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Agency and high school science students' motivation, engagement, and classroom support experiences☆

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ABSTRACT

Agentic engagement is a potential gateway to improving the classroom climate and adolescent students' motivation. The current investigation provided the first test of daily and short-term longitudinal relations between U.S. high school science students' agentic engagement during class and their psychological need satisfaction, other forms of engagement (behavioral, cognitive, emotional), and perceptions of teachers' autonomy relevant practices. Analyses were based on a six-week diary study with 208 urban and suburban U.S. high school students from 41 science classes. Multilevel modeling analyses suggested that agentic engagement predicted an increase in concurrent and longitudinal perceived teacher autonomy support, need satisfaction, and other forms of engagement. Mediational analyses supported theoretical depictions of agentic engagement as emerging out of an autonomy supportive context and dynamically shaping that context and students' motivational experiences over the course of an instructional unit. The implications and fit of the findings with theory are discussed.

Student engagement in the high school classroom, that is, their active involvement in learning activities (e.g., (Christenson, Reschly, and Wylie, 2012)), remains a concern for educators for good reason. Engagement in the classroom is an indicator of students' positive academic functioning and serves as the mechanism through which students make academic progress, as a consistent predictor of academic success (e.g., (Jang, Kim, & Reeve, 2012; Ladd & Dinella, 2009; Reeve & Lee, 2014; Skinner, Kindermann, Connell, & Wellborn, 2009)). Concerns about student engagement are particularly heightened for adolescents in science, with evidence suggesting that students' engagement in science declines from kindergarten through grade 12 (e.g. (Gottfried, Marcoulides, Gottfried, & Oliver, 2009; Sinatra, Heddy, & Lombardi, 2015; Vedder-Weiss & Fortus, 2011)).

Traditionally, scholars have conceptualized students' engagement as a multidimensional construct that includes behavioral (e.g., effort attention and participation), emotional (e.g., interest, enjoyment, and other positive emotions), and cognitive components (e.g., regulation of the learning process) (Fredricks, Blumenfeld, and Paris, 2004; Sinatra et al., 2015) that are largely responsive to proximal conditions in the classroom, such as teachers' autonomy support, warmth, structure, and use of effective instruction (e.g., (Jang, Kim, & Reeve, 2016; Patall, Vasquez, Steingut, Trimble, & Pituch, 2017; Reeve, 2013; Skinner & Belmont, 1993)). However, (Reeve, Nix, & Hamm, 2003; Reeve & Tseng, 2011)) recently proposed that students' proactive, constructive attempts to assert their agency and influence the flow of instruction represents a fourth, unique form of engagement, known as *agentic engagement.* Preliminary evidence suggests that agentic engagement has consequences for the classroom environment and students' motivation and achievement (e.g., (Reeve, 2013; Reeve & Tseng, 2011)).

Agentic engagement stands out as a gateway to enhancing the classroom climate and various forms of student motivation and learning in science (Reeve, 2013), particularly during adolescence when gaining greater autonomy, agency, individuation, and independence are key developmental tasks (Eccles et al., 1993; Erikson, 1968; Hill & Holmbeck, 1986). Thus, the purpose of the current investigation was to extend prior work and our understanding of agentic engagement by examining the short-term (daily and weekly) links between agentic engagement, perceptions of autonomy relevant teaching practices,

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motivation, and other forms of engagement in a six-week diary study with a diverse sample of urban and suburban U.S. high school science students.

Supporting adolescent engagement from a self-determination theory perspective

The quality of students' engagement in the classroom varies from one day to the next. On one day, a student may be attentive, interested, and attempt to use sophisticated learning strategies, while the next day the same student may exert limited effort, be bored, and use superficial learning strategies. This variation depends on a variety of factors, most importantly, the support students receive from teachers, particularly the extent to which teachers are perceived to support students' experience of autonomy (e.g., (Jang et al., 2016; Patall et al., 2018)).

According to self-determination theory, students have fundamental psychological needs for autonomy, competence, and relatedness that underlie their motivation, engagement, and well-being (Ryan & Deci, 2000). Students thrive, realizing internalized forms of motivation (e.g., intrinsic motivation) and greater engagement, when they feel: their behavior emanates from an understanding of self (i.e., autonomy); successful in interacting with the environment (i.e. competence); and connected with other individuals (i.e., relatedness) (e.g., (Jang et al., 2016)). In this sense, students come to the classroom already possessing inner motivational resources that equip them to engage meaningfully in learning activities. Teachers either support or thwart those resources.

Teachers who adopt a motivational approach in which they identify, nurture, and develop students' inner motivational resources support autonomy, as well as students' other needs (Reeve, 2009). Autonomy supportive teachers offer choices, encourage students to work in their own way or at their own pace, and attempt to structure course activities around students' interests when possible. They also provide meaningful rationales to explain the usefulness or importance of even “boring” course activities, are open and responsive to students' negative feelings in the classroom, and provide informational feedback that encourages students to continue efforts to make progress (see (Reeve, 2009; Reeve & Jang, 2006); or (Su & Reeve, 2011) for reviews). Extensive longitudinal and experimental evidence suggests that teachers' autonomy support predicts students' enhanced need satisfaction, motivation, and engagement (e.g., (Cheon, Reeve, & Moon, 2012; Jang et al., 2016; Patall et al., 2017; Patall, Steingut, Vasquez, et al., 2018; Reeve, Jang, Carrell, Jeon, & Barch, 2004)).

While teachers' autonomy and motivation support has benefits for students of all ages, adolescents' increasing need for self-governance and autonomy ensures that teachers' autonomy support is particularly critical starting in early adolescence and increasingly as students progress onward to middle and late adolescence (e.g., (Collins & Steinberg, 2006; Eccles et al., 1993)). This increased desire for autonomy is rooted in biological (e.g., onset of puberty), cognitive (e.g., enhanced complex thinking), and social (e.g., increased time spent with peers) changes that occur during adolescence and has implications for adolescents' adaptive psychosocial development and functioning (Collins & Steinberg, 2006; Eccles et al., 1993). Longitudinal research suggests that support for autonomous functioning and decision-making across adolescence normatively increases cross-culturally and is critical to psychological health, with adolescents who experience a balance between independent or joint decision making and positive relationships with authority figures, such as parents and teachers, demonstrating more optimal psychosocial adjustment (e.g., (Fuligni & Eccles, 1993; Hasebe, Nucci, & Nucci, 2004; Helgeson, 1994; Qin, Pomerantz, & Wang, 2009; Sessa & Steinberg, 1991; Smetana, 1988; Smetana, Campione-Barr, & Daddis, 2004; Steinberg, 2002)).

Developmental perspectives have often emphasized adolescents' independence, separateness, and sometimes even detachment from others to define autonomy, with mixed findings depending on the definition (Blos, 1979; Zimmer-Gembeck & Collins, 2003). However, from a self-determination theory perspective, the experience of autonomy is not exclusively about independent decision-making. Rather, in self-determination theory, autonomy is defined by self-endorsed or volitional functioning, that is, the extent to which one behaves in line with personally valued interests, preferences, and needs (Ryan & Deci, 2000). Even when defined as self-endorsed functioning, research suggests that autonomy increases with age as adolescents internalize external values (e.g., (Van Petegem, Beyers, Vansteenkiste, & Soenens, 2012)). Moreover, self-endorsed functioning is consistently found to be strongly related to greater adolescent motivation, well-being, and less problem behavior (e.g., (Reeve et al., 2003; Ryan, Deci, Grolnick, & LaGuardia, 2006; Vansteenkiste, Niemiec, & Soenens, 2010)). In fact, the developmental mismatch between adolescents' increased need for autonomy and teachers' stalled (or declining) support for that autonomy in middle school and high school has been routinely put forth as an explanation for students declining engagement in school across grades (e.g., (Eccles et al., 1993; Steinberg, 1990)).

Agentic engagement

Undoubtedly, motivational characteristics of instruction and learning activities predict the extent to which students experience need satisfaction and behaviorally, emotionally, and cognitively engage, which in turn explains skill or knowledge development. However, this model overlooks students' agency to influence their learning experiences and environment (Bandura, 2006; Reeve, 2013), a form of engagement that is likely to become more prominent over the course of adolescence as students develop both a greater sense of autonomy and identity (e.g., (Erikson, 1968; Marcia, 1988)).

In contrast to other forms of engagement, *agentic engagement* describes students' involvement in terms of their proactive and constructive attempts to influence instruction and educational activities so that the activities better support their own motivation and learning by making them more interesting, valuable, or personal (Reeve, 2013; Reeve & Tseng, 2011). Agentically engaged students deliberately and purposefully try to enrich and transform their learning opportunities in the classroom by offering input and collaborating with instructors to make those experiences more valuable. Students who agentically engage do so by, for example, offering input or suggestions, expressing their preferences or interests, asking questions, recommending a goal or focus, communicating their needs, or asking the teacher to clarify the relevance or importance of activities. Compared to other forms of engagement, agentic engagement is more proactive-transactional in nature and should have mutually reinforcing consequences for *both* the classroom climate *and* students' other forms of motivation and engagement (Reeve, 2013; Reeve & Tseng, 2011).

In line with prior research (e.g., (Reeve, 2013; Reeve & Tseng, 2011)), we focus on students' agentic engagement during adolescence, and primarily, middle adolescence during the high school years, given that the increasing need for autonomy implicates agentic engagement in students' development during this period and makes it more likely that agentic engagement will occur and will have benefits. While students of all ages are likely to agentically engage and experience its benefits to some extent, the developmental process of exploring and committing to various identities that occurs especially during middle adolescence (e.g., (Erikson, 1968; Marcia, 1988)) gives particular meaning to agentic engagement during this period. During middle adolescence, as impending life decisions about college and careers loom, students give greater focus to developing a rich sense of identity that includes an understanding of their authentic interests and values (e.g., (Assor, 2018)). As such, agentic engagement may both be guided by these schemas for identity, interests, and values that develop during adolescence, as well as inform them as students explore and re-evaluate those schemas through their agentic engagement.

The functions of agentic engagement in the classroom and for adolescents' outcomes

Like other forms of engagement, agentic engagement can be a response to supportive conditions in the environment and need satisfaction, while serving as a pathway to learning and academic progress (e.g., (Jang et al., 2016; Reeve & Tseng, 2011)). However, agentic engagement is distinct, having modest correlations with the other forms of engagement and uniquely predicting academic achievement even after accounting for other components of engagement (e.g., (Reeve, 2013; Reeve & Tseng, 2011)).

Rather than being only a response to teachers' support for student motivation, agentic engagement also facilitates students' need satisfaction, motivation, and experience of the environment (Reeve, 2015). First, students' agentic engagement intentionally transforms teachers' instructional behavior to create a more motivationally supportive environment, that in turn, supports students' subsequent experiences of motivation and engagement in the classroom and for schoolwork (e.g., (Reeve, 2013)). Indeed, the role of agentic engagement in the classroom is quite consistent with psychological theory emphasizing the role of agency in bringing about academic outcomes (e.g., (Bandura, 2006)) and research that has long documented this bi-directional relationship in which teachers' motivation support is also a response to students' motivation, engagement, or disengagement (Jang et al., 2016; Patall, Vasquez, Steingut, Trimble, & Pituch, 2016; Pelletier, Séguin-Lévesque, & Legault, 2002; Skinner & Belmont, 1993). In support of this premise, Reeve (Reeve, 2013) found that that Korean middle school students' agentic engagement early in the semester predicted an increase in perceptions of teachers' autonomy support later in the semester, controlling for perceptions of autonomy support earlier in the semester. Moreover, given longitudinal evidence that secondary school teachers sometimes struggle to align their practice with adolescents' growing need for autonomy (e.g., (Eccles et al., 1993)), agentic engagement may particularly have benefits in the high school classroom.

Second, students' agentic engagement may also *directly* contribute to students' subsequent experiences of need satisfaction, motivation, other forms of engagement, learning, and achievement (e.g., (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012; Jang et al., 2012;Reeve, 2013; Reeve & Lee, 2014; Reeve & Tseng, 2011)). That is, agentic engagement represents a strategy by which adolescents attempt to interact and participate in the environmental transactions that will allow them to satisfy psychological needs. Agentically engaging directs students' attention to what is most interesting or valuable about their learning experiences and may thereby serve to alter students' perceptions of their own motivation and experiences in the classroom separate from and regardless of the objective features of the classroom context. This hypothesis is supported by longitudinal evidence suggesting that students' engagement (aggregated across all forms) early in a semester predicts an increase in later semester need satisfaction, self-efficacy, and mastery goals and by correlational evidence linking agentic engagement with autonomous forms of motivation and need satisfaction among Asian adolescents (e.g., (Reeve, 2013; Reeve & Lee, 2014; Reeve & Tseng, 2011)). Fig. 1 illustrates this conceptual model.

Contribution of the present investigation

Agentic engagement is a potentially powerful tool in the arsenal of strategies adolescents have to construct their own motivation and learning in the classroom. With self-determination theory and the work of predecessors (e.g., (Bandura, 2006; deCharms, 1976)) as a starting point, Reeve et al. [49,56] have provided a strong conceptual and empirical base for making predictions about the role of agentic engagement in shaping students' experiences in the classroom over time. However, as a relatively new construct, there is still evidence to gather.

Agentic engagement is conceptualized to provoke in-the-moment, state-like changes to adolescents' motivation, engagement, and teachers' support for motivation, as well as short- and long-term changes as such experiences accumulate. Given this, a comprehensive understanding of agentic engagement requires examining both the daily functions of agentic engagement as it fluctuates within students from one day to the next, as well as the short-range functions of agentic engagement in the classroom over time from one student to the next. Moreover, there has yet to be a study exploring agentic engagement in a non-Chinese or South Korean sample. It is critical to establish that agentic engagement is a viable strategy for enhancing motivation and improving the classroom climate across a variety of adolescent student populations, including economically and racially diverse U.S. students in urban and suburban centers. Finally, though agentic engagement is conceptualized as a critical stimulus for students' motivation and teachers' autonomy support, the extent to which it uniquely predicts perceptions of the classroom and motivation after controlling for other forms of engagement has yet to be examined.

We addressed these considerations in the current diary study where students provided reports of their classroom experiences for six weeks in order to examine: 1) the extent to which students' daily agentic engagement predicts changes in their daily motivation, other forms of engagement, and perceptions of teachers' autonomy support both the same and following class day, and 2) the extent to which students' agentic engagement predicts changes in their perceptions of the classroom, motivation, and other forms of engagement in short (1.5 to 3 week) increments over the course of a six-week instructional unit.

We hypothesized that on days when students' agentic engagement was greater than (their own) average, they would experience an increase in need satisfaction and autonomy support relative to the prior class day, even after controlling for other forms of engagement. In order to gain a deep understanding of the functions of agentic engagement in the classroom, we examined not only relations with autonomy supportive teacher behaviors, but also relations with an autonomy thwarting behavior. Specifically, and somewhat antagonistic with theoretical conceptions of agentic engagement, we expected daily agentic engagement to slightly increase perceptions that teachers suppressed student perspectives on the same day (even as they also engaged in more autonomy supportive practices), based on our sense that teachers

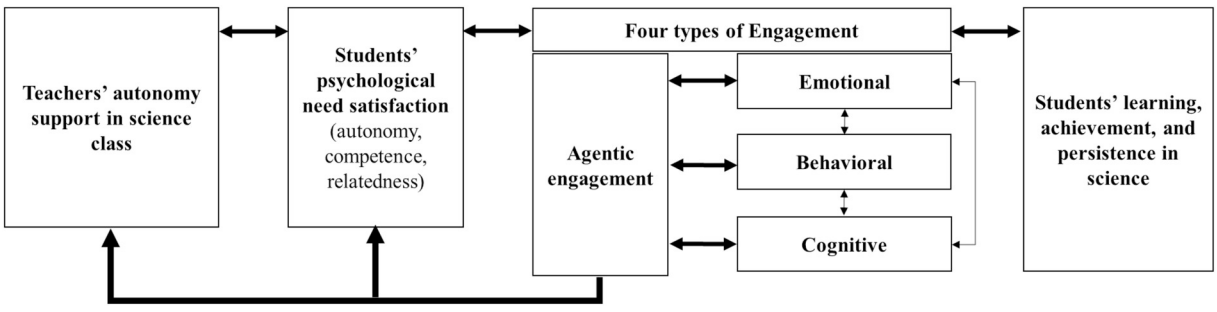

Fig. 1. Conceptual model illustrating the how agentic engagement functions in the high school science classroom.

would feel a need to restrict an abundance of student requests on a single given day and longitudinal evidence suggesting that high school teachers may struggle to align their practice with adolescents' growing need for autonomy (e.g., (Eccles et al., 1993)). We also expected that greater agentic engagement on a given day would predict an increase in students' behavioral, cognitive, and emotional engagement that day more strongly than each of those forms of engagement would predict a change in the day's agentic engagement. In contrast to these same day relationships, we did not expect students' agentic engagement to predict outcomes the next class day. We made this prediction based on the premise that agentic engagement and the autonomy support, need satisfaction, and engagement it elicits occur largely in the moment and requires some accumulation (across days) in order to have consequences for outcomes at future time points.

We also predicted that greater agentic engagement earlier in the unit would predict an increase in students' need satisfaction and perception of autonomy support, but not suppression of student perspectives, later in the instructional unit, even after controlling for other forms of student engagement. Likewise, we expected agentic engagement earlier in the unit to predict an increase in students' other forms of engagement later in the unit more strongly than the reverse. Along these lines and in reflection of theoretical arguments about how agentic engagement shapes the flow of instruction and students' motivational experiences in the classroom over time, we also expected to find evidence for two sets of mediational pathways. Namely, we hypothesized that a) early unit perceptions of autonomy support would predict mid unit agentic engagement, which in turn would predict late unit need satisfaction, other forms of engagement, as well as more autonomy support. Second, we hypothesized that early (or mid) unit agentic engagement would predict mid (or late) unit autonomy support, which in turn would predict late unit need satisfaction and other forms of engagement.

To gain a deeper understanding of how agentic engagement relates to perceptions of the motivational climate of the classroom, exploratory analyses examined the relationships between agentic engagement and individual components of autonomy support (e.g., provision of choices, consideration for student interests, etc.). We had little to inform predictions. However, we suspected that agentic engagement may predict different forms of autonomy support earlier in the instructional unit compared to later in the instructional unit. Namely, we speculated that the nature of student needs earlier in an instructional unit (when new information is being presented to learn and interest needs to be triggered) may elicit teacher attempts to create interesting activities that considered students' preferences, provide choices, and rationales of importance for activities. In contrast, we suspected the nature of students needs later in an instructional unit (when information is often being reviewed and tested and greater competence is developed) would be more likely to elicit teacher attempts to be sensitive to students' negative affect about activities or provide encouraging, informational feedback (e.g., see (Hidi & Renninger, 2006) model of interest development for a perspective that supports this hypothesis).

To rigorously test these hypotheses, we controlled for a variety of student and classroom characteristics (e.g., students' sex, race, free or reduced price lunch eligibility, age, and prior course grade, as well as course domain and content difficulty), since prior research suggests that these student and classroom factors may influence students' engagement and perceptions of the environment (e.g., (Clotfelter, Ladd, & Vigdor, 2010; Eccles et al., 1993; Murdock, 1999; Solomon, Battistich, & Hom, 1996)), particularly within the science domain (e.g., (Patall et al., 2016; Sinatra et al., 2015)). We also explored the extent to which age, sex, and race moderated relations with agentic engagement, though we expected that agentic engagement would have similarly positive relations with outcomes across ages in middle adolescence and for students of varying gender and race.

Overall, the current study aims to extend evidence related to agentic engagement by contextualizing the research within U.S. high school science classrooms and providing an opportunity to examine the unique daily associations within students, as well as the unique short-term associations across time between students.

Method

Participants

The current study makes use of confidential data obtained from The Autonomy Support in High School Science investigation, where it has been used to address research questions distinct from the current study (see (Patall et al., 2016; Patall et al., 2017; Patall, Hooper, Vasquez, Pituch, & Steingut, 2018; Patall, Steingut, Freeman, Pituch, & Vasquez, 2018; Patall, Steingut, Vasquez, et al., 2018)). Two-hundred and eight students (54% female; 41% eligible for free or reduced lunch) from 41 science classrooms across eight urban and suburban public high schools in the southwestern United States participated. These high school students were largely middle adolescents (see (Smetana, Campione-Barr, & Metzger, 2006), for description of the developmental periods of adolescence), with most students ranging between 14 and 17 years of age (n = 186), and some as young as 13 (n = 2) and as old as 18 (n = 20). Students responded to a questionnaire about classroom experiences after every science class during a six-week instructional unit (2176 total reports). The study was conducted between January 2013 and May 2014.

Every classroom was led by a different science teacher. Forty-eight percent of students were enrolled in a grade-level biology, physics, or chemistry and the rest were enrolled in an advanced biology, physics, or chemistry or a specialty topic science course (anatomy, environmental systems, engineering, or aquatic science). Forty-two percent of the students across these classes were Hispanic/Latino, 32% were white, 10% were black, 2% were Asian, and 14% were of mixed race/ethnicity or another race/ethnicity. Forty-two percent of students were 9th graders, 24% were 10th graders, 17% were 11th graders, and 17% were 12th graders. The mean baseline grade point average (GPA) was 2.92 (SD = 0.96; minimum = 0.82, maximum = 4.0) on a 4-point scale. A comparison of our sample demographics to demographics of the urban and suburban school districts from which students were drawn indicated that our sample was representative of the overall student population. Three to six students in each class participated in the study, with students randomly selected from a pool of volunteers. Students were paid $5 for every complete survey and received a $50 bonus for completing all reports for which they were present in class.

Teachers were 25 to 66 years of age (M = 38.12; SD = 12.49) and had between 0 and 40 years of experience (M = 10.40, SD = 9.85). Most teachers were white (30) and female (30). One teacher was Black, three were Asian, three were Hispanic/Latino and four were of mixed race/ethnicities or another race/ethnicity. Teachers received $50 for participation. Schools received $100 for every teacher who participated in the study.

Procedure

Teachers were recruited in group information sessions and were informed that the purpose of the study was to examine the relationship between students' experiences in the classroom and their motivation and engagement. Participating teachers were allowed to select the class section that would participate in the study primarily based on scheduling needs and the diversity of the students in the course. Across all schools, approximately 40% of teachers participated in the study.

Student participants were recruited via in-person classroom visits in which the study was described. During these visits, a parent information letter and consent documents in both English and Spanish were distributed. A box was set up in the main office of each school so students could return signed consent documents in a sealed envelope without teacher knowledge.

Each participant met individually with a member of the research team for orientation. During this meeting, participating students received an Apple iPod touch for completing surveys. Student participants practiced using the iPod during this meeting and completed a background survey regarding their age, grade level, sex, race, eligibility for free or reduced lunch at school based on U.S. government policy, school GPA, and science course grade for the most recent instructional unit.

On every class day of the six-week instructional unit, students were emailed during their first non-instructional (or "free") period following the science class session with a survey about their teachers' practices, their experiences of need satisfaction, and their engagement in class. All surveys were programmed using Qualtrics and completed by students online. All classes met 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). Students had until the next class meeting to complete their daily report. Student participants completed between 1 and 17 reports across the instructional unit (Mean = 10; SD = 3.77; Mode = 10). One student who completed just one report was excluded.

Measures[1]

Engagement

Building on prior work on agentic engagement (e.g., (Reeve, 2013)), students' daily engagement in science class was assessed with fifteen items we adapted from the Engagement versus Disaffection with Learning Student Report (Furrer & Skinner, 2003; Skinner et al., 2009; Skinner & Belmont, 1993), the Metacognitive Strategies Questionnaire (Wolters, 2004) and the Agentic Engagement Scale (Reeve & Tseng, 2011). The Engagement versus Disaffection with Learning Student Report contains scales for behavioral and emotional engagement from which we adapted seven items (3 behavioral and 4 emotional engagement; e.g., "I worked as hard as I can in science class today" and "When I was in science class today, I felt good") for the daily context (mean daily $\alpha = .68$ and .89). Four items measuring learning strategies adapted from the Metacognitive Strategies Questionnaire were used to assess students' cognitive engagement in science class (e.g., "I tried to connect what I was learning in science class today with my own experiences"; mean daily $\alpha = .86$). Students' agentic engagement in science class was assessed with four items adapted from the Agentic Engagement Scale (e.g., "I let my science teacher know what I needed and wanted today"; mean daily $\alpha = .80$; (Reeve & Tseng, 2011)). For all engagement items, students rated the extent to which they agreed with each item on a 5-point Likert scale ranging from not at all true (1) to extremely true (5). The validity and reliability of all engagement scales for cross-sectional research have been established in previous studies (Furrer & Skinner, 2003; Reeve, 2013; Reeve & Tseng, 2011; Wolters, 2004). We confirmed the factor structure of the measure with multilevel confirmatory factor analyses (ML-CFA; see supplemental materials for a description of analyses). In addition to using each component of daily engagement separately in analyses, we also created a composite engagement variable by averaging daily behavioral, emotional, and cognitive engagement scales (but not agentic engagement; mean daily $\alpha = .89$) to be used in some student level analyses in which engagement was included as a covariate. We call the variable BEC engagement. Sizeable correlations between these engagement factors (daily level rs = .30 to .42; student level rs = .43 to .65), particularly at the student level, supported using a composite when a particular component of engagement was not the focus of the analysis.

Need satisfaction

Students' daily need satisfaction in science class was assessed with twelve items adapted from the Perceived Self-Determination Scale [53], the Perceived Competence Scale, (Williams & Deci, 1996), and perceived relatedness subscale of the Activity-Feeling States (Reeve & Sickenius, 1994). Autonomy need satisfaction was measured with six items from the Perceived Self-Determination Scale (e.g., "I felt I did what I wanted to be doing in my science class today"; mean daily $\alpha = .87$). Competence need satisfaction was assessed with three items from the Perceived Competence Scale (e.g., "I felt competent while working on assignments for my science class today"; mean daily $\alpha = .82$). Relatedness need satisfaction was assessed with three items from the Activity-Feeling States for the relatedness subscale (e.g., "Today in science class, I felt I belonged and the people in class care about me"; mean daily $\alpha = .88$). Students rated the extent to which they agreed with each item on a 5-point Likert scale ranging from not at all true (1) to extremely true (5). Previous studies have established the validity and reliability of all scales for cross-sectional research (Reeve et al., 2003; Reeve & Jang, 2006; Reeve & Sickenius, 1994) and ML-CFAs confirmed a three-factor structure. We calculated the scale score for each of the three forms of daily need satisfaction but then created a composite need satisfaction variable by averaging daily perceived autonomy, perceived competence, and perceived relatedness scales (mean daily $\alpha = .90$). This approach is consistent with prior research in which needs are aggregated in a single measure (e.g., (Jang et al., 2016)).

Perceived autonomy supportive teacher practices

Students' perceptions of the extent to which their teachers used practices theorized to support autonomy on a given class day were assessed by drawing on a variety of prior measures used in cross-sectional research ((Patall, Dent, Oyer, & Wynn, 2013); as well as (Assor, Kaplan, Kanat-Maymon, & Roth, 2005; Assor, Kaplan, & Roth, 2002; Belmont, Skinner, Wellborn, & Connell, 1992; Connell, 1990; Katz, Kaplan, & Gueta, 2010; Reeve & Jang, 2006; Wellborn & Connell, 1987)). Twenty-two items assessed perceptions of six autonomy supportive daily practices and one autonomy thwarting daily practice. Supportive practices included (a) provision of choices and opportunities for students to work in their own way (e.g., "My teacher provided options for the kinds of assignments or activities I could do today"), (b) consideration for student opinions, preferences, and interests (e.g., "My teacher took my preferences into consideration for assignments today", (c) rationales regarding the usefulness and importance of course material (e.g., "My teacher demonstrated how what we were learning today is useful", (d) student question opportunities and responding (e.g., "My teacher provided opportunities for me to ask questions today"), (e) consideration for students' negative affect (e.g., My teacher was open to hearing criticism or complaints about activities today"), and (f) encouraging, informational feedback (e.g., "My teacher gave suggestions when I struggled with course work today"). The one thwarting practice examined in this investigation was suppression of student perspectives (e.g., "My teacher stopped me from asking questions in class today"). Students rated the extent to which they agreed with each item on a 5-point Likert scale ranging from not at all true (1) to extremely true (5). Multilevel exploratory factor analyses confirmed that our abbreviated measures were appropriate for our daily context.[2] Scale scores for each perceived teacher practice were calculated by taking the mean of all items on each factor (mean daily $\alpha = .73$ to .87). Consistent with previous research (e.g., (Jang et al., 2012; Katz et al.,

[1] A table of items for all measures, along with reliabilities for all subscales can be found in the supplementary materials (Table S1). In addition, a description of all ML-CFAs for measures can be found in supplementary materials.

[2] Additional details for these multilevel exploratory factor analyses can be found in Patall, Vasquez, Steingut, Trimble, & Pituch, 2017.

2010)), we also created a composite perceived autonomy support variable by averaging daily perceptions across the six support subscales (mean daily α = .91).

Framework for multilevel analyses

We tested our hypotheses about the extent to which daily agentic engagement predicted daily perceptions of teacher autonomy supportive practices and suppression, daily experiences of need satisfaction, and other forms of daily engagement with a series of three-level (day, student, and class) regressions where the intercept was allowed to vary randomly using the Mixed procedure in SPSS 21. For all multilevel models (also known as hierarchical linear models; HLM) examining relationships at the daily level, at level 1 (day level) we included the class day (time) and the outcome reported on the previous day, in addition to daily agentic engagement for the same and prior class day. The class day (time) variable consecutively numbers each class session during the unit starting with zero. The prior class session's outcome was entered to control for possible carryover effects from one class day to the next (e.g. see (Sheldon, Gable, Roscoe, & Ryan, 2000) for an example of this strategy). To minimize missing data, reports were carried forward to the next available day of reporting when creating lagged variables. Including the prior class session's outcome value as a predictor allowed us to predict day-to-day change in the outcome rather than overall level (Cohen & Cohen, 1983). In models where daily perceived autonomy support, daily suppression, or daily need satisfaction were the outcomes, same and prior day behavioral, emotional and cognitive engagement were also included as covariates.

At the student level, we included the following student variables in all models: gender (0 = male, 1 = female), race (0 = white or Asian, 1 = black, Hispanic/Latino, or other ethnic minority), free or reduced price lunch eligibility (0 = not eligible, 1 = eligible), age, and course grade for the prior unit. At the class level, we included variables representing whether the class was a biological science versus another science area (e.g., physics, chemistry, engineering, environmental science; 0 = non-biological focus, 1 = biological focus) and whether the class was advanced or grade typical (0 = grade typical, 1 = advanced).

To decompose within-student (day) effects from between-student and between-class effects, daily engagement predictors were student-mean centered (around each student's own average score). Control variables, including student and class level covariates, class day (time), and the value of the outcome variable from the prior class session were grand-mean centered. To treat missing data, we used a maximum likelihood estimation procedure with robust estimates of standard errors (REML). We specified an auto-regressive correlated error structure (AR(1)) since adjacent residuals may be correlated across repeated measures (Bolger & Laurenceau, 2013).

We fit two-level (student and class) models using REML to test our hypotheses about the extent to which agentic engagement predicted perceived autonomy-relevant practices, need satisfaction and other forms of engagement over time across students (rather than within students). For these analyses, we created aggregated daily scores across 1) the first four days, 2) next four days, and 3) remaining days of the instructional unit for all day level variables in order to create early,

Table 1
Multilevel regressions with same and prior day agentic engagement and covariates predicting daily perceptions of composite autonomy support and suppression.

Fixed effects	Autonomy Support composite		Suppression of perspectives	
	b(SE)	*β*	*b*(SE)	*β*
Class level				
Intercept	2.73 (0.05)		1.56 (0.03)	
Advanced class	0.04 (0.11)	0.02	−0.05 (0.07)	−0.03
Science domain	0.05 (0.11)	0.03	0.08 (0.07)	0.05
Student level				
Sex	−0.08 (0.08)	−0.05	−0.06 (0.06)	−0.04
Race/ethnicity	−0.04(0.09)	−0.03	−0.02 (0.07)	−0.01
Age	0.04 (0.04)	0.07	−0.05 (0.03)	−0.09*
Free/reduced lunch	0.16 (0.09)	0.10	0.12 (0.07)	0.07
Prior unit grade	0.001 (0.002)	0.02	−0.003 (0.002)	−0.07
Day level				
SD behavioral eng	0.06 (0.02)	0.05**	0.01 (0.02)	0.01
SD emotional eng	0.11 (0.02)	0.09***	−0.07 (0.02)	−0.05***
SD cognitive eng	0.11 (0.02)	0.08***	0.04 (0.03)	0.03
SD agentic eng	**0.20 (0.02)**	**0.15*** **	**0.05 (0.02)**	**0.04***
PD behavioral eng	−0.01 (0.02)	−0.01	−0.02 (0.02)	−0.01
PD emotional eng	0.01 (0.02)	0.01	0.06 (0.02)	0.04**
PD cognitive eng	0.002 (0.02)	0.002	−0.01 (0.02)	−0.01
PD agentic eng	**−0.02 (0.02)**	**−0.02**	**0.02 (0.02)**	**0.01**
Time	0.001 (0.003)	0.01	0.007 (0.003)	0.04***
PD outcome	0.10 (0.02)	0.10***	0.41 (0.02)	0.40***
Random effects	Variance	SE	Variance	SE
Class (level 3) intercept	0.05	0.03	0.01	0.01
Student (level 2) intercept	0.23***	0.05	0.15***	0.03
Day (level 1)				
Residual	0.21***	0.008	0.25***	0.01
Autocorrelation	0.05	0.08	−0.21***	0.04

Notes. Level 1 (daily reports) n = 1850 reports. Level 2 (students) n = 197. Level 3 (classes) n = 41. SD = same class day. PD = prior class day. Eng = Engagement. The "time" variable reflects the day of reporting across the 6-week instructional unit. For student sex, 0 = male and 1 = female. For student race/ethnicity, 0 = white or Asian and 1 = black, Hispanic/Latino, or other ethnic minority. For free and reduced lunch status, 0 = not eligible for free/reduced lunch and 1 = eligible for free/reduced lunch. For advanced class, 0 = grade typical class and 1 = advanced class. For science domain, 0 = physical science course and 1 = biological science course. b = unstandardized regression coefficient. β = standardized regression coefficient. Standardized estimates were computed using the following formula (Hox, 2010): $\beta = (b_{*}sdx)/sdy$. SE = standard error.

* p < .05.
** p < .01.
*** p < .001.

Table 2
Multilevel regressions with same and prior day agentic engagement and covariates predicting daily need satisfaction.

Fixed effects	Autonomy NS		Competence NS		Relatedness NS	
	b(SE)	*β*	*b*(SE)	*β*	*b*(SE)	*β*
Class level						
Intercept	2.81 (0.07)		3.32 (0.04)		2.52 (0.07)	
Advanced class	0.03 (0.13)	0.01	0.10 (0.08)	0.05	0.11 (0.14)	0.05
Science domain	0.03 (0.14)	0.02	0.11 (0.09)	0.06	0.24 (0.15)	0.10
Student level						
Sex	−0.27 (0.11)	−0.14**	−0.15 (0.08)	−0.08	−0.21 (0.10)	−0.09*
Race/ethnicity	0.08 (0.12)	0.04	0.03 (0.10)	0.02	0.08 (0.11)	0.03
Age	0.05 (0.05)	0.07	0.09 (0.04)	0.12*	0.003 (0.05)	0.003
Free/reduced lunch	0.10 (0.12)	0.05	−0.18 (0.09)	0.09	−0.02 (0.12)	−0.01
Prior unit grade	0.001 (0.003)	0.01	0.006 (0.002)	−0.11**	0.003 (0.003)	0.04
Day level						
SD behavioral eng	−0.03 (0.02)	−0.02	0.22 (0.03)	0.14***	0.10 (0.03)	0.05***
SD emotional eng	0.44 (0.02)	0.30***	0.36 (0.02)	0.24***	0.24 (0.03)	0.13***
SD cognitive eng	0.10 (0.02)	0.06***	0.13 (0.03)	0.07***	0.10 (0.03)	0.05***
SD agentic eng	**0.22 (0.02)**	**0.14*** **	**0.04 (0.02)**	**0.02**	**0.31 (0.03)**	**0.16*** **
PD behavioral eng	−0.01 (0.02)	−0.005	−0.02 (0.03)	−0.01	−0.04 (0.03)	−0.02
PD emotional eng	−0.03 (0.02)	−0.02	−0.07 (0.02)	−0.05**	−0.08 (0.03)	−0.05***
PD cognitive eng	−0.02 (0.02)	−0.005	−0.02 (0.03)	−0.01	−0.04 (0.03)	−0.02
PD agentic eng	**0.01 (0.02)**	**0.004**	**−0.04 (0.02)**	**−0.02**	**−0.08 (0.03)**	**−0.04****
Time	0.007 (0.003)	0.03*	−0.005 (0.003)	−0.02	−0.0003 (0.003)	−0.001
PD outcome	0.03 (0.02)	0.03	0.23 (0.003)	0.23***	0.30 (0.02)	0.30***
Random effects	Variance	SE	Variance	SE	Variance	SE
Class (level 3) intercept	0.08	0.05	0.006	0.02	0.11*	0.05
Student (level 2) intercept	0.44***	0.08	0.27***	0.05	0.35***	0.06
Day (level 1)						
Residual	0.23***	0.01	0.30***	0.01	0.36***	0.01
Autocorrelation	0.14*	0.07	−0.14**	0.05	−0.09	0.05

Notes. Level 1 (daily reports) n = 1850 reports. Level 2 (students) n = 197. Level 3 (classes) n = 41. SD = same class day. PD = prior class day. Eng = Engagement. NS = need satisfaction. The "time" variable reflects the day of reporting across the 6-week instructional unit. For student sex, 0 = male and 1 = female. For student race/ethnicity, 0 = white or Asian and 1 = black, Hispanic/Latino, or other ethnic minority. For free and reduced lunch status, 0 = not eligible for free/reduced lunch and 1 = eligible for free/reduced lunch. For advanced class, 0 = grade typical class and 1 = advanced class. For science domain, 0 = physical science course and 1 = biological science course. *b* = unstandardized regression coefficient. *β* = standardized regression coefficient. Standardized estimates were computed using the following formula (Hox, 2010): $\beta = (b*sdx)/sdy$. SE = standard error.

* p < .05.
** p < .01.
*** p < .001.

mid, and late unit scores for each student. We fit one series of models in which early unit engagement predicted mid unit outcomes and a separate set of models in which mid unit engagement predicted late unit outcomes. In either case, at the student level we included early unit (or mid unit) agentic engagement, as well as the early unit (or mid unit) score for the outcome, again allowing us to predict change in the outcome rather than sheer level (Cohen & Cohen, 1983). These models also included the same set of student and class covariates as in our daily analysis as well as other forms of engagement as covariates when perceived autonomy support, daily suppression, or daily need satisfaction were the outcomes. We class-mean centered engagement predictors and the value of the outcome variable at the prior time and grand mean centered all other student-level and class-level covariates.

Results[3]

Daily agentic engagement relationships within students

Daily agentic engagement significantly predicted an increase in same day perceptions of autonomy support as a whole and perceptions that teachers suppressed student perspectives (see Table 1), as well as an increase in perceptions of five of six components of autonomy support (choice: $\beta = 0.13$; $p < 0.001$; interesting activities: $\beta = 0.13$; $p < 0.001$; question opportunities: $\beta = 0.14$; $p < 0.001$; openness to negative affect: $\beta = 0.08$, $p < 0.001$; and encouraging feedback: $\beta = 0.14$; $p < 0.001$; see supplemental Table S4 for additional details[4]), controlling for time, the value of the perceived practice outcome on the prior class day, other forms of same and prior class day engagement (behavioral, emotional, and cognitive), and the set of student and classroom covariates. Although other components of engagement also significantly predicted changes in daily autonomy support, agentic engagement was the strongest predictor of same day autonomy support as a whole as well as five of the six components of autonomy support. Not surprisingly, older compared to younger students experienced significantly less suppression of their perspectives, and perceived teacher practices (each type) the prior day significantly predicted corresponding practice the subsequent class day. Suppression appeared to increase over time and was predicted positively by prior day emotional engagement. Prior class day agentic engagement significantly predicted a decrease in perceptions that teachers provided opportunities for question opportunities and responses ($\beta = -0.06$; $p < 0.001$) but did not predict any other autonomy-relevant practice. Agentic engagement, on either the same or prior class day, did not significantly predict daily perceptions that teachers provided more daily rationales regarding the

[3] Preliminary correlational analyses among the main study variables at both daily and student levels were computed and supported hypotheses. Correlation tables (Table S2 and S3) can be found among Supplementary materials.

[4] Tables reporting the additional details of multilevel modeling results for each component of autonomy support (Table S4 and S5) can be found among Supplementary materials.

Table 3
Multilevel regressions with same and prior day agentic engagement and covariates predicting daily behavioral, emotional, and cognitive engagement.

Fixed effects	Behavioral Eng		Emotional Eng		Cognitive Eng	
	b(SE)	*β*	*b*(SE)	*β*	*b*(SE)	*β*
Class level						
Intercept	3.25 (0.04)		3.08 (0.06)		2.75 (0.05)	
Advanced class	0.06 (0.08)	0.03	0.02 (0.12)	0.01	0.12 (0.10)	0.06
Science domain	0.13 (0.08)	0.07	0.15 (0.13)	0.07	0.18 (0.11)	0.08
Student level						
Sex	−0.09 (0.07)	−0.05	−0.28 (0.10)	−0.13**	−0.10 (0.09)	−0.05
Race/ethnicity	0.11 (0.08)	0.06	0.14 (0.12)	0.06	0.09 (0.11)	0.04
Age	0.01 (0.03)	0.02	0.07 (0.05)	0.08	0.03 (0.04)	0.04
Free/reduced lunch	−0.06 (0.08)	−0.03	−0.01 (0.12)	−0.004	0.02 (0.11)	0.007
Prior unit grade	0.004 (0.002)	0.07†	0.001 (0.003)	0.02	0.003 (0.003)	0.04
Day level						
SD agentic eng	**0.42 (0.02)**	**0.27*** **	**0.42 (0.02)**	**0.24*** **	**0.33 (0.02)**	**0.19*** **
PD agentic eng	**−0.13 (0.02)**	**−0.08*** **	**−0.10 (0.02)**	**−0.06*** **	**−0.09 (0.04)**	**−0.05*** **
Time	−0.01 (0.003)	−0.07***	−0.01 (0.003)	−0.03*	0.004(0.003)	0.02
PD outcome	0.32 (0.02)	0.33***	0.19 (0.02)	0.19***	0.28 (0.02)	0.28***
Random effects	Variance	SE	Variance	SE	Variance	SE
Class (level 3) intercept	0.01	0.01	0.06	0.04	0.02	0.03
Student (level 2) intercept	0.18***	0.04	0.38***	0.07	0.35***	0.07
Day (level 1)						
Residual	0.32***	0.01	0.40***	0.01	0.31***	0.01
Autocorrelation	−0.11*	0.05	−0.06	0.05	0.002	0.06

Notes. Level 1 (daily reports) n = 1852 reports. Level 2 (students) n = 197. Level 3 (classes) n = 41. SD = same class day. PD = prior class day. Eng = Engagement. The "time" variable reflects the day of reporting across the 6-week instructional unit. For student sex, 0 = male and 1 = female. For student race/ethnicity, 0 = white or Asian and 1 = black, Hispanic/Latino, or other ethnic minority. For free and reduced lunch status, 0 = not eligible for free/reduced lunch and 1 = eligible for free/reduced lunch. For advanced class, 0 = grade typical class and 1 = advanced class. For science domain, 0 = physical science course and 1 = biological science course. b = unstandardized regression coefficient. β = standardized regression coefficient. Standardized estimates were computed using the following formula (Hox, 2010): β = (b*sdx)/sdy. SE = standard error.

† p < .05.
* p < .05.
** p < .01.
*** p < .001.

value of engaging in course activities.

Daily agentic engagement also significantly predicted changes in need satisfaction (see Table 2). Specifically, daily agentic engagement significantly predicted an increase in same class day experiences of autonomy and relatedness need satisfaction, controlling for time, the value of the need satisfaction outcome on the prior class day, other forms of same and prior class day engagement, and the set of student and classroom covariates. Other forms of engagement also predicted need satisfaction components, with daily agentic engagement being the strongest predictor of same day relatedness satisfaction and emotional engagement being the strongest predictor of same day autonomy satisfaction. Prior day agentic engagement significantly predicted a decrease in relatedness satisfaction, along with prior day emotional engagement, which predicted a decrease in both relatedness and competence satisfaction. However, prior day agentic engagement did not predict other components of need satisfaction. Consistent with well-known gender disparities in science (National Science Foundation, 2017), girls reported experiencing significantly less autonomy and relatedness need satisfaction compared to boys. Not surprisingly, autonomy increased over time, competence and relatedness (but not autonomy) need satisfaction on the prior day significantly predicted itself on the subsequent class day, and older students experienced significantly greater competence need satisfaction. Counterintuitively, students with higher relative to lower prior unit grades experienced significantly less daily competence need satisfaction. Agentic engagement, either the same or prior class day, did not predict daily competence satisfaction.

Daily agentic engagement also significantly predicted an increase in experiences of behavioral, emotional, and cognitive engagement on the same day, controlling for time, the value of the engagement outcome on the prior class day, and the set of student and classroom covariates (Table 3). In contrast, prior class day agentic engagement significantly predicted a decrease in daily experiences of behavioral, emotional, and cognitive engagement. Again, and not surprisingly, girls experienced significantly less emotional engagement in class than boys, behavioral and emotional engagement decreased over time, and each form of engagement on a prior day predicted itself the subsequent class day. It is worth noting that same day agentic engagement was a stronger predictor of daily emotional engagement than emotional engagement on the prior class day.[5]

To assess whether daily agentic engagement and other forms of engagement predicted autonomy support more strongly or more weakly than the reverse, we ran a parallel multilevel model in which same and prior day perceived autonomy support, perceived suppression, behavioral engagement, emotional engagement, and cognitive engagement were included as predictors of agentic engagement, controlling for student and classroom covariates, time, and agentic engagement on the prior class day. Both autonomy relevant practices (support: $\beta = 0.13$; $p < 0.001$; suppression: $\beta = 0.04$; $p = 0.005$) and the three forms of engagement (behavioral: $\beta = 0.14$; $p < 0.001$; emotional: $\beta = 0.12$; $p < 0.001$; cognitive: $\beta = 0.09$; $p < 0.001$) all significantly predicted increases in same day agentic engagement since the last class, though the strength of the relationships were weaker in this direction than the reverse. Time ($\beta = 0.04$; $p = 0.003$) and prior class day agentic engagement ($\beta = 0.21$; $p < 0.001$) also predicted agentic engagement, as did gender ($\beta = -0.10$; $p < 0.05$). Prior day perceived autonomy

[5] We explored whether age, race/ethnicity, or sex moderated relationships between daily agentic engagement and outcomes, both for all science classes, as well as for biological and physical science courses separately. However, there was limited evidence for any consistent pattern of moderation.

Table 4
Multilevel regressions with students' early (or mid) unit agentic engagement and covariates predicting mid (or late) unit perceptions of composite autonomy support and suppression.

Fixed effects	Autonomy Support composite		Suppression of perspectives	
	b(SE)	*β*	*b*(SE)	*β*
	Mid unit (MU) outcomes			
Class level				
Intercept	2.70 (0.06)		1.58 (0.06)	
Advanced class	0.05(0.13)	0.04	−0.07 (0.12)	−0.04
Science domain	0.02 (0.14)	0.02	0.21 (0.12)	0.14
Student level				
Sex	−0.03 (0.07)	−0.02	−0.06 (0.08)	−0.04
Race/ethnicity	−0.05 (0.08)	−0.04	0.09 (0.09)	0.05
Age	0.02 (0.04)	0.04	−0.03 (0.04)	−0.04
Free/reduced lunch	0.13 (0.08)	0.10	0.08 (0.09)	0.05
Prior unit grade	−0.001 (0.002)	−0.02	0.001 (0.002)	0.03
EU BEC engagement	0.07 (0.07)	0.06	0.05 (0.09)	0.04
EU Agentic engagement	**0.14 (0.07)**	**0.14***	**0.008 (0.08)**	**0.007**
EU outcome	0.60 (0.08)	0.47***	1.01 (0.08)	0.69***
Random effects	Variance	SE	Variance	SE
Class (level 2) intercept	0.13**	0.04	0.08*	0.03
Student (level 1) residual	0.16***	0.02	0.25***	0.03
	Late unit (LU) outcomes			
Class level				
Intercept	2.71 (0.06)		1.61 (0.06)	
Advanced class	−0.03(0.12)	−0.03	−0.12 (0.12)	−0.07
Science domain	0.05 (0.13)	0.04	0.08 (0.13)	0.05
Student level				
Sex	0.19 (0.07)	0.14**	0.06 (0.07)	0.04
Race/ethnicity	−0.06 (0.08)	−0.05	−0.14 (0.07)	−0.09
Age	0.10 (0.04)	0.19**	−0.07 (0.04)	−0.12
Free/reduced lunch	0.06 (0.08)	0.04	0.10 (0.08)	0.06
Prior unit grade	−0.0002 (0.002)	−0.005	−0.002 (0.002)	−0.04
MU BEC engagement	0.01 (0.08)	0.01	−0.10 (0.08)	−0.08
MU Agentic engagement	**0.22 (0.07)**	**0.25*****	**0.07 (0.07)**	**0.07**
MU outcome	0.55 (0.08)	0.44***	0.89 (0.04)	0.75***
Random effects	Variance	SE	Variance	SE
Class (level 2) intercept	0.11**	0.04	0.12**	0.04
Student (level 1) residual	0.14***	0.02	0.14***	0.02

Notes. Level 1 (students) $n = 187$ for MU outcomes; 178 for LU outcomes. Level 2 (classes) n = 41. EU = Early unit. MU = Mid unit. LU = Late unt. Eng = Engagement. For student sex, 0 = male and 1 = female. For student race/ethnicity, 0 = white or Asian and 1 = black, Hispanic/Latino, or other ethnic minority. For free and reduced lunch status, 0 = not eligible for free/reduced lunch and 1 = eligible for free/reduced lunch. For advanced class, 0 = grade typical class and 1 = advanced class. For science domain, 0 = physical science course and 1 = biological science course. *b* = unstandardized regression coefficient. *β* = standardized regression coefficient. Standardized estimates were computed using the following formula (Hox, 2010): $\beta = (b*sdx)/sdy$. SE = standard error.

* $p < .05$.
** $p < .01$.
*** $p < .001$.

support, perceived suppression, behavioral engagement, emotional engagement, and cognitive engagement variables did not predict changes in agentic engagement.

Agentic engagement relationships across students over time

Students' agentic engagement early in the unit significantly predicted an increase in mid unit perceptions of overall autonomy support, controlling for a composite of the other forms of early unit engagement (behavioral, emotional and cognitive, which we subsequently refer to as BEC engagement), early unit perceived autonomy support, and student and class covariates. Likewise, mid unit agentic engagement significantly predicted an increase in late unit perceptions of autonomy support, controlling for mid unit BEC engagement and autonomy support, as well as student and class covariates (see Table 4). Multilevel models examining these relationships for each component of autonomy support separately revealed that students' early unit agentic engagement significantly predicted an increase in mid unit perceptions of teachers' consideration for student interests ($\beta = 0.25$; $p < 0.001$) and provision of rationales ($\beta = 0.16$; $p < 0.05$), but not perceptions of other autonomy supportive practices mid unit. Students' mid unit agentic engagement significantly predicted increases in late unit perceptions that teachers were open to hearing students' negative affect ($\beta = 0.21$; $p < 0.01$) and provided encouraging, informational feedback ($\beta = 0.25$; $p < 0.001$), but not perceptions of other autonomy supportive practices late in the unit (see Supplemental Table S5 for details). Neither early nor mid unit agentic engagement predicted subsequent perceived suppression, and BEC engagement did not predict subsequent autonomy support or suppression across the unit (see Table 4). Not surprisingly, the outcome at the prior time period positively predicted itself later in all cases, suggesting that teachers are perceived to consistently use autonomy support and suppression over time. In addition, gender and age positively predicted late unit autonomy support, suggesting that girls and older students perceived more autonomy support at the end of the unit compared to boys and younger students. This finding for autonomy support as a whole was primarily driven by variation in perceptions of receiving late unit choices ($\beta = 0.13$; $p < 0.05$) and question opportunities ($\beta = 0.15$; $p < 0.01$) by gender and variation in late unit question opportunities by age ($\beta = 0.26$; $p < 0.01$). In addition, black and Latino students perceived fewer late unit question opportunities ($\beta = -0.16$; $p < 0.01$).

Students' agentic engagement early in the unit significantly predicted an increase in mid unit perceptions of relatedness satisfaction,

Table 5
Multilevel regressions with students' early (or mid) unit agentic engagement and covariates predicting mid (or late) unit need satisfaction.

	Autonomy NS		Competence NS		Relatedness NS	
Fixed effects	*b*(SE)	*β*	*b*(SE)	*β*	*b*(SE)	*β*
	Mid unit (MU) outcomes					
Class level						
Intercept	2.79 (0.07)		3.30 (0.06)		2.47 (0.11)	
Advanced class	−0.02 (0.15)	−0.01	0.12 (0.11)	0.07	0.27 (0.21)	0.12
Science domain	0.07 (0.16)	0.04	0.13 (0.12)	0.08	0.29 (0.22)	0.13
Student level						
Sex	−0.05 (0.09)	−0.03	−0.03 (0.09)	−0.02	−0.12 (0.11)	−0.05
Race/ethnicity	0.18 (0.11)	0.10	0.14 (0.11)	0.08	0.20 (0.13)	0.09
Age	0.04 (0.05)	0.06	0.08 (0.04)	0.12	−0.02 (0.06)	−0.02
Free/reduced lunch	−0.006 (0.11)	−0.003	−0.23 (0.10)	−0.14*	−0.08 (0.13)	−0.03
Prior unit grade	−0.001 (0.003)	−0.02	0.006 (0.003)	−0.13*	0.0005 (0.003)	0.007
EU BEC eng	0.04 (0.05)	0.03	0.04 (0.12)	0.03	−0.09 (0.12)	−0.05
EU agentic eng	**0.11 (0.09)**	**0.09**	**0.04 (0.09)**	**0.03**	**0.22 (0.10)**	**0.14***
EU outcome	0.63 (0.08)	0.52***	0.68 (0.08)	0.58***	0.72 (0.08)	0.54***
Random effects	Variance	SE	Variance	SE	Variance	SE
Class (level 2) intercept	0.15**	0.05	0.06	0.04	0.36***	0.11
Student (level 1) residual	0.30***	0.04	0.31***	0.04	0.41***	0.05
	Late unit (LU) outcomes					
Class level						
Intercept	2.82 (0.08)		3.21 (0.06)		2.51 (0.11)	
Advanced class	−0.03 (0.16)	−0.02	0.15 (0.13)	0.09	0.004 (0.22)	0.003
Science domain	−0.09 (0.17)	−0.06	0.15 (0.14)	0.09	0.31 (0.22)	0.19
Student level						
Sex	−0.10 (0.09)	−0.06	−0.02 (0.09)	−0.01	−0.05 (0.11)	−0.03
Race/ethnicity	−0.13 (0.10)	−0.08	−0.07 (0.10)	−0.04	−0.16 (0.11)	−0.10
Age	0.02 (0.05)	0.03	0.09 (0.05)	0.15*	0.06 (0.06)	0.10
Free/reduced lunch	0.07 (0.10)	0.04	−0.04 (0.11)	−0.03	0.02 (0.12)	0.01
Prior unit grade	−0.0004 (0.002)	−0.01	0.003 (0.003)	0.06	−0.005 (0.003)	−0.11
MU BEC eng	−0.003 (0.11)	−0.003	−0.02 (0.13)	−0.01	0.10 (0.13)	0.08
MU agentic eng	**0.07 (0.08)**	**0.06**	**0.18 (0.10)**	**0.17***	**−0.01 (0.10)**	**−0.01**
MU outcome	0.70 (0.07)	0.59***	0.58 (0.08)	0.52***	0.69 (0.07)	0.61***
Random effects	Variance	SE	Variance	SE	Variance	SE
Class intercept	0.19**	0.06	0.09*	0.04	0.37***	0.11
Student residual	0.23***	0.03	0.29***	0.04	0.35***	0.04

Notes. Level 1 (students) n = 186 for MU outcomes; 178 for LU outcomes. Level 2 (classes) n = 41. EU = Early unit. MU = Mid unit. LU = Late unit. NS = Need satisfaction. Eng = Engagement. For student sex, 0 = male and 1 = female. For student race/ethnicity, 0 = white or Asian and 1 = black, Hispanic/Latino, or other ethnic minority. For free and reduced lunch status, 0 = not eligible for free/reduced lunch and 1 = eligible for free/reduced lunch. For advanced class, 0 = grade typical class and 1 = advanced class. For science domain, 0 = physical science course and 1 = biological science course. *b* = unstandardized regression coefficient. *β* = standardized regression coefficient. Standardized estimates were computed using the following formula (Hox, 2010): $\beta = (b*sdx)/sdy$. SE = standard error.

* p < .05.
** p < .01.
*** p < .001.

controlling for early unit BEC engagement, early unit relatedness satisfaction, and student and class covariates, but did not predict mid unit autonomy or competence satisfaction. Students' agentic engagement mid unit significantly predicted an increase in late unit competence need satisfaction, controlling for mid unit BEC engagement, mid unit competence satisfaction, and student and class covariates, but did not predict late unit autonomy or relatedness satisfaction (see Table 5). The need satisfaction outcome at the prior time period positively predicted itself later in all cases. Moreover, as we might expect given discrepancies in achievement by social class (e.g., (Reardon, 2013)) and the skill growth that occurs over time, students free or reduced price lunch status predicted lower mid unit competence need satisfaction and age predicted greater late unit competence need satisfaction. Counter-intuitively, students' prior unit grades negatively predicted mid unit competence need satisfaction, though this relationship was not revealed for late unit competence satisfaction.

For other engagement outcomes (see Table 6), students' agentic engagement early in the unit significantly predicted an increase in mid unit emotional engagement, controlling for early unit emotional engagement and student and class covariates. However, early unit agentic engagement but did not predict mid unit behavioral or cognitive engagement. Students' agentic engagement mid unit significantly predicted an increase in late unit behavioral and cognitive engagement, controlling for the mid unit value of the engagement outcome (corresponding to the outcome) and student and class covariates. However, mid unit agentic engagement did not predict late unit emotional engagement. Again, each engagement outcome at the prior time period positively predicted itself later in all cases. Interestingly, black and Hispanic/Latino students reported more mid unit behavioral and emotional engagement compared to white and Asian counterparts, though this relationship did not persist for late unit outcomes.

To compare the strength of agentic engagement as a predictor of perceived autonomy support and other forms of engagement versus the reverse, we fit a parallel pair of multilevel models in which early (or mid) unit perceived autonomy support, perceived suppression, and BEC engagement were included as predictors of mid (or late) unit agentic engagement, controlling for early (or mid) unit agentic engagement and student and classroom covariates. Early unit perceived autonomy support significantly predicted increases in mid unit agentic engagement ($\beta = 0.16$; $p = 0.02$), but early unit suppression and BEC engagement did not. The size of the relationship was similar both when early unit perceived autonomy support predicted changes in mid unit agentic engagement and the reverse. Mid unit perceived autonomy support did not predict changes in late unit agentic engagement, nor did mid unit perceived suppression or BEC engagement. Interestingly, black and Hispanic/Latino students reported less late unit (but not mid unit)

Table 6
Multilevel regressions with students' early (or mid) unit agentic engagement and covariates predicting mid (or late) unit behavioral, emotional, cognitive engagement.

Fixed effects	Behavioral Eng		Emotional Eng		Cognitive Eng	
	b(SE)	*β*	*b*(SE)	*β*	*b*(SE)	*β*
	Mid unit (MU) outcomes					
Class level						
Intercept	3.26 (0.06)		3.09 (0.08)		2.74 (0.08)	
Advanced class	0.09 (0.12)	0.05	0.03 (0.17)	0.02	0.27 (0.16)	0.14
Science domain	0.12 (0.13)	0.07	0.09 (0.18)	0.05	0.15 (0.17)	0.08
Student level						
Sex	0.01 (0.10)	0.008	−0.04 (0.10)	−0.02	−0.11 (0.11)	−0.06
Race/ethnicity	0.26 (0.11)	0.15*	0.25 (0.12)	0.12*	0.07 (0.12)	0.04
Age	−0.01 (0.05)	−0.02	−0.004 (0.06)	−0.005	0.04 (0.06)	0.05
Free/reduced lunch	−0.14 (0.11)	−0.08	−0.12 (0.12)	−0.07	0.04 (0.12)	0.02
Prior unit grade	0.003 (0.003)	0.08	−0.001 (0.003)	−0.03	0.004 (0.003)	0.07
EU agentic eng	**0.16 (0.08)**	**0.14**	**0.23 (0.08)**	**0.16****	**0.03 (0.09)**	**0.02**
EU outcome	0.62 (0.09)	0.51***	0.59 (0.07)	0.49***	0.72 (0.08)	0.59***
Random effects	Variance	SE	Variance	SE	Variance	SE
Class (level 2) intercept	0.07*	0.03	0.19**	0.07	0.16**	0.06
Student (level 1) residual	0.34***	0.04	0.38***	0.05	0.40***	0.05
	Late unit (LU) outcomes					
Class level						
Intercept	3.20 (0.06)		3.03 (0.08)		2.77 (0.08)	
Advanced class	0.13 (0.12)	0.08	−0.05 (0.17)	−0.03	0.13 (0.17)	0.07
Science domain	0.24 (0.13)	0.17	0.10 (0.18)	0.06	0.24 (0.18)	0.12
Student level						
Sex	−0.02 (0.09)	−0.01	−0.08 (0.10)	−0.04	0.15 (0.11)	0.08
Race/ethnicity	−0.03 (0.10)	−0.02	−0.14 (0.11)	−0.07	−0.03 (0.12)	−0.01
Age	0.06 (0.05)	0.11	0.11 (0.06)	0.15	0.09 (0.06)	0.12
Free/reduced lunch	0.02 (0.11)	0.01	0.03 (0.11)	0.02	−0.04 (0.12)	−0.02
Prior unit grade	0.001 (0.002)	0.03	0.002 (0.003)	0.05	0.0008 (0.003)	0.02
MU agentic eng	**0.19 (0.08)**	**0.19***	**0.04 (0.07)**	**0.03**	**0.18 (0.08)**	**0.14***
MU outcome	0.48 (0.08)	0.46***	0.73 (0.07)	0.63***	0.65(0.07)	0.55***
Random effects	Variance	SE	Variance	SE	Variance	SE
Class intercept	0.08*	0.04	0.20**	0.07	0.19**	0.07
Student residual	0.27***	0.03	0.33***	0.04	0.37***	0.05

Notes. Level 1 (students) n = 186 for MU outcomes; 178 for LU outcomes. Level 2 (classes) n = 41. EU = Early unit. MU = Mid unit. LU = Late unit. Eng = Engagement. For student sex, 0 = male and 1 = female. For student race/ethnicity, 0 = white or Asian and 1 = black, Hispanic/Latino, or other ethnic minority. For free and reduced lunch status, 0 = not eligible for free/reduced lunch and 1 = eligible for free/reduced lunch. For advanced class, 0 = grade typical class and 1 = advanced class. For science domain, 0 = physical science course and 1 = biological science course. *b* = unstandardized regression coefficient. *β* = standardized regression coefficient. Standardized estimates were computed using the following formula (Hox, 2010): $\beta = (b*sdx)/sdy$. SE = standard error.

* $p < .05$.
** $p < .01$.
*** $p < .001$.

agentic engagement compared to white and Asian counterparts ($\beta = -0.18$; $p < 0.001$). Not surprisingly, early (and mid) unit agentic engagement predicted itself mid (and late) in the unit ($\beta = 0.43$ and .50; $p < 0.001$).

Mediational analyses across students over time

We conducted a series of mediational analyses to examine the extent to which early unit perceptions of autonomy support predicted mid unit agentic engagement, which in turn predicts late unit need satisfaction, other forms of engagement, as well as more autonomy support. To capture the *a* path from the predictor (early unit perceived autonomy support) to the mediator (mid unit agentic engagement), we fit a two-level model similar to the reverse causal model previously described, but omitting suppression from the model. In this model, early unit perceived autonomy support was the main predictor of mid unit agentic engagement, controlling for early unit BEC engagement, early unit agentic engagement, and student and classroom covariates. Next, we conducted a series of models to estimate the *b* path from the mediator (mid unit agentic engagement) to each outcome (late unit perceived autonomy support, BEC engagement, and composite need satisfaction). In these models, early unit perceived autonomy support and mid unit agentic engagement were both included as predictors of late unit outcomes, controlling for early unit BEC engagement, the early unit value for the outcome (in the case of need satisfaction), and student and classroom covariates. Then we used the Monte Carlo method for assessing mediation (MCMAM; Selig & Preacher, 2008) using 20,000 replications.

As expected, student perceptions of early unit autonomy support significantly predicted an increase in mid unit agentic engagement. Mid unit agentic engagement also significantly predicted increases in late unit perceived autonomy support, need satisfaction, and BEC engagement (see Fig. 2A). More importantly, tests of the indirect effects suggested mid unit agentic engagement mediated the relationship between early unit perceived autonomy support and late unit perceived autonomy support (indirect path $b = .07$, 95% confidence interval [CI .004, .16]), need satisfaction ($b = .05$, 95% CI [.003, .12]), and engagement ($b = .07$, 95% CI [.003, .15]).

We also conducted a series of mediational analyses to examine the extent to which early unit agentic engagement predicts mid unit autonomy support, which in turn predicts late unit need satisfaction and other forms of engagement using an approach similar to previously described. Confidence intervals for indirect effects included 0, indicating the absence of such an effect, when mid unit composite autonomy support was used as the mediator. Thus, we explored whether mid unit perceptions that teachers' considered interests and provided

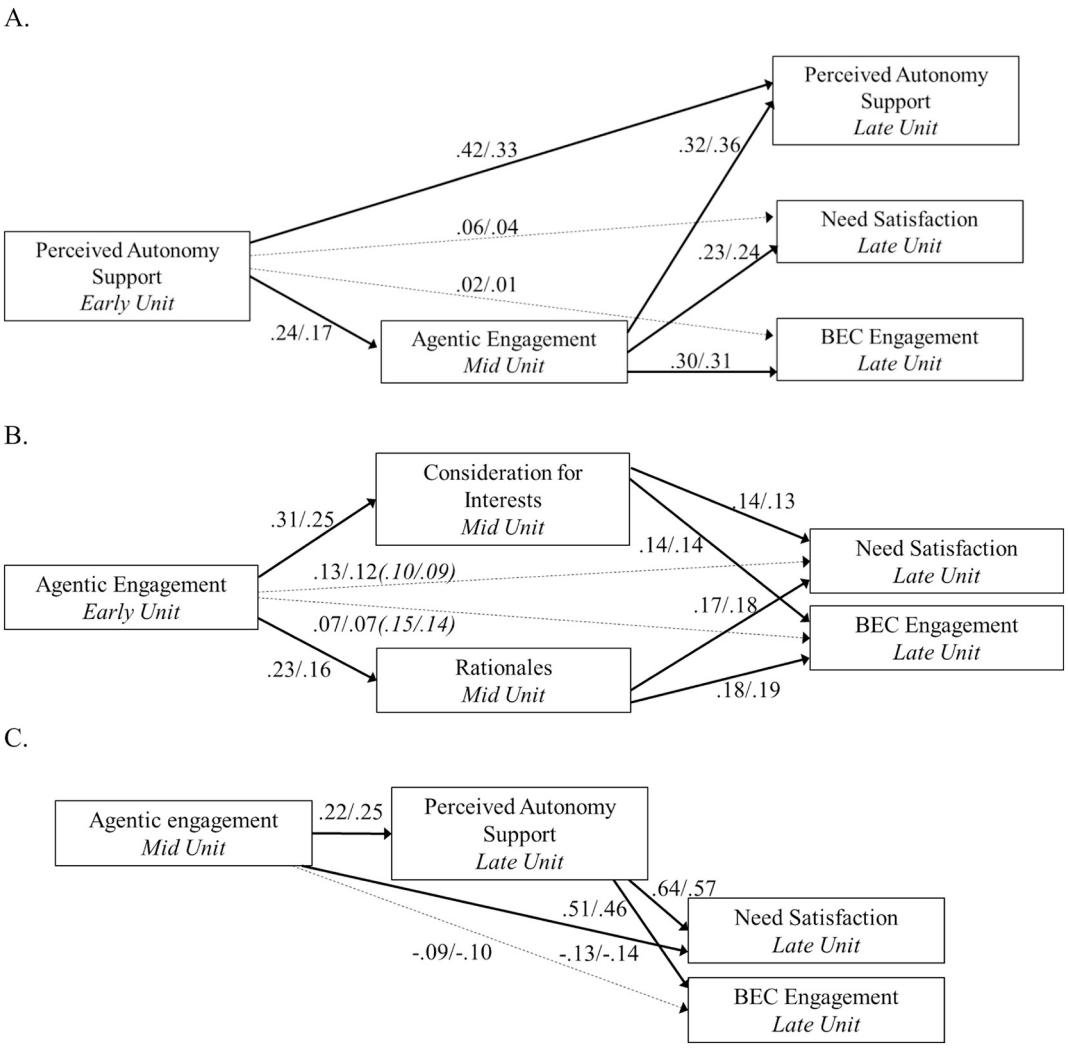

Fig. 2. Unstandardized coefficients (to the left of the slash) and standardized coefficients (to the right of the slash) summarizing tests of the mediational hypotheses at the student level. Solid lines represent significant paths, $p < .05$. Indirect effects for each mediator were examined separately. Not pictured, prior unit control variables and student and classroom characteristics.
For the paths from early unit agentic engagement to late unit outcomes in Fig. 2B, coefficients outside the parentheses are for models when consideration for students' interests was the mediator and coefficients inside parentheses are for models in which rationale provision was the mediator. The path from early unit agentic engagement to late unit BEC engagement was statistically significant only when rationale provision was included as the mediator.

rationales mediated the relationships between early unit agentic engagement with late unit need satisfaction and BEC engagement (in separate models for each mediator), controlling for early unit BEC and agentic engagement, and student and classroom covariates, as well as the early unit value for the outcome in the case of the need satisfaction (see Fig. 2B). As expected, mid unit perceptions that teachers considered student interests and provided rationales significantly predicted increases in late unit need satisfaction and BEC engagement. More importantly, tests of the indirect effects suggested mid unit perceived consideration for student interests and provision of rationales mediated the relationship between early unit agentic engagement and late unit need satisfaction (interests: $b = .04$, 95% CI [.01, .09]; rationales: $b = .04$, 95% CI [.004, .09]) and BEC engagement (interests: $b = .04$, 95% CI [.004, .10]; rationales: interests: $b = .04$, 95% CI [.004, .09]).

Finally, we conducted a series of mediation analyses to examine the extent to which mid unit agentic engagement predicts late unit autonomy support, which in turn predicts late unit need satisfaction and other forms of engagement (see Fig. 2C). As expected, late unit perceptions of autonomy support significantly predicted increases in late unit need satisfaction and BEC engagement, controlling for mid unit BEC engagement, mid unit agentic engagement, the mid unit value for the outcome (in the case of need satisfaction), and student and classroom characteristics. More importantly, tests of the indirect effects suggested late unit perceived autonomy support mediated the relationship between early unit agentic engagement and late unit need satisfaction ($b = .14$, 95% CI [.05, .24]) and engagement ($b = .11$, 95% CI [.04, .20]).

Discussion

The present investigation examined the extent to which agentic engagement in science class predicted experiences of teacher autonomy support and suppression of student perspectives, as well as need satisfaction and other forms of engagement among a sample of ethnically and economically diverse U.S. high school students. We examined these associations both on a daily basis within students, as well as across students over the course of a six-week instructional unit.

Findings were largely consistent with hypotheses derived from self-determination theory and prior theory and research related to agentic engagement (e.g., (Reeve, 2013; Reeve & Tseng, 2011)), as well as developmental theory emphasizing the increasing importance of autonomy and agency during adolescence (e.g. (Collins & Steinberg, 2006;

Eccles et al., 1993; Erikson, 1968)). Based on within-student daily analyses, we found that on days when students agentically engaged at a level greater than their own average, they perceived teachers to increase support for their autonomy that same day, even after controlling for other forms of engagement and a variety of student and classroom characteristics. We found a significant positive relationship between agentic engagement and five of six perceived autonomy-supportive practices, including perceptions that teachers (a) provided choices, (b) considered student interests in course activities, (c) created opportunities and were responsive to student questions, (d) were open to students' negative affect, and (e) provided encouraging, informational feedback. The size of the relationships across the various perceived practices were quite similar. The one notable exception was that agentic engagement did not predict perceptions that teachers provided more daily rationales about the importance or relevance of course activities. We suspect that this form of autonomy support is strategically elicited on class days when new topics or activities are introduced rather than being an everyday occurrence. In line with our predictions that agentic engagement might prompt some autonomy thwarting teacher behaviors along with autonomy supportive behaviors as teachers struggle to fully support students' autonomy and attempt to balance students' needs with their own daily teaching agendas, agentic engagement predicted a small increase in perceptions that teachers' suppressed students' perspectives. We believe this last finding is important to note as it leaves open the possibility that students who agentically engage may not only come to see how they can often be an agent of change in the classroom, but may also become aware that there are limits on their ability to shape the flow of instruction and in turn, limits on their learning imposed by the education system. Nonetheless, all together, these results suggest that adolescents' agentic engagement predicts the perception that teachers are largely responsive to students' psychological needs through their use of autonomy support across a variety of practices.

Also, in line with our predictions, we found that on days when students agentically engaged at a level greater than their own average, they experienced an increase in need satisfaction and an increase in other forms of engagement. In particular, daily agentic engagement predicted increases in that days' experience of autonomy and relatedness need satisfaction, but not competence need satisfaction. We suspect that the benefits of agentic engagement for feelings of autonomy and relatedness derive from adolescents growing needs for autonomy and to make connections outside the family and emerge immediately in the moment, as students observe teachers expressing respect for their personal perspectives. However, benefits for feelings of competence may emerge over time as students interact with learning tasks in a climate of autonomy and relatedness, a speculation supported, in part, by the pattern of results for student-level analyses over time (described next). Moreover, it is worth noting that same day agentic engagement predicted autonomy and relatedness need satisfaction even after accounting for emotional engagement and other forms of engagement, though in the case of autonomy need satisfaction, same day emotional engagement was still a stronger predictor. This is quite a rigorous test, as the feelings of interest and enjoyment that define emotional engagement are in some respects synonymous with experiences of autonomy. This evidence suggests that agentic engagement is potentially an effective pathway by which adolescents can influence their own daily motivational experiences in the classroom. Along these lines, agentic engagement predicted daily changes in other forms of engagement more strongly than the reverse.

Consistent with our expectations regarding the time course of these processes, these positive relationships were limited to when engagement, need satisfaction, and perceptions of autonomy relevant practice occurred on the same day. Null or small negative relationships occurred between agentic engagement on the prior class day and perceptions of autonomy support, suppression, need satisfaction, and other forms of engagement. As to why agentic engagement on one day might predict less engagement of other forms the following class day, we can only speculate. However, we suggest it might reflect a sort of contrast effect as positive experiences associated with above average agentic engagement on a given day are contrasted with experiences on subsequent days. At minimum, we believe this highlights the importance of students' day-to-day experiences and the fluctuation in motivation that occurs as the context and one's behavior in the context changes.

Analyses examining relationships across phases of the instructional unit further supported our predictions that adolescents' agentic engagement can trigger the experiences of autonomy support, need satisfaction, and other forms of engagement. However, these analyses also revealed some variability in the nature of those relationships across the unit. We found that greater agentic engagement earlier in the unit predicted an increase in subsequent perceptions that teachers were autonomy supportive, particularly (a) mid unit perceptions that teachers' considered students' interests in creating course activities and provided rationales about the importance of activities and (b) late unit perceptions that teachers were open and responsive to students' negative affect about the course and provided encouraging, informational feedback. These results highlight the developmental nature of students' motivational needs as they progress through an instructional unit. At the beginning of an instructional unit, when new topics and activities are being introduced, adolescents' motivational needs may relate to triggering interest and understanding value (e.g., see (Renninger & Hidi, 2016)). As learning progresses in the instructional unit, students' motivational needs shift to a desire for reassurance and guidance in the face of challenge and evaluation. Agentic engagement may “train” teachers to respond in motivationally-supportive manner that is aligned with adolescents' needs at each phase of instruction. While daily analyses suggested that teachers may be perceived to respond to agentic engagement with slightly more concurrent suppression of student perspectives, between student analyses suggested that agentic engagement earlier in unit does not train teachers to be more suppressive as the unit progresses, a reassuring finding given the potential for teacher suppression in response to agentic engagement leading to a backfire effect for students' motivation. Moreover, autonomy support early in an instructional unit may set the tone for students agentically engaging, in line with the finding that early unit autonomy support predicted increases in mid unit agentic engagement. However, as the unit progresses, teachers' support for motivation may become primarily a response to students' expressed needs rather than the reverse, as mid unit autonomy support did not predict late unit increases in agentic engagement.

Partially in line with our expectations, we found that greater early unit agentic engagement predicted an increase in students' mid unit relatedness need satisfaction, and mid unit agentic engagement predicted an increase in late unit competence need satisfaction, even after controlling for other forms of engagement. Surprisingly, the positive relationship between agentic engagement and autonomy need satisfaction was not significant at either phase of the instructional unit. We also found that early unit agentic engagement predicted an increase in students' mid unit emotional engagement, whereas mid unit agentic engagement predicted an increase in behavioral and cognitive engagement. We again suggest that this pattern of results may reflect the developmental nature of motivational needs and experiences as learning progresses. Namely, while motivation in initial learning experiences may be more dependent on feeling safe and connected (related) to others in the learning environment and emotionally invested, motivation during later phases of learning may depend more on experiencing a sense of competence and sustaining behavioral and cognitive engagement. As such, adolescents may use agentic engagement at each phase strategically to elicit the appropriate motivational experience. As to why agentic engagement predicted experiences of autonomy need satisfaction on a daily basis within students but not between students across the unit, we can only speculate that the experience of autonomy is more context specific than other needs, such that the experience of autonomy is primarily a function of students in-the-moment

agentic engagement or experience of autonomy support. Other forms of engagement earlier in the unit did not predict later unit agentic engagement, suggesting that agentic engagement is a driver of other motivational experiences over time more so than the reverse.

Mediational analyses provided a formal test of our hypotheses that agentic engagement emerges from autonomy support, and dynamically shapes the flow of instruction and students' motivational experiences as the instructional unit progresses. Mediational analyses supported theoretical depictions of agentic engagement as emerging out of a context of early perceived autonomy support and in turn, predicting even greater perceived autonomy support from teachers later in a unit, as well as increases in need satisfaction and other forms of engagement later in a unit, both directly and indirectly through experiences of increased teacher autonomy support.

Taken together, the evidence in this investigation points to the potential power of agentic engagement for shaping middle adolescents' motivational experiences and the motivational climate of the classroom in-the-moment and over time. The findings of this study make sense in the context of developmental and education theory that emphasizes the importance of experiencing autonomy and asserting one's developing identity during adolescence (e.g., (Assor, 2018; Erikson, 1968; Marcia, 1988)). Findings also stand in opposition to some students' belief that there is little they can do to influence their own motivation and engagement in class. Rather, the current evidence is consistent with other research and theory (e.g., (Bandura, 1997; Reeve, 2013; Skinner & Belmont, 1993)) that implicates students' classroom behavior as a critical factor in predicting the development of students' engagement and teachers' support for engagement. The findings of this investigation imply that differences in adolescents' motivation and achievement may be influenced by their attempts over time to regulate their own engagement and recruit teachers' support for their motivation (e.g., see (Chen, Ellsworth, & Schwarz, 2015; O'Keefe, Horberg, & Plante, 2017; Thoman, Sansone, & Geerling, 2017) for related arguments).

As such, findings point to a need to develop interventions that explicitly target and enhance adolescents' agentic engagement. By tapping into core needs that become particularly prominent during adolescence, such interventions may provide a powerful lever to help teachers' align their instruction with the motivational needs of adolescents and promote the development of students' motivation and, ultimately, learning. We expect that a focus on agentic engagement may have particular utility in science education, given continued concerns about interrupting students' declining engagement in science as they approach high school and college (e.g., (Gottfried et al., 2009; Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013)) and finding tools that help to better engage students that have traditionally been underrepresented in STEM college majors and careers, including girls and non-Asian students of color (e.g., (National Science Foundation, 2017)). A focus on agentic engagement provides a framework for adolescents to assert their own vision of motivation support and collaborate with teachers in this goal.

Limitations and implications for future research

Given the potential importance of agentic engagement in shaping students' motivational experiences, we hope that the current study, along with other seminal work (e.g., (Reeve, 2013; Reeve & Tseng, 2011)), can serve as base for replication and extension in future research. However, a number of limitations should be addressed in future research.

The exclusive reliance on student reports in the current investigation presents a limitation in terms of response-bias and shared-method variance that future research should address. Although observations present their own set of limitations and biases, future research will want to include independent observations of teachers' autonomy support and students' engagement in the classroom. To extend this work, we would also encourage that agentic engagement processes should be explored further among students at other developmental stages (e.g., early adolescence and emerging adulthood) and in other educational settings (e.g., informal and non-traditional) to better understand commonalities and areas of variation. We would encourage researchers to further investigate a wide set of psychological processes and the long-term consequences of agentic engagement for students' learning and achievement, as well school and career outcomes.

By the same token, future research might investigate the factors that lead some students to agentically engage more than others and on some days more than others or the factors that influence the effectiveness of agentic engagement. We believe a variety of factors are likely at play, including the extent to which the classroom is initially autonomy supportive or controlling, students' own initial values for course activities and beliefs about the malleability of their motivation in class (e.g., (Yeager & Dweck, 2012)), and the extent to which students believe their behavior will be perceived by teachers as constructive versus defiant. Some of these factors, particularly expectations about how behavior will be perceived by teachers, are likely to vary also with students' race, gender, and socioeconomic background (e.g., (Gregory, Skiba, & Noguera, 2010)), making it important to consider students' racial, cultural, and gender identities and backgrounds in future work. Moreover, the specific content and activities on a given day may have implications for both the nature of agentic engagement as well as its effects on student experiences and teacher practice. Researchers may find it useful to take an even more fine-grained situational approach or employ qualitative approaches to understand agentic engagement processes as they unfold in the classroom, including teachers' perceptions of and responses to agentic engagement.

Finally, the correlational nature of the current design means that the present findings cannot be taken to imply causation. Findings of this investigation can be corroborated with experimental designs in authentic classroom contexts that intentionally attempt to target students' agentic engagement. Not only will research that attempts to manipulate agentic engagement help to isolate and understand its causal effects, but such investigations can help build a foundation for educational reform that prioritizes students' motivation and engagement.

Conclusion

In conclusion, this investigation adds to a vital body of research exploring the development of students' motivation and engagement in the STEM classroom. Results highlight that during adolescence, motivation and engagement is a dynamic daily and longitudinal process, involving both teachers' motivation support and students' constructive, agentic attempts to create a motivationally-supportive environment. We encourage researchers and educators to continue to explore the potential processes, benefits, and limits of agentic engagement. We believe agentic engagement represents a powerful pathway for enhancing the motivational climate of the classroom and adolescents' subjective experiences of motivation.

Declarations of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appdev.2019.01.004.

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