Overall our research questions were:

1) Is daily perceived difficulty in science classwork associated with daily feelings of competence?
2) Does daily perceived competence mediate the association between daily perceived difficulty and daily disengagement?
3) Do perceived teacher autonomy-supportive practices moderate the relationship between daily perceived difficulty of science classwork and feelings of competence and the indirect relationship between daily perceived difficulty of science classwork and disengagement via feelings of competence?

We hypothesized that students' daily perceptions that science classwork was difficult would be associated with a decrease in daily feelings of competence since the last class day and in turn increased daily disengagement (e.g., Reeve, 2012; Ryan & Deci, 2017). In addition, we expected that, overall, teacher autonomy-supportive practices would protect students from experiencing a decrease in perceived competence, and in turn disengaging from science class, on days when classwork was perceived to be difficult (Reeve, 2012). However, we also expected that this pattern would be stronger for strategies that emphasize teachers' attuning to students' needs (e.g., considering students' interests, providing rationales, acknowledging negative affect, and providing encouraging, information feedback) compared to strategies that emphasize soliciting students' participation (e.g., choices, question opportunities) (Aelterman, Vansteenkiste, Soenens, Haerens, & Reeve, in press).

4. Method

4.1. Participants

The current analysis makes use of data from The Autonomy Support in High School Science investigation. The current analysis focused on the relationship between perceived difficulty, perceived competence, and disengagement, and the moderators of those relationships. This dataset has been used to address research questions distinct from the current study, including questions related to the link between situational interest and engagement, the extent to which various teacher practices support experiences of autonomy, as well as the extent to which autonomy-relevant practices support motivation and engagement (see Patall, Vasquez, Steingut, Trimble, & Pituch, 2016, 2017a; 2018).

Participants were two-hundred and eighteen urban and suburban high school science students from 43 science classrooms across eight public high schools in the southwest region of the United States. Participants' age ranged from 13 to 18 ($M = 15.57$, $SD = 1.25$). Forty percent were in the 9th grade, 25% were in the 10th grade, 18% were in the 11th grade, and 17% were in the 12th grade. Slightly over half of the students were females (55%) and 42% were eligible for free or reduced-price lunch. Our sample was ethnically diverse, with 40% Hispanics/Latino, 32% Caucasian, 10% Black, 4% Asian, and 13% mixed ethnicities or other ethnicities.

Our participants were enrolled in various science classes. Approximately 16% of them enrolled in grade-level survey biology, 15% in grade-level physics, 10% in grade-level chemistry, 6% in grade-level combined physics and chemistry, 19% in advanced survey biology, 12% in advanced chemistry, 7% in advanced physics courses, and 15% enrolled in a specialty topic science course such as engineering. Participants' science teachers' age ranged from 25 to 66 ($M = 38$, $SD = 12.29$). Their years of experience ranged from 0 to 40 ($M = 10.45$, $SD = 9.62$). The majority of the teachers were white (70%) and female (73%).

4.2. Procedure

Recruitment of participants occurred in stages. Science teachers were recruited in group information sessions following obtaining permission from the two southwestern U.S.

school districts, as well as individual high school principals, vice principals, and science chairs at each of the eight schools. Teachers were informed of the purpose and methods involved in the study. For all participating schools, the school year was divided into graded six-week (approximately) instructional units. Teachers were allowed to select both the course that would participate in the study and the instructional unit during which the study occurred among those between January 2012 and May 2014. Science teachers and their students participated in the study for one instructional unit only.

Student participants were recruited via in-person science classroom visits in which the study was described, and a parent information letter and consent documents in both English and Spanish were distributed. Students were asked to return signed consent documents in a sealed envelope to a box located at the main office of the school.

Due to the resource and time intense nature of a six-week diary study, in recruiting students, the goal was to randomly select five student participants from each of the 43 classes among those students that volunteered to participate. In the majority of classrooms (37 of 43), at least five students volunteered to participate, and students were randomly selected in cases where more than five volunteers were available. Five students participated in each of 27 classes, and six students participated in each of 10 other classes. In some classes, less than five students volunteered. Four students participated in each of 5 classes, and in one class just three students participated. Students were paid $5 for every survey completed and received a $50 bonus for completing all reports for which they did not have an excused absence from class.

Upon recruitment and selection and prior to the start of the six-week instructional unit, participating students met with a member of the research team to learn about their responsibilities as a participant, as well as to receive and set-up an Apple iPod touch used to complete surveys for the duration of the diary study. During this initial meeting, student participants practiced using the iPod by completing a short background survey regarding their age, grade level, sex, ethnicity, eligibility for free or reduced lunch at school based on U.S. government policy, and course grade for the most recent instructional unit. In addition, this initial meeting was used to establish the student's school and personal schedule and determine the ideal time for the student to receive and complete daily reports.

On every science class day of the six-week instructional unit, students were emailed during their first free period (i.e. non-instructional time) following the class session with a survey asking them to respond to questions about their science teachers' practices and their experiences of motivation and engagement in science class. All questionnaires were programmed using Qualtrics and completed by students online using the Apple iPod touch provided by the researchers. All science classes met on a block schedule, approximately every other school day. The number of scheduled class sessions ranged between 11 and 17, with classes having between 8 and 17 opportunities to report on experiences as a result of various disruptions to class sessions (Median = 14). Daily report surveys remained available for students to complete for approximately 24–48 h until the next class session began. The number of

Table 1
Variance partition coefficients (VPC) and Intraclass correlation coefficients (ICC).

Variable	N	Day level	Student level		Class level
		VPC	VPC	ICC	VPC/ICC
Daily perceived difficulty	2137	.58	.35	.42	.08
Daily perceived competence	2294	.46	.45	.54	.09
Daily disengagement	2298	.43	.54	.57	.03
Daily perceived autonomy support	2304	.45	.41	.55	.13

Notes. N total reports = 2306 across all students. The VPC describes the proportion of total variance that is due to days, students, or classes. The ICC describes the degree to which observations are correlated within students or within teachers. The expressions for the VPC and ICC are identical at the teacher level. They are calculated as follows.
VPC (day level) = residual variance/(residual variance + student-level variance + class-level variance).
VPC (student level) = student-level variance/(residual variance + student-level variance + class-level variance).
ICC (student level) = (student-level variance + teacher-level variance)/(residual variance + student-level variance + class-level variance).
ICC (teacher level) = VPC (teacher level) = teacher-level variance/(residual variance + student-level variance + class-level variance).

reports that student participants actually completed across the instructional unit ranged from 1 to 17 ($M = 11$, $SD = 3.73$; Mode = 10). Only one student completed just one report, and this student's responses could not be used in the analysis. The total number of reports was 2306 across all students. The number of reports for each variable is provided in Table 1. The proportion of missing data within available reports was 7.4% for perceived difficulty and negligible for all other variables.

4.3. Measures

4.3.1. Daily perceived difficulty

Students' daily perceived difficulty in science classes was assessed with one item designed for this investigation: "The material and activities in class today were way too hard for me." Response options ranged from not at all true (1) to extremely true (5). Higher values indicated more class difficulty.

4.3.2. Daily perceived competence

Students' daily experience of perceived competence was assessed with three items adapted from the Perceived Competence Scale (Williams & Deci, 1996) most relevant to the daily context. The three items were: "I felt competent while working on assignments for my science class today", "I felt confident about my ability to learn the material during science class today", and "I felt able to perform well in science class today". Response options ranged from not at all true (1) to extremely true (5). Higher values indicated more competence. The mean daily alpha was .82 (SD = .03).

4.3.3. Daily disengagement

Students' daily disengagement in science class was assessed with nine items relevant to the daily context adapted from the Engagement versus Disaffection with Learning Student Report (Furrer & Skinner, 2003; Skinner & Belmont, 1993; Skinner et al., 2008). Three items were indicators of *behavioral disengagement* (e.g., "Today in science class I just did enough to get by; " mean daily alpha = .69; SD = .06). Six items were indicators of *emotional disengagement* (e.g., "When I was in science class today, I felt bad; " daily mean alpha = .91; SD = .02). For both measures, response options range from not at all true (1) to extremely true (5). Higher values indicated more disengagement. We then averaged the emotional disengagement and behavioral disengagement indices (mean daily correlation coefficient = .46 for the two scales). The structure of this disengagement was established through a multilevel exploratory factor analyses (MLEFA), and reported in a separate paper (Patall et al., 2018).

4.3.4. Student reported daily teacher autonomy-supportive practices

We designed a student perceived teacher autonomy-supportive practices measure based on prior measures used in cross-sectional research (Assor et al., 2002; Connell, 1990; Katz, Kaplan, & Gueta, 2009; Patall et al., 2013; Reeve & Jang, 2006; Reeve, 2006; Reeve et al., 2004). We assessed students' perceptions of six autonomy-supportive daily teacher practices: (a) provision of choices and opportunities (5 items; e.g. "My teacher provided options for the kinds of assignments or activities I could do today; " mean daily alpha = .83, SD = .04), (b) rationales regarding the usefulness and importance of course material (4 items; e.g. "My teacher explained how what we were learning today is important; " mean daily alpha = .85, SD = .03), (c) opportunities for students to express negative affect (2 items; e.g. "My teacher was open to hearing criticism or complaints about activities today; " mean daily alpha = .79, SD = .06), (d) student question opportunities and responding (3 items; e.g. "My teacher acknowledged and responded to my questions in class today; " mean daily alpha = .74, SD = .05), (e) consideration for student opinions, preferences, and interests (3 items; e.g. "My teacher structured class activities today around my interests; " mean daily alpha = .84, SD = .04), and (f) encouraging and informational feedback (3 items; e.g. "My teacher gave suggestions when I struggled with course work today; " mean daily alpha = .76, SD = .76). Response options range from not at all true (1) to extremely true (5). Higher values indicated greater levels of autonomy-supportive practices. The structure of these measures was established through a multilevel exploratory factor analyses (MLEFA) and reported in a separate paper (Patall, Vasquez, Steingut, Trimble, & Pituch, 2017a). The correlations between the six perceived practices ranged between .13 and .17 (see Patall et al., 2017a for more information). However, given that SDT research has argued that multidimensional teacher autonomy support is the most beneficial because it is essential for the environment as a whole to speak to students' needs (Black & Deci, 2000; Reeve et al., 2004), we first calculated the scale score for each of the six practices but then averaged the six categories (mean daily $\alpha = .80$ for the total scale) to create a multidimensional measure.

4.4. Analysis plan

All analyses were conducted in the R software package. The daily diary data has a three-level structure (day, student, class). As such, a series of three-level random intercept models were estimated with the *nlme* package (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2009), which allows specification of a correlated level-1 residual structure. In the current study, given our assumption that student reports on adjacent days were more highly correlated than student reports on days further apart, we used a first-order auto-regressive AR (1) model. To treat missing outcome data, we used maximum likelihood estimation with robust estimates of standard errors (REML).

To answer the first research question regarding the relationship between daily perceived difficulty and daily perceived competence, we modeled the daily perceived competence outcome (Y) on the same day's (within-person) perceived difficulty of science classwork (*wp*), controlling for student (within-class) perceived difficulty of classwork (*wc*), and class (between-class) perceived difficulty of classwork (*bc*) for day i within student j within class k in a multi-level random-intercept model. To decompose between and within-person effects, day level (within-person) predictors were person-mean centered (around each person's own average score), student level (within-class) predictors were class-mean centered (around the average score for each student), and class level (between-class) predictors were calculated as each class's average score. The statistical representation of our model is shown below:

Level 1

$$Y_{ijk} = \beta_{0jk} + \beta_{1jk}(wp)_{ijk} + e_{ijk}$$

$$e_{ijk} \sim N(0, \Sigma) \text{ Homogenous AR (1)}$$

$$\Sigma = \begin{bmatrix} \sigma^2 & \sigma^2\rho & \sigma^2\rho^2 & \cdots & \sigma^2\rho^{i-1} \\ \sigma^2\rho & \sigma^2 & \sigma^2\rho & \cdots & \sigma^2\rho^{i-2} \\ \sigma^2\rho^2 & \sigma^2\rho & \sigma^2 & & \sigma^2\rho^{i-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \sigma^2\rho^{i-1} & \sigma^2\rho^{i-2} & \sigma^2\rho^{i-3} & \cdots & \sigma^2 \end{bmatrix}$$

Level 2

$$\beta_{0jk} = \gamma_{00k} + \gamma_{01k}(wc)_{jk} + r_{0jk}$$

$$\beta_{1jk} = \gamma_{10k}$$

$$r_{0jk} \sim N(0, \tau^2)$$

Level 3

$$\gamma_{00k} = \delta_{000} + \delta_{001}(bc)_k + \mu_{00k}$$

$$\gamma_{01k} = \delta_{010}$$

$$\gamma_{10k} = \delta_{100}$$

$$\mu_{00k} \sim N(0, \varphi^2)$$

Other covariates are not shown in the equation above to simplify the presentation. However, at level 1 (day level), time and the outcome from the previous day (i.e., $(wp)_{(i-1)jk}$) were included in the analysis and were grand-mean centered. We constructed the time variable by consecutively numbering each class session during the unit starting with zero. When we assessed the relationships between variables at the day level, we included the prior class session's outcome value as a predictor to control for possible carryover effects from one class day to the next (e.g., Reis, Sheldon, Gable, Roscoe, & Ryan, 2000). When the outcome from the immediate prior day was missing, the most recent day of reporting was carried forward. There were 418 instances of carrying forward prior reports for perceived competence and 414 instances of carrying forward prior reports for disengagement. Including the prior class session's outcome value as a predictor allowed us to predict day-to-day change in the outcome rather than sheer level (Cohen & Cohen, 1982) as a function of students' perceptions of difficult coursework reported on the same class day as the outcome.

At level 2 (student level), we included several covariates representing students' demographic information: student sex (0 = male, 1 = female), student ethnicity (three dummy-coded variables of White, Black, and other ethnic minorities with Hispanic/Latino as the reference group), students' free or reduced-price lunch eligibility (0 = not eligible, 1 = eligible), and students' age. At level 3 (class level), we included variables representing class and school characteristics: whether the class was a biological science[1] (0 = non-biological courses, 1 = biological courses), whether the class participated in the fall or spring (0 = Fall, 1 = Spring), and whether the school had title I status[2] or not (0 = no title I status, 1 = title I status). We included this set of covariates given past research suggesting that each has been associated with motivation and achievement outcomes in science (e.g., Gottfried, Marcoulides, Gottfried, & Oliver, 2009; National Science Foundation, 2017; Wang & Degol, 2013).

To test the second research question—whether daily perceived competence mediates the association between daily perceived difficulty and daily disengagement—we estimated two three-level models similar to the perceived competence model described above for disengagement. The second version of this model also included person-mean centered daily perceived competence at level 1 as a predictor. The Monte Carlo (MCMAM) method for assessing mediation (Selig & Preacher, 2008) allowed us to specify the aforementioned level-1 residual structure in our three-level multilevel models and simultaneously estimate and test indirect effects at the day level. To test an indirect effect, 20,000 Monte Carlo replications were used (Selig & Preacher, 2008).

To test the third research question, we estimated a series of three-level regression models in which we tested the interaction between daily perceived difficulty of classwork and daily perceived teacher autonomy support at level 1 for daily perceived competence. These models included the same covariates and used the same approach to centering variables. We explored this interaction using the multi-dimensional measure of daily perceived autonomy support and each individual daily perceived practice separately. A significant interaction between perceived difficulty and perceived autonomy-supportive practice at the day level was depicted with a plot using the sjp. int function of the *sjPlot* package (Lüdecke, 2017).

Finally, to test the fourth research question, we estimated a moderated mediation model (Hayes, 2013) which allows us to test the conditional indirect effects. Specifically, focusing on the multi-dimensional measure of perceived autonomy support, we examined whether the indirect effect of daily perceived difficulty of classwork on disengagement via perceived competence was moderated by perceptions of teacher autonomy support. The moderated mediation analyses and the tests of MCMAM indirect effects were based on mediation models (as described above) that also included the interaction between perceived difficulty and perceived teacher autonomy support and estimated indirect effects at various levels of the moderator following the recommendations of Preacher, Rucker, and Hayes (2007), Tein, Sandler, MacKinnon, and Wolchik (2004), and Selig and Preacher (2008).

5. Results

5.1. Preliminary analyses

Variance partition components (VPC) and intraclass correlation coefficients (ICC) are presented in Table 1. Means, standard deviations, and bivariate correlations are presented in Table 2. VPCs indicated that between 43% and 58% of the variance in the variables was at the day level. A similar amount of variance was at the student level (VPCs ranged between 35% and 54%), and limited variability was observed at the classroom level (VPCs ranged between 3% and 13%). In particular, 58% of the variance in perceived difficulty was at the day level. Results suggested that there was a substantial daily variation in students' experiences inside the classroom. In line with our hypotheses, daily perceived difficulty of classwork was negatively correlated with daily perceived competence and positively correlated with daily disengagement (see Table 2). In addition, daily perceived competence was negatively correlated with daily disengagement.

[1] Past research has shown that students view biology significantly differently from other science subjects, such as physics and chemistry, in terms of how interesting, useful, and easy the subject is (see Osborne, Simon, & Collins, 2003). In addition, Texas requires high school students to pass standardized tests in two STEM courses. Algebra for math and biology for science. There are other courses they are required to take in STEM to graduate, but the only tests they must pass are in biology and algebra (along with US history and English).Thus, we believe whether the class was a biology course or not is a confounding variable we need to control for in our study.

[2] Title I schools are U.S.A. public schools with at least 40% students from low-income families (U.S. Department of Education. Office of Elementary and Secondary Education, Office of State Support., 2015).

Table 2
Means, standard deviations, and bivariate correlations.

	M	SD	1	2	3
1. Daily perceived difficulty	1.72	1.02			
2. Daily perceived competence	3.35	0.99	−.31***		
3. Daily disengagement	1.91	0.75	.52***	−.33***	
4. Daily perceived autonomy support	2.76	0.77	.01	.49***	−.05*

Notes. Means, standard deviations, and bivariate correlations of main research variables (uncentered) reported in the table. *$p < .05$, **$p < .01$, ***$p < .001$.

5.2. Daily class difficulty, competence, and disengagement

First, we tested whether daily perceived difficulty of classwork predicted daily perceived competence. Results are reported in Table 3. Controlling for within- and between-class perceived difficulty of classwork, students' perceived competence during the prior class session, and all the other covariates, daily perceived difficulty of science classwork was negatively associated with daily perceived competence ($b = -0.18$, 95% CI [−0.22, −0.14], $p < .001$). That is, when a student perceived classwork as more difficult than average on a given day, they experienced a decrease in perceived competence on that day relative to the prior class session.

Next, we examined whether daily class difficulty was related to disengagement. Results reported in Table 3 show that daily perceived difficulty of classwork significantly predicted an increase in daily disengagement ($b = 0.18$, 95% CI [0.15, 0.21], $p < .001$), controlling for within-and between-class difficulty, the lagged outcomes, time, and all the other covariates.

Next, to address the degree to which daily perceived competence mediates the association between daily perceived difficulty and daily engagement, the Monte Carlo (MCMAM) method for assessing mediation (Selig & Preacher, 2008) was used to estimate the indirect effect of daily perceived difficulty of classwork on daily disengagement via daily competence. We had already estimated path *c*, which tested the relationship between daily perceived difficulty of classwork and daily perceived disengagement without the mediator and path *a*, which tested the relationship between daily perceived difficulty of classwork and daily perceived competence (shown in Table 3). Our final steps were to estimate paths *b* and *c'* in a model where daily perceived disengagement was predicted by daily perceived competence and daily perceived difficulty of classwork, controlling for covariates. As expected, perceived competence significantly predicted a decrease in daily disengagement ($b = -0.22$, 95% CI [−0.26, −0.19], $p < .001$), controlling for daily perceived difficulty, within-and between-class difficulty, the lagged outcome, time, and all the other covariates. Daily perceived difficulty of classwork also continued to significantly predict an increase in daily disengagement ($b = 0.15$, 95% CI [0.12, 0.18], $p < .001$). Finally, we found an indirect effect of daily perceived difficulty of classwork through daily perceived competence on daily disengagement ($b = 0.04$, 95% CI [0.03, 0.05]). These results suggest that one reason students may disengage from science class is that they experience a decrease in perceived competence when the class or materials are perceived to be more difficult for them than average. However, the significant relationship between perceived difficulty and disengagement after including perceived competence suggests that other mediators not examined here may also contribute.

In exploratory analyses, we examined these relationships for each component of disengagement (behavioral and emotional) separately. The same pattern of relationships as described above emerged for each component. As such, in further analyses we focused on the combined

Table 3
Multilevel regressions with daily perceived difficulty of classwork predicting perceived competence and disengagement with covariates.

Predictor	Perceived Competence		Disengagement	
	Unstandardized	Standardized	Unstandardized	Standardized
Day Level				
Daily perceived difficulty-within person	−0.18***(0.02)	−0.13***(0.02)	0.18***(0.02)	0.17***(0.02)
Lagged outcome	0.12***(0.02)	0.12***(0.05)	0.24***(0.02)	0.24***(0.02)
Time	−0.01*(0.004)	−0.04*(0.02)	0.001 (0.003)	0.01 (0.02)
Person Level				
Student perceived difficulty-within class	−0.29***(0.08)	−0.18***(0.05)	0.45***(0.05)	0.35***(0.04)
Female	−0.17 (0.09)	−0.09 (0.05)	0.05 (0.05)	0.03 (0.03)
Free/reduced lunch	−0.25*(0.12)	−0.13*(0.06)	−0.02 (0.07)	−0.01 (0.04)
Age	0.06 (0.04)	0.08 (0.05)	−0.003 (0.02)	−0.01 (0.04)
Black (ref. Latino)	0.18 (0.16)	.05 (.05)	−0.06 (0.09)	−0.02 (0.04)
White (ref. Latino)	0.06 (0.13)	0.03 (0.06)	0.10 (0.07)	0.06 (0.05)
Other (ref. Latino)	0.08 (0.14)	0.03 (0.06)	−.003 (0.08)	−0.01 (0.04)
Class Level				
Intercept	3.93***(0.19)	−0.02 (0.05)	1.28***(0.12)	0.01 (0.04)
Class perceived difficulty-between class	−0.35***(0.11)	−0.16***(.05)	0.38**(0.07)	0.21***(0.04)
Session	0.02 (0.10)	0.01 (0.05)	0.07 (0.07)	0.04 (0.04)
Biology	0.10 (0.10)	0.05 (0.05)	−0.04 (0.09)	−0.03 (0.04)
Title-1 school	0.14 (0.11)	0.07 (0.06)	−0.03 (0.10)	−0.04 (0.04)
Random effects				
Class (Level 3) intercept	0.0003		0.09	
Student (Level 2) intercept	0.57		0.31	
Day (Level 1)				
Residual	0.61		0.46	
Autocorrelation	0.09		−0.10	
AIC	3625.97		2630.03	
BIC	3729.27		2733.37	

Notes. Unstandardized and standardized multilevel regression coefficients and standard errors reported. *$p < .05$, **$p < .01$, ***$p < .001$.

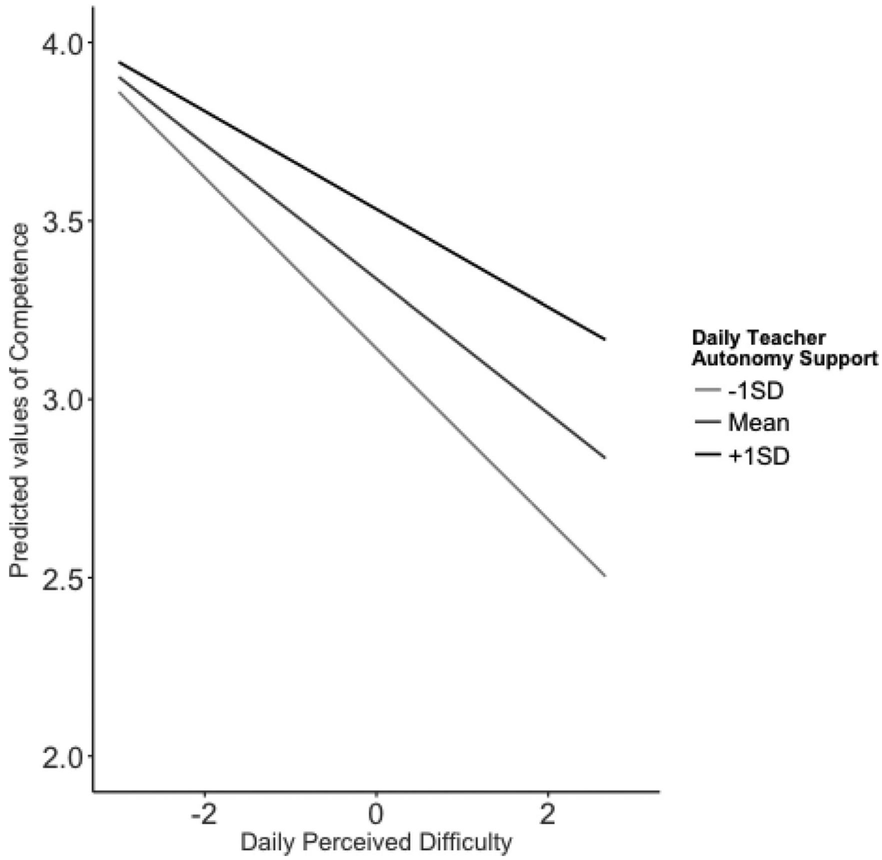

Fig. 1. Daily perceived teacher autonomy support buffers the effect of daily perceived difficulty on perceived competence.

disengagement measure. A complete set of results can be found in Table S1 through S3 of the supplementary materials.[3]

5.3. *Autonomy support buffers negative relationship between perceived difficulty and perceived competence*

To explore the extent to which perceived autonomy-support may diminish the undesirable associations between perceiving classwork to be more difficult than the average day and perceived competence, we added the multidimensional measure of daily perceived autonomy-supportive teacher practice along with its interaction with daily perceived difficulty in the multilevel models previously described in Table 3. As depicted in Fig. 1, results showed that there was a significant interaction between daily perceived difficulty and perceived autonomy-support predicting perceived competence ($b = 0.13$, $p = .004$). Simple slope analyses showed that the magnitude of the association between daily perceived difficulty and perceived competence was smaller when students perceived more autonomy support (+1 SD; $b = -.13$, $p < .001$), compared to when they perceived less autonomy support (−1 SD; $b = -.25$, $p < .001$).

To explore the extent to which each component of perceived autonomy-supportive practice may buffer the undesirable associations between perceiving classwork to be more difficult than usual and students' perceived competence, we conducted six multilevel models with an interaction term between each of the six unique perceived autonomy-supportive teacher practices and perceived difficulty. As expected, a positive interaction emerged for all six practices (choice: $b = .05$, $p = .18$; rationales: $b = .09$, $p = .01$; openness to negative affect: $b = .09$, $p = .003$; questions: $b = .05$, $p = .06$; consideration for student interests: $b = .06$, $p = .049$; encouraging, informational feedback: $b = .09$, $p = .005$). However, also consistent with our predictions, the magnitude of the interaction term was greater for attuning strategies including rationales, openness to negative affect, consideration for student interests, and encouraging, information feedback compared to participative practices. In fact, the interaction term was not significant for the daily perceived provision of choice or daily perceived question opportunities.[4] Results suggested that the more students perceived their teachers to provide rationales regarding the usefulness and importance of the classwork, acknowledged negative affect, structured activities around students' interests, and provided encouraging, informational feedback, the smaller the decrease in students' perceived competence relative to the prior class day as a function of perceiving classwork to be more difficult than usual. Given that the direction of interaction was consistent across components of autonomy, even if not statistically significant across all components, in further analyses we focused on the multidimensional measure of autonomy support.

5.4. *Moderated mediation*

Previously, we found that the mediation from daily perceived difficulty to daily disengagement via daily perceived competence was present, and that the path from daily perceived difficulty to daily perceived competence was moderated by daily perceived teacher autonomy support. These findings indicated that the indirect effect depended on daily perceived autonomy support. That is to say, perceived class difficulty predicted disengagement via perceived competence differentially depending on the extent to which students perceived their

[3] Available at https://motivationlab.wordpress.com/publications/.

[4] See Figure S1 in the supplementary materials at https://motivationlab.wordpress.com/publications/for depiction of interactions between daily perceived difficulty and each component of daily perceived autonomy support.

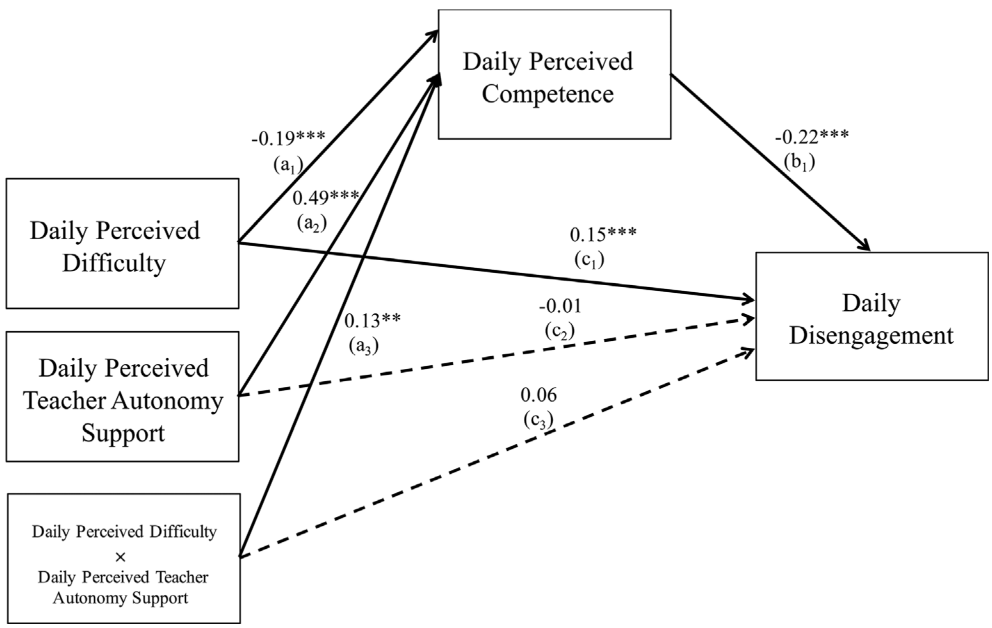

Fig. 2. Path model showing that the indirect effect of daily perceived difficulty on daily disengagement via daily perceived competence is moderated by daily perceived teacher autonomy support. Unstandardized multilevel regression coefficients reported. Covariates included but not displayed. *$p < .05$, **$p < .01$, ***$p < .001$.

Table 4
The indirect effect from daily perceived difficulty to daily disengagement via daily perceived competence for various values of daily teacher autonomy support.

Moderator: Perceived Daily Teacher Autonomy Support	a_1	b	Indirect effect	SE	95% CI Lower Bound	95% CI Upper Bound
Extremely low	−0.37***	−.22***	0.05	0.01	0.04	0.09
Very low	−0.31***	−.22***	0.05	0.009	0.03	0.07
Low	−0.25***	−.22***	0.04	0.006	0.03	0.05
Mean	−0.18***	−.22***	0.03	0.004	0.02	0.04
High	−0.12***	−.22***	0.02	0.005	0.01	0.03
Very High	−0.06	−.22***	0.01	0.007	−0.005	0.02
Extremely High	0.01	−.22***	0	0.01	−0.02	0.02

Notes. We tested the indirect effects of daily perceived difficulty predicting daily disengagement via daily perceived competence at various levels of perceived daily teacher autonomy support. Extremely low/high: −/+ 3SD; very low/high = −/+ 2SD; low/high = −/+ SD. Unstandardized coefficients are presented for path a_1 (from perceived difficulty to perceived competence), path b (from perceived competence to disengagement), and the indirect effect (a_1b) at each level of the moderator. *$p < .05$, **$p < .01$, ***$p < .001$.

teachers to provide autonomy support on a given day. Fig. 2 combines the previous mediation and moderation models and presents the results of the overall model.

Given findings of moderated mediation, we conducted post hoc evaluations of the strength of the indirect effects to determine its strength at different levels of perceived autonomy support. Since there was a consistent pattern across all components of autonomy support, we focused on the multidimensional measure of autonomy support. Table 4 presents the results of these analyses, which suggest that the indirect effect of daily perceptions of class difficulty on disengagement via perceived competence was lessened as perceived daily autonomy support increased. More specifically, evaluation of the simple indirect effects suggested that there was a significant indirect effect of daily perceptions of class difficulty on disengagement via perceived competence when perceived daily autonomy support was extremely low (3 standard deviations below the mean) to high (1 standard deviation above the mean). However, when autonomy support was very or extremely high (2 or 3 standard deviations above the mean), the indirect effect was no longer significant. The nature of these indirect effects suggested that daily perceived difficulty increases disengagement through diminished perceived competence when autonomy support is low or somewhat present. But, when autonomy support is very high, perceived difficulty does not have a significant relationship with disengagement via perceived competence.

6. Discussion

For high school students, science classes can be very challenging and sometimes too challenging. Using a daily diary approach, the present research suggested that on days when students perceive their science classwork to be more difficult than typical, they experience a decrease in perceived competence, which predicts increased disengagement (both behavioral and emotional) in science class that day. More importantly, we asked: What can help students deal with those days when science class is difficult? To address this question, the current research investigated the extent to which perceptions of autonomy-supportive practices buffered this association. As predicted, we found that the decrease in perceived competence as a function of perceived difficulty was reduced when students perceived their teachers to provide autonomy support. The pattern of interaction was similar across all components of perceived autonomy support. However, the interaction was statistically significant only for practices that emphasized teachers' attuning to students' needs (e.g., provision of rationales, openness to negative affect, consideration of student interests, and encouraging, informational feedback), and not for participative practices that emphasized soliciting students' input (e.g., choice provision and question opportunities).

6.1. Fit of the findings with prior research and theory

The present research makes several theoretical and practical contributions. First, the current research highlights the importance of studying students' daily experiences in classrooms, including their perceived difficulty, perceived competence, and disengagement, as we saw a great amount of variation ranging from 43% to 58% for these three constructs at the daily level. These daily variations are in line with previous research on situational engagement. For example, Vasalampiet al. (2016) found that 50% of the variation in 7th grade Finnish students' engagement was within individuals across lessons. Similarly, Pöysä et al. (2018) reported over 60% of the variation in students' engagement was across lessons and within days. Building on this previous research, the current study focused on one subject for each individual across days and found substantial intra-individual variation in all research variables.

Second, the current study extended the task difficulty research to the context of authentic science classes and modeled changes in daily experiences of competence and disengagement as a function of perceptions of difficult coursework. Results are consistent with previous task difficulty research suggesting that when the task is very difficult, especially when task challenge is much greater than student skills, individuals are less likely to be motivated and interested in the task (e.g., Tulis & Fulmer, 2013). As an extension of the prior research, the current study highlighted students' daily experiences in science classes and confirmed that the daily experience of perceiving science classes to be more difficult than average also predicts students' daily outcomes.

It is worth mentioning that perceived course work difficulty was related to students' daily perceived competence and disengagement at all levels of analysis, i.e., daily level, student level, and class level. That is, not only did daily perceived competence and disengagement decrease when classwork was perceived to be more difficult than the average day, but students' sense of competence for the instructional unit as a whole was lower among those who perceived the course to be difficult overall, and classes where more students perceived the course to be difficult had lower perceptions of competence on average. Somewhat surprisingly, none of the covariates (e.g., gender, ethnicity, course topic, etc.) but lagged disengagement was related to daily disengagement. Additionally, we found two covariates that were related to daily perceived competence, time and free/reduced lunch. Consistent with prior research suggesting that students' perceived competence declines over time (e.g., Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002), we saw a decrease in students' perceived competence over the six-week instructional unit. In addition, students who received free/reduced lunch reported feeling less daily competence. The relationship between SES and perceived competence has been found in previous research (e.g., Twenge & Campbell, 2002), suggesting that a lack of resources at home contributes to students lesser experiences of competence. The current research demonstrates that SES not only predicts students' outcomes at the student level, but also at the daily level.

Further, the current study is the first to demonstrate the indirect effect of perceived difficulty of classwork on disengagement via perceived competence on a daily basis in authentic classrooms. In line with the predictions of SDT, experiencing difficulty in the science classroom challenges students' sense of competence, which in turn, can trigger students to disengage in class. While past literature and theory provided evidence of the relationship between perceived difficulty, perceived competence, and disengagement (e.g., Schweinle et al., 2006), it was unclear if these relationships would exist on a daily basis. The current research investigated students' daily experiences and tested mediation with these daily-level constructs. The current investigation supported the mediational path from daily perceived difficulty of classwork to daily disengagement via daily perceived competence.

In addition, bridging self-determination theory and the task difficulty research, the current study suggested that autonomy-supportive teaching practices may provide a buffer against the negative correlates of students' perceptions that tasks in class are too challenging. Noting that the present study did not establish causal relations, which should be explicitly examined in future intervention research, the current research suggests that autonomy-supportive teaching practices has the potential to protect students from the motivational conundrums that emerge when science class is more difficult than usual. Attuning autonomy-supportive practices such as providing opportunities for students to express negative feelings about activities in class and being open, responsive, and encouraging in the context of such perspectives are among the strategies teachers might find most helpful for supporting autonomy and mitigating the detriments of difficulties in the class. We note here again, that participative strategies like providing choices and opportunities for questions did not emerge as statistically significant buffers of the negative relationship between daily perceived difficulty and perceived competence, in line with our expectations that such strategies may simultaneously provide support and pose a threat to students' sense of competence when presented in the context of difficult tasks. This finding is also not surprising given prior research highlighting the complexity of using choice provision for bolstering students' motivation (e.g., Patall & Hooper, 2017b). However, we also note that including these strategies among a multidimensional set of autonomy-supportive strategies is likely to have benefits as research has routinely highlighted that autonomy-supportive strategies function in concert to create an overall supportive climate (e.g., Deci et al., 1994).

Finally, these results extend the previous research focused on the interplay between structure and autonomy support (Curran, Hill, & Niemiec, 2013; Jang et al., 2010; Vansteenkiste et al., 2012). Like prior research suggesting that the presence of both elements predict the most positive student outcomes, the current research also underscored the importance of providing an autonomy-supportive environment and the ways it interacts with components of classroom structure. Although having both structure in the form of tasks that are well-aligned tasks with students' skills and autonomy support may be most beneficial, the current research extends prior work by suggesting that autonomy support reduces some of the undesirable correlates of a perceived lack of structure (in this case, perceiving course work to be difficult). This is important because there may be many times when teachers cannot avoid some of the course work being perceived as difficult to at least a portion of students in the classroom.

6.2. Limitations and future directions

One of the main strengths of the current research is that it investigates within-person daily processes with a daily diary approach. To strengthen our conclusions, we conducted analyses that modeled changes in the outcomes at the day level as a function of perceived difficulty by controlling for the influence of the outcome from the prior day and modeling an autocorrelated error structure. However, despite these strengths, it is important to note that this data is still correlational and cannot establish causality. While we estimated associations among our study variables controlling for many theoretically-related covariates, there may be other confounding variables we overlooked or that are simply unknown. Moreover, reciprocal causality remains a plausible possibility. Low perceived competence on a given day could lead students to perceive the class as being more difficult or teachers' autonomy support practices could be, in part, a response to students' engagement or disengagement (see for example Jang, Kim, & Reeve, 2016). To explore the possibility that students' daily perceived competence or disengagement may actually predict their daily experiences of difficulty in the class, we ran several exploratory multilevel models with this reverse causal ordering. The results of these models suggested that the reverse causal order is also likely to exist, though model fit statistics of the original models were better than the reverse order models. A complete set of results can be found in Table S3 of the supplementary materials. However, to fully explore causal relations, future research should implement experimental designs in authentic classrooms.

Second, the current research relies on students' self-reports. From one perspective, students are the most knowledgeable source of their own experience of difficulty, disengagement, and teachers' practices in the class. In other words, students' perceptions are the most powerful predictors when it comes to explaining students' outcomes. That said, when students report their own feelings and perceptions, their responses might be biased towards more socially desirable responding (Paulhus, 1984). For example, due to response biases, students might be less likely to report that classes are too hard for them or more likely to report that they feel competent. We note that while one advantage of this study was that it asked students to report on their experiences soon after class, limiting retrospective bias, students still had an opportunity to respond until the following class, which could have been a couple days later. Future studies may want to further limit the opportunity for biased retrospective reporting by restricting the time students have to report on their classroom experiences even more or exploring whether the delay in reporting influences findings. Moreover, while we believe that students' own perception of class difficulty, competence, and teacher practices are the most meaningful to investigate, future research should examine the extent to which teacher or observer reports would yield similar findings.

Third, it is important to note that the current research used only one face valid item measuring perceived coursework difficulty "The material and activities in class today were way too hard for me." There are several concerns we have with this measure. First, with only one item, we cannot assess reliability of the measure. Second, we did not measure different aspects of difficulty. Perceived difficulty from different sources and aspects might have different implications. Third, when students encounter difficult learning material, it is quite likely that there is variability in how they might interpret the experiences. For example, some students may question their identity thinking "science is not for me," some may blame their teachers thinking "my teacher does not know how to teach," and perhaps some students embrace a growth mindset and perceive the difficult coursework as an opportunity to learn. Those different interpretations should have very different consequences for students' competence and learning. Taken together, it is important for future research to explore more dynamic assessments of students' perceptions of difficulty.

Along the same lines, in this investigation, we focused on a particular component of the classroom context (perceived difficulty of classwork) hypothesized to reduce students' sense of competence. However, in line with the dual-process model in SDT (e.g., Jang et al., 2016), it might have also been informative to measure students' experience of competence frustration and the extent to which perceived difficulty predicted competence frustration, rather than competence satisfaction. By the same token, we focused on autonomy support as a potential antidote to students experiencing classwork as difficult. However, it is possible that other components of classroom structure (e.g., clear expectations, guidelines, scaffolding), may be able to compensate for the undesirable qualities of students perceiving classwork to be difficult. We recommend that future research explore the relationships between perceived difficulty with both need satisfaction and need thwarting and the role of various components of classroom structure in these relationships. Along these same lines of the need for broader measurement, the disengagement measure in the current study included only behavioral disengagement and emotional disengagement. However, cognitive disengagement may be especially relevant in the context of perceived difficulty in science classes. We would encourage future research to examine relationships between perceived difficulty and cognitive disengagement and test the extent to which the current findings apply to cognitive disengagement.

Finally, while we believe that one strength of this investigation was that it focused specifically on the science domain in authentic science classrooms, we also note that the findings may not generalize to other domains. Science is a domain that many students find particularly challenging and often disengage from during high school (e.g., Aschbacher et al., 2010). Future research should attempt to replicate the relationships observed in this investigation in other domains.

7. Conclusion

The present research contributes to the literature on perceived classwork difficulty and self-determination theory. This study underscored the importance of students' daily experiences of difficulty in science classes by examining its relationship with perceived competence and in turn, disengagement. The present research also highlighted that perceived autonomy-supportive practices disrupted the undesirable relationships between daily perceived difficulty, perceived competence, and disengagement. We hope the findings of the current investigation provide guidance for future research and teachers seeking to minimize students' disengagement even when science coursework is challenging.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.learninstruc.2018.07.004.

References

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*(5), 564–582. https://doi.org/10.1002/tea.20353.

Assor, A., Kaplan, H., & Roth, G. (2002). Choice is good, but relevance is excellent: Autonomy-enhancing and suppressing teacher behaviours predicting students' engagement in schoolwork. *British Journal of Educational Psychology, 72*(2), 261–278. https://doi.org/10.1348/000709902158883.

Balfanz, R., Herzog, L., & Mac Iver, D. J. (2007). Preventing student disengagement and keeping students on the graduation path in urban middle-grades schools: Early identification and effective interventions. *Educational Psychologist, 42*(4), 223–235. https://doi.org/10.1080/00461520701621079.

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

Carini, R. M., Kuh, G. D., & Klein, S. P. (2006). Student engagement and student Learning: Testing the linkages. *Research in Higher Education, 47*(1), 1–32. https://doi.org/10.1007/s11162-005-8150-9.

Cohen, J., & Cohen, P. (1982). *Applied multiple regression/correlation analysis for the behavioral sciences.* Hillsdale, NJ: Lawrence Erlbaum.

Connell, J. P. (1990). Context, self and action: A motivational analysis of self-system processes across the life-span. *The self in transition: From infancy to childhood* (pp. 61–97). Chicago: University of Chicago Press.

Curran, T., Hill, A. P., & Niemiec, C. P. (2013). A conditional process model of children's behavioral engagement and behavioral disaffection in sport based on self-determination theory. *Journal of Sport & Exercise Psychology, 35*(1).

De Castella, K., Byrne, D., & Covington, M. (2013). Unmotivated or motivated to fail? A cross-cultural study of achievement motivation, fear of failure, and student disengagement. *Journal of Educational Psychology, 105*(3), 861–880. https://doi.org/10.1037/a0032464.

Deci, E. L. (1975). *Intrinsic motivation.* New York, NY: Plenum Press.

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating Internalization: The self-determination theory perspective. *Journal of Personality, 62*(1), 119–142. https://doi.org/10.1111/j.1467-6494.1994.tb00797.x.

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

Fayer, S., Lacey, A., & Watson, A. (2017). *Bls spotlight on statistics: Stem occupations-past, present, and future. U.S. Bureau of labor statistics.* Retrieved from: http://digitalcommons.ilr.cornell.edu/key_workplace/1923/.

Fong, C. J., Zaleski, D. J., & Leach, J. K. (2015). The challenge-skill balance and antecedents of flow: A meta-analytic investigation. *The Journal of Positive Psychology, 10*(5), 425–446. https://doi.org/10.1080/17439760.2014.967799.

Fulmer, S. M., & Frijters, J. C. (2011). Motivation during an excessively challenging reading task: The buffering role of relative topic interest. *The Journal of Experimental Education, 79*(2), 185–208. https://doi.org/10.1080/00220973.2010.481503.

Furrer, C., & Skinner, E. (2003). Sense of relatedness as a factor in children's academic engagement and performance. *Journal of Educational Psychology, 95*(1), 148–162. https://doi.org/10.1037/0022-0663.95.1.148.

Gottfried, A. E., Marcoulides, G. A., Gottfried, A. W., & Oliver, P. H. (2009). A latent curve model of parental motivational practices and developmental decline in math and science academic intrinsic motivation. *Journal of Educational Psychology, 101*(3), 729–739. https://doi.org/10.1037/a0015084.

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach.* New York, NY: The Guilford Press.

Henry, K. L., Knight, K. E., & Thornberry, T. P. (2012). School disengagement as a predictor of dropout, delinquency, and problem substance use during adolescence and early adulthood. *Journal of Youth and Adolescence, 41*(2), 156–166. https://doi.org/10.1007/s10964-011-9665-3.

Jacobs, J. E., Lanza, S., Osgood, D. W., Eccles, J. S., & Wigfield, A. (2002). Changes in Children's self-competence and Values: Gender and domain differences across grades one through twelve. *Child Development, 73*(2), 509–527. https://doi.org/10.1111/1467-8624.00421.

Jang, H., Kim, E. J., & Reeve, J. (2016). Why students become more engaged or more disengaged during the semester: A self-determination theory dual-process model. *Learning and Instruction, 43*, 27–38. https://doi.org/10.1016/j.learninstruc.2016.01.002.

Jang, H., Reeve, J., & Deci, E. L. (2010). Engaging students in learning activities: It is not autonomy support or structure but autonomy support and structure. *Journal of Educational Psychology, 102*(3), 588–600. https://doi.org/10.1037/a0019682.

Katz, I., Kaplan, A., & Gueta, G. (2009). Students' needs, teachers' support, and motivation for doing homework: A cross-sectional study. *The Journal of Experimental Education,*

78(2), 246–267. https://doi.org/10.1080/00220970903292868.
Keller, J., & Bless, H. (2008). Flow and regulatory compatibility: An experimental test of the flow model of intrinsic motivation. *Personality and Social Psychology Bulletin, 34*, 196–209.
Kuh, G. D., Cruce, T. M., Shoup, R., Kinzie, J., & Gonyea, R. M. (2008). Unmasking the effects of student engagement on first-year college grades and persistence. *The Journal of Higher Education, 79*(5), 540–563. https://doi.org/10.1353/jhe.0.0019.
Lüdecke, D. (2017). sjPlot: data visualization for statistics in social science [R package version 2.3.1]. Retrieved from: https://CRAN.R-project.org/package=sjPlot.
Malmberg, L.-E., Walls, T. A., Martin, A. J., Little, T. D., & Lim, W. H. T. (2013). Primary school students' learning experiences of, and self-beliefs about competence, effort, and difficulty: Random effects models. *Learning and Individual Differences, 28*, 54–65. https://doi.org/10.1016/j.lindif.2013.09.007.
Moneta, G. B., & Csikszentmihalyi, M. (1996). The effect of perceived challenges and skills on the quality of subjective experience. *Journal of Personality, 96*(2), 275–310.
Nakamura, J., & Csikszentmihalyi, M. (2014). *The concept of flow. In flow and the foundations of positive psychology.* Springer Netherlandshttps://doi.org/10.1007/978-94-017-9088-8_16.
National Science Foundation (2017). *Women, minorities, and persons with disabilities in science and engineering: 2017. (Special report NSF 17-310)*. Arlington, VA. Retrieved from: www.nsf.gov/statistics/wmpd/.
OECD (2017). *OECD employment outlook 2017*. Paris: OECD Publishing. Retrieved from: https://doi.org/10.1787/empl_outlook-2017-en.
Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079. https://doi.org/10.1080/0950069032000032199.
Patall, E. A., Dent, A. L., Oyer, M., & Wynn, S. R. (2013). Student autonomy and course value: The unique and cumulative roles of various teacher practices. *Motivation and Emotion, 37*(1), 14–32. https://doi.org/10.1007/s11031-012-9305-6.
Patall, E. A., & Hooper, S. Y. (2017). The role of choice in understanding adolescent autonomy and academic functioning. In B. Soenens, S. Van Petegem, & M. Vansteenkiste (Eds.). *Autonomy in adolescent Development: Towards conceptual clarity (studies in adolescent development)*. New York, NY: Routledge.
Patall, E. A., Steingut, R. R., Vasquez, A. C., Trimble, S. S., Pituch, K. A., & Freeman, J. L. (2018). Daily autonomy supporting or thwarting and students' motivation and engagement in the high school science classroom. *Journal of Educational Psychology, 110*(2), 269–288. https://doi.org/10.1037/edu0000214.
Patall, E. A., Sylvester, B. J., & Han, C. (2014). The role of competence in the effects of choice on motivation. *Journal of Experimental Social Psychology, 50*, 27–44. https://doi.org/10.1016/j.jesp.2013.09.002.
Patall, E. A., Vasquez, A. C., Steingut, R. R., Trimble, S. R., & Pituch, K. A. (2016). Daily interest, engagement, and autonomy support in the high school science classroom. *Contemporary Educational Psychology, 46*, 180–194. https://doi.org/10.1016/j.cedpsych.2016.06.002.
Patall, E. A., Vasquez, A. C., Steingut, R. R., Trimble, S. S., & Pituch, K. A. (2017a). Supporting and thwarting autonomy in the high school science classroom. *Cognition and Instruction, 35*(4), 337–362. https://doi.org/10.1080/07370008.2017.1358722.
Paulhus, D. L. (1984). Two-component models of socially desirable responding. *Journal of Personality and Social Psychology, 46*(3), 598–609.
Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., & Core Team, R. (2009). nlme: Linear and nonlinear mixed effects models. *R Package Version, 3*, 96.
Pöysä, S., Vasalampi, K., Muotka, J., Lerkkanen, M.-K., Poikkeus, A.-M., & Nurmi, J.-E. (2018). Variation in situation-specific engagement among lower secondary school students. *Learning and Instruction, 53*, 64–73. https://doi.org/10.1016/j.learninstruc.2017.07.007.
Preacher, K. J., Rucker, D. D., & Hayes, A. F. (2007). Addressing moderated mediation hypotheses: Theory, methods, and prescriptions. *Multivariate Behavioral Research, 42*(1), 185–227. https://doi.org/10.1080/00273170701341316.
Reeve, J. (2006). Thematic Issue: Autonomy, volitional motivation, and wellness. *Motivation and Emotion, 30*(4), 257–258. https://doi.org/10.1007/s11031-006-9050-9.
Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educational Psychologist, 44*(3), 159–175. https://doi.org/10.1080/00461520903028990.
Reeve, J. (2012). A self-determination theory perspective on student engagement. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.). *Handbook of research on student engagement* (pp. 149–172). Boston, MA: Springer US. Retrieved from: http://link.springer.com/10.1007/978-1-4614-2018-7_7.
Reeve, J., & Jang, H. (2006). What teachers say and do to support students' autonomy during a learning activity. *Journal of Educational Psychology, 98*(1), 209–218. https://doi.org/10.1037/0022-0663.98.1.209.
Reeve, J., Jang, H., Carrell, D., Jeon, S., & Barch, J. (2004). Enhancing students' engagement by increasing teachers' autonomy support. *Motivation and Emotion, 28*(2), 147–169.
Reis, H. T., Sheldon, K. M., Gable, S. L., Roscoe, J., & Ryan, R. M. (2000). Daily well-being: The role of autonomy, competence, and relatedness. *Personality and Social Psychology Bulletin, 26*(4), 419–435.
Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness.* New York, NY, US: Guilford Press.
Schweinle, A., Meyer, D. K., & Turner, J. C. (2006). Striking the right balance: Students' motivation and affect in elementary mathematics. *The Journal of Educational Research, 99*(5), 271–294. https://doi.org/10.3200/JOER.99.5.271-294.
Selig, J. P., & Preacher, K. J. (2008, June). *Monte Carlo method for assessing mediation: An interactive tool for creating confidence intervals for indirect effects [Computer software]*. Available from: http://quantpsy.org/.
Sierens, E., Vansteenkiste, M., Goossens, L., Soenens, B., & Dochy, F. (2009). The synergistic relationship of perceived autonomy support and structure in the prediction of self-regulated learning. *British Journal of Educational Psychology, 79*(1), 57–68. https://doi.org/10.1348/000709908x304398.
Skinner, E. A., & Belmont, M. J. (1993). Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology, 85*(4), 571.
Skinner, E., Furrer, C., Marchand, G., & Kindermann, T. (2008). Engagement and disaffection in the classroom: Part of a larger motivational dynamic? *Journal of Educational Psychology, 100*(4), 765–781. https://doi.org/10.1037/a0012840.
Strambler, M. J., & Weinstein, R. S. (2010). Psychological disengagement in elementary school among ethnic minority students. *Journal of Applied Developmental Psychology, 31*(2), 155–165. https://doi.org/10.1016/j.appdev.2009.11.006.
Su, Y.-L., & Reeve, J. (2011). A meta-analysis of the effectiveness of intervention programs designed to support autonomy. *Educational Psychology Review, 23*(1), 159–188. https://doi.org/10.1007/s10648-010-9142-7.
Tein, J.-Y., Sandler, I. N., MacKinnon, D. P., & Wolchik, S. A. (2004). How did it work? Who did it work for? Mediation in the context of a moderated prevention effect for children of divorce. *Journal of Consulting and Clinical Psychology, 72*(4), 617–624. https://doi.org/10.1037/0022-006X.72.4.617.
Tolvanen, A., Kiuru, N., Leskinen, E., Hakkarainen, K., Inkinen, M., Lonka, K., et al. (2011). A new approach for estimating a nonlinear growth component in multilevel modeling. *International Journal of Behavioral Development, 35*(4), 370–379. https://doi.org/10.1177/0165025411406564.
Tulis, M., & Fulmer, S. M. (2013). Students' motivational and emotional experiences and their relationship to persistence during academic challenge in mathematics and reading. *Learning and Individual Differences, 27*, 35–46. https://doi.org/10.1016/j.lindif.2013.06.003.
Twenge, J., & Campbell, W. K. (2002). Self-esteem and socioeconomic status: A meta-analytic review. *Personality and Social Psychology Review, 6*https://doi.org/10.1207/S15327957PSPR0601_3.
U.S. Department of Education (2015). Office of elementary and secondary education, office of state support. *Improving basic programs operated by local educational agencies (title I, Part A)*. Retrieved from: https://www2.ed.gov/programs/titleiparta/index.html.
Vansteenkiste, M., Sierens, E., Goossens, L., Soenens, B., Dochy, F., Mouratidis, A., et al. (2012). Identifying configurations of perceived teacher autonomy support and structure: Associations with self-regulated learning, motivation and problem behavior. *Learning and Instruction, 22*(6), 431–439. https://doi.org/10.1016/j.learninstruc.2012.04.002.
Vasalampi, K., Muotka, J., Pöysä, S., Lerkkanen, M.-K., Poikkeus, A.-M., & Nurmi, J.-E. (2016). Assessment of students' situation-specific classroom engagement by an InSitu instrument. *Learning and Individual Differences, 52*, 46–52. https://doi.org/10.1016/j.lindif.2016.10.009.
Vygotsky, L. (1978). Interaction between learning and development. *Readings on the Development of Children, 23*(3), 34–41.
Wang, M.-T., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy–value perspective to understand individual and gender differences in STEM fields. *Developmental Review, 33*(4), 304–340. https://doi.org/10.1016/j.dr.2013.08.001.
Wang, M.-T., & Eccles, J. S. (2013). School context, achievement motivation, and academic engagement: A longitudinal study of school engagement using a multidimensional perspective. *Learning and Instruction, 28*, 12–23. https://doi.org/10.1016/j.learninstruc.2013.04.002.
Wang, M.-T., & Holcombe, R. (2010). Adolescents' perceptions of school environment, engagement, and academic achievement in middle school. *American Educational Research Journal, 47*(3), 633–662. https://doi.org/10.3102/0002831209361209.
Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of Personality and Social Psychology, 70*(4), 767–779. https://doi.org/10.1037/0022-3514.70.4.767.

Further reading

Aelterman, N., Vansteenkiste, M., Soenens, B., Haerens, L., & Reeve, J. (2018). Toward an integrative and fine-grained insight in motivating and demotivating teaching styles: The merits of a circumplex approach. *Journal of Educational Psychology* (in press).