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Who Likes the Going When the Going Gets Tough? Need for Cognition Moderates Associations Between Class Difficulty and Students' Engagement

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When confronted with challenging schoolwork, some students flourish, whereas others disengage. Why do students respond so differently to difficult classes? In this study, we examined the possibility that Need for Cognition, as the individual tendency to actively seek and enjoy cognitive effort, explains differences in engagement with challenging course content in mathematics classes. We tested this in an experience sampling method study in real-life mathematics classes in which 414 students ($M_{age} = 16.2$ years, 238 females), over a period of 10 consecutive school days, repeatedly rated the perceived level of difficulty of the class and five components of their momentary engagement (i.e., enjoyment, interest, concentration, active participation, and boredom). Associations between perceived class difficulty and students' engagement were investigated both at the between-person and within-person level. Also, we tested whether differences among students in these associations were significantly related to students' Need for Cognition. First, at both levels, a negative quadratic association (inverse U-shape) between difficulty and engagement was observed, with student engagement being lower when students rated classes as very easy or very difficult. Second, substantial differences in difficulty–engagement associations were observed between students. Third, beyond having a positive main effect on student engagement, students' Need for Cognition was found to moderate difficulty–engagement associations at both levels, with more positive difficulty–engagement associations among students with high relative to low Need for Cognition. These findings highlight differences between students in how class difficulty is associated with student engagement and underscore the importance of Need for Cognition in understanding these differences.

Educational Impact and Implications Statement

Students differ in how they engage with difficult study material: whereas some students become particularly engaged when classes are highly difficult, others lose interest and disengage from the class. In this study, we showed that the personality characteristic of Need for Cognition, which is defined as the individual tendency to actively seek and enjoy cognitive effort, partially explained these differences between students. Specifically, we measured students' engagement and perceived class difficulty in real-life mathematics classes. We found that students with high Need for Cognition reported higher engagement, particularly in difficult mathematics classes, than students with low Need for Cognition. This suggests that the personality trait of Need for Cognition is associated with how students motivationally respond to highly challenging material.

Keywords: Need for Cognition, engagement, challenge, experience sampling method, mathematics

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Providing students with appropriately challenging schoolwork might support school engagement, as the experience of being able to advance their competences may give students a sense of accomplishment and fulfillment (Shernoff et al., 2016; Strati et al., 2017). However, not all students respond equally favorably to classes they perceive as difficult or challenging (David et al., 2022):

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some students appear to appreciate challenging schoolwork much more than others (Engeser & Rheinberg, 2008). How can these differences between students be understood?

Intellectual investment theory provides a theoretical framework to investigate interindividual differences in the association between perceived class difficulty and student engagement. This theory proposes that intellectual development is determined by specific personality traits that guide how, when, and where individuals apply and invest their intellectual abilities (Ackerman, 1996). In particular, the personality trait of Need for Cognition, conceptualized as the extent to which individuals actively seek, engage in, and enjoy effortful cognitive activity (Cacioppo et al., 1996), has been identified as a key intellectual investment trait (Von Stumm & Ackerman, 2013). In this study, we examined whether students' Need for Cognition would moderate the association between student-perceived class difficulty and five components of students' engagement (i.e., enjoyment, interest, concentration, active participation, and boredom). To study student engagement within its natural environment, an experience sampling method (ESM) design was adopted, with students repeatedly completing brief surveys gauging their momentary engagement and perceptions of class difficulty during real-life mathematics classes. By exploring how Need for Cognition is associated with students' engagement in difficult mathematics classes, this study thus advances the understanding of interindividual differences in motivational responses to cognitive challenge.

Associations Between Schoolwork Difficulty and Student Engagement

School engagement, defined as the quality of students' involvement with the endeavor of schooling, is an important predictor of students' academic success and well-being (Fredricks et al., 2004; Skinner et al., 2008). It has repeatedly been shown that engagement is malleable and responds to contextual factors in students' learning environment (e.g., task characteristics; Christenson et al., 2012). Engagement is widely recognized to be multidimensional in nature, with common distinctions between its emotional, behavioral, and cognitive dimensions (Wong & Liem, 2022). In addition, disengagement constitutes not just the absence of engagement, but rather a specific motivational state indicative of a disconnection to the learning process (Wong & Liem, 2022). Acknowledging this multidimensional nature of engagement, the present study distinguished between several components of school engagement, specifically student enjoyment and interest (indicative of emotional engagement), concentration (indicative of behavioral and cognitive engagement), active participation (indicative of behavioral engagement), and boredom (indicative of emotional disengagement).

Theoretically, it has been argued that a moderate level of schoolwork difficulty would be beneficial for student engagement, (Shernoff et al., 2014). In particular within the framework of flow theory (Csikszentmihalyi, 1997), it has been argued that too easy schoolwork would make students feel bored and disaffected, whereas too difficult schoolwork could induce frustration or anxiety among students (Acee et al., 2010). By contrast, tasks of moderate difficulty would let students expand their skills, which would make students feel efficacious and deepen their engagement (Hamari et al., 2016). The association between schoolwork difficulty and student engagement would then take the shape of an inverse U, with the highest levels of student engagement observed when schoolwork is moderately difficult. In addition, students' own subjective evaluation of class difficulty, rather than some objective account, has been argued to be decisive for students' experiences and thus for their school engagement (Efklides et al., 1998).

In empirical studies, it indeed has been reported that students are most engaged when they perceive their schoolwork to be moderately challenging, with lower levels of engagement among students who rate their schoolwork either as very easy or as very difficult (Baten et al., 2020; Lavrijsen et al., 2021; Shernoff et al., 2016; Strati et al., 2017). However, other studies have found that students seem to appreciate also very easy classes (Norsworthy et al., 2021; Nuutila et al., 2021; Patall et al., 2018), which they associate not with disaffection, but rather with relaxation and comfort (Engeser & Rheinberg, 2008; Nuutila et al., 2021). This noteworthy appreciation of very easy classes, which stands somewhat at odds with predictions from flow theory, has been explained by the nature of the school setting (Norsworthy et al., 2021). In particular, flow theory was initially formulated within the context of voluntary low-stakes activities (e.g., playing music), in which too-easy tasks are naturally deprecated as a boring waste of time (Engeser & Rheinberg, 2008). By contrast, school classes are obligatory, and students often feel highly concerned about their performance. Under such circumstances, students may start to appreciate even very easy tasks as these do not bear the threat of failure nor demand high-effort investment (Norsworthy et al., 2021). This may lead students to like very easy classes (or at least dislike to a lesser extent than very difficult classes).

To date, most research has targeted associations between difficulty and engagement at the between-student level, relating students' overall evaluation of their schoolwork difficulty to their overall degree of school engagement (e.g., Lavrijsen et al., 2021). However, the difficulty of the tasks students are often confronted with often varies considerably over time (Krannich et al., 2022). Similarly, it is increasingly emphasized that student engagement is a state which fluctuates over time, rather than a fixed trait (Dietrich et al., 2022; Flunger et al., 2022). Hence, when it comes to students' perceptions of class difficulty and students' engagement, there can be variation both between students (i.e., some students may find their schoolwork more difficult than others; some students may be generally more engaged than others) and within students (i.e., a student may find a particular task or class to be more difficult than usual; a student may feel more engaged during a particular task or class than usual). As argued by Curran and Bauer (2011), associations observed at the between-student level do not necessarily translate into similar associations at the within-student level. In a recent study (Krannich et al., 2022), associations between perceived challenge and students' boredom were investigated both at the between-student and within-student levels. Their study found that students who generally felt over- or underchallenged reported higher overall levels of boredom (i.e., a finding at the between-student level); in addition, students reported more boredom during classes in which they felt more over- or underchallenged than usual (i.e., a finding at the within-student level). In the present study, we analyzed between-student and within-student associations between perceived class difficulty and a broader set of engagement components beyond students' boredom.

In the present study, we focused on students' engagement in one particular domain, that is, in mathematics classes. The choice to focus on this particular subject was informed by the facts that many students find mathematics a difficult subject (Brown et al., 2008; Dowker et al., 2016; Gottfried et al., 2001) and that there is

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considerable variability in students' engagement in mathematics (Petričević et al., 2022), which substantially affects students' academic trajectories (Lauermann et al., 2017).

Need for Cognition as a Moderator of Associations Between Schoolwork Difficulty and Student Engagement

Importantly, beyond average associations between schoolwork difficulty and student engagement, there may also be differences between students in how engagement and difficulty are related (Engeser & Rheinberg, 2008; Nuutila et al., 2021). Within flow theory, it is already recognized that individuals might differ in how they approach and engage in challenging activities (Csikszentmihalyi, 1997), suggesting that so-called "autotelic personalities" would be more inclined to seek and master challenges (Tse et al., 2020). At school as well, students may respond very differently to difficult schoolwork: some students start to work harder and more focused, whereas others tend to disengage (D'Mello & Graesser, 2012). Such differences between students in difficulty–engagement associations may emerge not only at the between-student level but also at the within-student level, that is, there may be interindividual variability in the intraindividual associations between students' momentary evaluation of schoolwork difficulty and their momentary engagement. As an example of such variability at the within-student level, some students may report increased engagement at times they experience a particular class to be more difficult than usual, whereas other students may report lower engagement when they find a class to be more difficult than usual.

Whereas these differences in how students deal with challenging schoolwork have been related to a number of motivational characteristics of students (e.g., mastery goal orientation; Engeser & Rheinberg, 2008; topic interest; Fulmer et al., 2015), a more comprehensive framework to address these is proposed by intellectual investment theory. Within investment theory, it is posited that people vary in the extent to which they allocate time and energy to cognitive activities (Ackerman, 1996; Cattell, 1987). These interindividual differences in intellectual investment are proposed to be governed by intellectual investment traits, that is, personality traits that guide how, when, and where individuals apply and invest their intelligence. By stimulating effort investment in cognitive activities, investment traits are then assumed to shape the intellectual development of individuals (Ackerman, 1996).

In the literature, several intellectual investment traits (e.g., openness, intellectual curiosity) have been proposed. In particular, the construct of Need for Cognition has been suggested to be at the core of these traits (Von Stumm & Ackerman, 2013). Need for Cognition is defined as the individual tendency to actively seek, engage in, and enjoy cognitive effort (Cacioppo & Petty, 1982; Cacioppo et al., 1996). Originally conceptualized as a domain-general trait (Cacioppo et al., 1996), recent research suggests that preferences for cognitive challenge may differ according to the domain (Keller, Strobel, Martin, & Preckel, 2019). Indeed, cognitive experiences are arguably colored by domain-specific abilities and interests; similarly, the intellectual development Need for Cognition is proposed to stimulate arguably takes place within specific domains (Keller, Strobel, Martin, & Preckel, 2019). Empirically, Keller, Strobel, Martin, and Preckel (2019) indeed observed the presence of domain-specific factors in Need for Cognition. As the present study was focused on engagement during mathematics classes, a mathematics-specific conceptualization of Need for Cognition was thus adopted.

Theoretically, students' Need for Cognition would thus be a plausible candidate to explain why some students tend to enjoy difficult schoolwork more than others. In experimental settings, Need for Cognition has indeed been found to moderate the relationship between task difficulty and task enjoyment, with participants with high Need for Cognition reporting greater enjoyment when doing complex tasks and individuals with low Need for Cognition preferring simpler tasks (Cacioppo & Petty, 1982; Steinhart & Wyer, 2009). Also in school settings, Need for Cognition has been argued to be an asset to students particularly when the academic demands of the learning environment are high (Colling et al., 2022). In a cross-sectional study among 3,002 Flemish seventh graders, Need for Cognition was found to positively interact with student-perceived schoolwork challenge in predicting school engagement (Lavrijsen et al., 2021), that is, students with high Need for Cognition reported higher school engagement particularly when they were appropriately challenged in school. In addition to its moderating effect, Need for Cognition was also found to have a positive main effect on student engagement (Lavrijsen et al., 2021). Being inherently inclined to enjoy cognitive effort arguably is an important asset for students in school, as many learning activities call for such efforts (Von Stumm et al., 2011).

Whereas Lavrijsen et al. (2021) thus provided a first account of the role of Need for Cognition in the association between schoolwork challenge and student engagement, it only cross-sectionally related students' general evaluation of schoolwork challenge to their general level of school engagement (i.e., it studied these associations only at the between-student level). The present study is the first to investigate how Need for Cognition would moderate difficulty–engagement associations both at the between-student and within-student level. Indeed, whereas Need for Cognition is considered to be a (relatively stable) student trait, it could impact both between-student associations (e.g., it might explain why some students who find their classes to be generally difficult, report high overall engagement) and within-student associations (e.g., it might explain why some students report high momentary engagement at times they experience a particular class to be more difficult than usual).

Other Student Characteristics Affecting School Engagement

Finally, to accurately investigate associations between class difficulty and student engagement, it is important to control for student background characteristics which have been shown to be related to student engagement (Christenson et al., 2012). First, girls generally tend to report higher levels of school engagement than boys (Lam et al., 2012). However, in mathematics and science, girls sometimes report worse motivational adjustment than boys (e.g., Preckel et al., 2008), which might possibly be related to the stereotyping of these subjects as "male" domains (Meece et al., 2006) leading girls to develop less positive attitudes toward them (Cvencek et al., 2021). Second, students tend to appreciate school better when they perform well, implying that student engagement is often higher in high-achieving than in low-achieving students (Vu et al., 2022). Third, students' school motivation tends to decrease over students' school career, suggesting school engagement may be lower in late compared to early grades (Scherrer & Preckel, 2019). Notwithstanding that there might be other sources that might affect

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student engagement (e.g., social background; ethnic origin; parental support), we decided to control for these three background student characteristics, that is, students' sex, age, and mathematics ability, that are widely recognized to affect student engagement (Betts et al., 2010; Christenson et al., 2012).

The Present Study

Study Purpose and Design

In this study, between-student and within-student associations between mathematics class difficulty and students' engagement were investigated, and differences between students in these associations were related to students' Need for Cognition. A sample of 414 students was recruited in Grades 11 and 12 of the academic track in Flanders. During these final years of secondary education, the academic and motivational foundations are laid for academic success in higher education (Richardson et al., 2012); it is thus of prime importance to shed light on the determinants of student engagement at this stage. An ESM design (Figure 1) was adopted in which, over a period of 2 weeks, students completed repeated momentary assessments of student-perceived class difficulty and multiple components of student engagement (i.e., student enjoyment, interest, concentration, active participation, and boredom; in the remainder of this study, "engagement" is used to refer to this set of components) during their regular mathematics classes. Students' Need for Cognition was measured 1 week before and students' mathematics ability 1 week after the ESM measures were collected.

Research Questions (RQs)

We put forward the following RQs and hypotheses (H). In all analyses, the impact of students' mathematics ability, grade level, and sex were control variables.

Research Question 1 (RQ1): How is student-perceived class difficulty in real-life mathematics classes associated with students' engagement components, that is, students' enjoyment, interest, concentration, active participation, and (inversely) boredom, both at the between-student and within-student level?

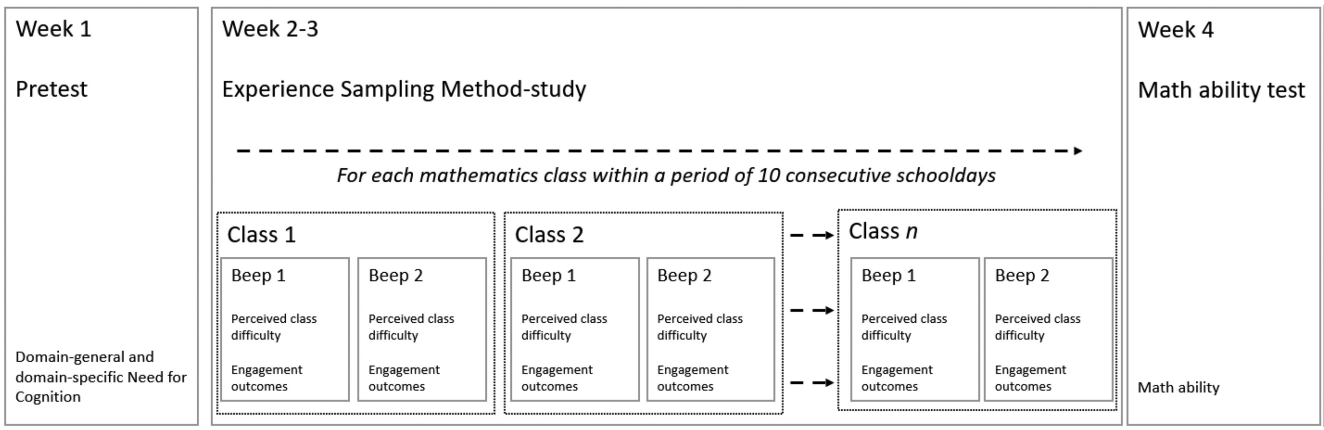
Hypothesis 1a (H1a): We hypothesized a negative quadratic association (i.e., an inverse U) between student-perceived difficulty and student engagement, both at the between-student and within-student level. At the between-student level, this corresponds to hypothesizing that students who, in general, find mathematics classes to be either very difficult or very easy, would report lower engagement than students who find mathematics classes, in general, to be moderately difficult. At the within-student level, this would indicate that when a student finds, as compared to the student's own average difficulty rating, a particular class to be either very difficult or very easy, engagement during that particular class would be lower. Although complete equivalence (e.g., a completely identical pattern of significant results) between the between-student and within-student level is not to be anticipated (Pekrun & Marsh, 2022), we did not have a priori reasons to expect fundamentally different results between both levels of analysis.

Hypothesis 1b (H1b): In addition, we expected students to dislike very difficult classes to a larger extent than that they would dislike very easy classes. That is, we expected the negative quadratic association between student-perceived difficulty and student engagement to take such a form that engagement would be discernibly lower at the upper compared to the lower end of the difficulty scale (e.g., as in Figure 2a), both at the between-student and within-student level.

Research Question 2 (RQ2): To what extent are there differences among students in the associations between student-perceived class difficulty and students' engagement components, both at the between-student and within-student level?

Hypothesis 2 (H2): We hypothesized that there would be substantial differences among students in how student-perceived class difficulty was related to students' engagement. At the between-student level, we thus expected variation around the average associations between students' general evaluations of schoolwork difficulty and their general engagement; at the within-student level, we expected interindividual variation in the intraindividual associations between students' momentary evaluations of schoolwork difficulty and their momentary engagement (i.e., a statistically significant random slope component).

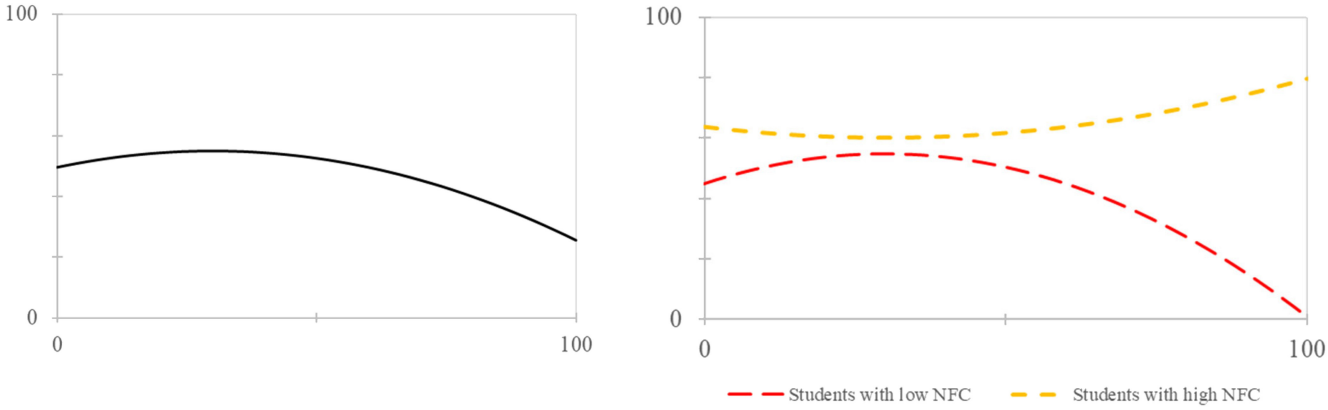
Figure 1
Timing of Measurements



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Figure 2

Hypothesized Associations Between Perceived Difficulty (x-Axis) and Student Engagement Outcomes (y-Axis)



Note. Left panel: Hypothesized general association. Right panel: Hypothesized associatons for a student with low NFC and a student with high NFC. NFC = Need for Cognition. See the online article for the color version of this figure.

Research Question 3 (RQ3): To what extent does students' mathematics-specific Need for Cognition moderate the association between student-perceived class difficulty and student engagement, both at the between-student and within-student level?

Hypothesis 3a (H3a): We expected a positive main effect of mathematics-specific Need for Cognition on student engagement.

Hypothesis 3b (H3b): We expected students' mathematics-specific Need for Cognition to positively interact with student-perceived class difficulty and its squared term when predicting students' engagement (e.g., as in Figure 2b), both at the between-student and within-student level of the analysis. At the between-student level, a positive student-level interaction between students' Need for Cognition and their overall difficulty rating would indicate that among students with high Need for Cognition, finding mathematics classes to be generally very difficult would be less negatively related to students' general level of engagement than among students with low Need for Cognition. At the within-student level, a positive cross-level interaction between students' fixed Need for Cognition and their momentary perceptions of class difficulty would indicate that for students with high Need for Cognition, finding a particular class to be very difficult would impair these students' momentary engagement to a smaller extent than for students with low Need for Cognition.

Method

Transparency and Openness

Below, we report how we determined the sample size, all data exclusions, manipulations, and measures in the study, and we follow the Journal Article Reporting Standards (Kazak, 2018). All data, analysis code, and research materials are available at https://osf.io/8s5yz/?view_only=8e314263930a4aada8b576712e269de7. Data were analyzed using SAS 9.4 (proc mixed) and R 4.2.2 (package r2mlm; Rights & Sterba, 2019; Shaw et al., 2023). This study's design and its analysis were not preregistered.

Procedure

The study was part of the broader MOMENT study, in which moment-to-moment fluctuations in school engagement in natural classroom environments were targeted to investigate how contextual factors (e.g., class difficulty; affective quality of teacher–student interactions; teacher and peers' emotions) drive these fluctuations over time. The study was approved by the ethical committee of the university affiliated with the authors. Based on a simulation-based statistical power analysis (Lafit et al., 2021) for a two-level model with cross-level interactions ($\alpha = .05$, power = .80), a minimum sample of 300 students was determined. An open call was launched to recruit the sample, yielding nine participating schools. Additionally, two schools were recruited among schools participating in another study (Lavrijsen et al., 2022). All participating schools were regular public schools. Grade 11 and/or Grade 12 students in these schools were invited to participate, resulting in a sample of 414 students (average age 16.2 years) from 25 class groups in 11 schools. Three schools completed data collection in May 2022, whereas the other eight schools participated in October and November 2022. Prior to conducting the study, we obtained informed consent from students and teachers.

In each school, data collection then took place over a period of 4 weeks (Figure 1). All data collection was done digitally, except the presurvey in one school and the mathematics test.

In Week 1, students completed a presurvey in class, which assessed their mathematics-specific Need for Cognition.

In Weeks 2 and 3, the ESM was used to collect a series of real-time assessments of students' momentary engagement (i.e., students' ratings of their enjoyment, interest, concentration, active participation, and boredom) and student-perceived class difficulty during mathematics classes. Students and teachers installed the m-Path app (Mestdagh et al., 2022) on their devices. The ESM survey targeted mathematics classes over a period of 10 consecutive school days. The number of mathematics classes within this period varied between class groups as in Flemish upper secondary education, students get a varied number of weekly mathematics classes depending on their study program. Across the study period of 10 days, the average class group took 9.12 mathematics classes, ranging between four

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and 13. Within each mathematics class (50 min), teachers were beeped twice semirandomly (i.e., beeps did not occur within the first 10 min or last 5 min of the class, and the time interval between beeps was at least 5 min and at most 15 min). After each beep, teachers instructed students to report on a set of single items capturing their momentary engagement and perceived difficulty of the class in m-Path. In total, 456 beeps were thus delivered to teachers (i.e., 25 class groups with on average 9.12 mathematics classes each, with two beeps within each class). After data collection, ESM data were prepared and cleaned (e.g., by considering beep response and completion time) following the guidelines of Myin-Germeys and Kuppens (2022).

Finally, in Week 4, students took a standardized mathematics test indicating their mathematics ability level.

Participants

The sample consisted of 414 students (238 females, average age 16.2 years, 314 students from Grade 11 and 100 students from Grade 12) from 25 class groups in 11 schools. During the ESM, 456 beeps were delivered to the teachers, which led to 6,332 completed ESM surveys among the students each capturing their perceived class difficulty and engagement components (see below).

In Flanders, upper secondary education is organized as a multitier system with four tracks. In Grades 11 and 12, 33% of the students follow the academic track, which is the academically most selective track and prepares students for higher education. Within the academic track, students can further choose between different study programs. About 41% of academic track students opt for a study program with a strong mathematical component. In the present study, all participants were in the academic track, with a majority (79%) in such a program with a strong mathematical component. Hence, the sample was selective on mathematics ability. Accordingly, students also had a somewhat more advantaged social background than average, with 18% of the sample receiving a school allowance (compared to 39% in the population) and 6% having a mother without a secondary school degree (22% in the population), whereas the share of students not speaking the language of instruction at home (20%) was comparable to that in the population (20%).

In the 25 participating class groups, there were 22 mathematics teachers (nine males, 13 females; three of these teachers participated with two class groups). Teachers indicated which instructional practice they were using during the class in a multiple-choice question which allowed to select more than one practice. Teachers reported to have used whole-class instruction in 60% of all classes and independent work in 42% of all classes. Group work (12%) or classroom discussion (17%) were used less often.

Measures

In order to compare the relative importance of predictors measured with different metrics, all continuous variables were put on a common metric (percentage of maximally possible [POMP] score), calculated as the percentage of the theoretically maximum score and thus ranging between 0 and 100 (Cohen et al., 1999).

Measures Collected Before ESM

Mathematics-Specific Need for Cognition. Following Keller, Strobel, Martin, and Preckel (2019), students' mathematics-specific Need for Cognition was assessed with an adaptation of the domain-general Need for Cognition scale by Preckel and Strobel (2017), to which a reference to the domain of mathematics was added (e.g., "In mathematics classes, I like problems where I have to think a lot"). The psychometric properties of the original scale and of the domain-specific adaptation have been well documented (Keller, Strobel, Martin, & Preckel, 2019; Keller, Strobel, Wollschläger, et al., 2019; Preckel, 2014; Preckel & Strobel, 2017). For example, the original scale has demonstrated convergent validity with another established Need for Cognition scale, discriminant validity with other noncognitive traits such as performance goals (Preckel, 2014), academic self-concept (Keller, Strobel, Wollschläger, et al., 2019) and open-minded thinking (Svedholm-Häkkinen & Lindeman, 2018), and incremental predictive validity for achievement above and beyond cognitive ability, persistence, openness, and school motivation (Keller, Strobel, Wollschläger, et al., 2019; Lavrijsen et al., 2023; Preckel, 2014). For the domain-specific adaptation, discriminant validity with domain interest was demonstrated and predictive validity for domain-specific achievement was established (Keller, Strobel, Martin, & Preckel, 2019). The survey scale was a Likert scale with five categories, with the endpoints labeled "completely disagree" and "completely agree." For the analysis, sum scores on the scale were converted into the percentage of maximum score (POMP). In the present study, the scale had excellent reliability ($\alpha = .94$).

Grade Level. This was coded with Grade 11 as the reference category (*Grade 11* = 0, *Grade 12* = 1).

Sex. Biological sex (assigned at birth) was retrieved from administrative records and coded with males as the reference category (*male* = 0, *female* = 1).

Measures Collected During ESM

During the ESM, single items instead of scales were used in order to interfere with the class as little as possible and to reduce participant burden and careless responding risks. The psychometrical validity of such single-item measures for intensive longitudinal studies has been well documented (Cloos et al., 2023). Items were rated with a slide bar ranging from 0 to 100, without a default starting point (Mestdagh et al., 2022). All items were preceded by "During the preceding part of the class, …." At each beep, students' momentary perceptions of class difficulty and engagement were assessed.

Student-Perceived Class Difficulty. Students rated the difficulty of the class with the item: "During the preceding part of the class, I found the class …." Students rated their agreement with the items using a slide bar with endings rated 0 = *too easy* to 100 = *too difficult*, without a default starting point (Mestdagh et al., 2022). In contrast to external ratings of class difficulty, this subjective difficulty rating contrasts class difficulty to students' individual skill level, thus indicating the extent to which each student found the class to be balanced to their capacities. To differentiate between the between-student and within-student level (Myin-Germeys & Kuppens, 2022; Wang & Maxwell, 2015), difficulty ratings at each measurement occasion were used to calculate students' mean level of perceived difficulty across all measurements (time-invariant predictor to assess associations at the between-student level: how difficult a student generally perceives mathematics classes to be) and measurement-specific residual scores, centered around the student mean (time-variant predictor at the within-student level: the

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degree to which a student perceives a specific mathematics class to be more difficult than usual).

Student Engagement. For each engagement component, momentary engagement scores were used as the outcome of a multilevel model (see below).

Enjoyment. Students' enjoyment of the class was assessed with the item "How much enjoyment did you experience during the class?" The labels at the end of the slide bar indicated 0 = *very little* to 100 = *very much*.

Interest. Students' evaluated how interesting they found the class with the item "How interesting did you find the class?" The labels at the end of the slide bar indicated 0 = *very little* to 100 = *very much*.

Concentration. Students' level of concentration was assessed with the question "How concentrated were you?" The labels at the end of the slide bar indicated 0 = *very little* to 100 = *very much*.

Active Participation. Students' active participation in the class was measured with the item "How actively did you participate during the class?." The labels at the end of the slide bar indicated 0 = *very little* to 100 = *very much*.

Boredom. Students' boredom was measured with the item "How bored were you during the class?" The labels at the end of the slide bar indicated 0 = *very little* to 100 = *very much*.

Measures Collected After ESM

Mathematics Ability. Mathematics ability was measured with a standardized 2 hr mathematics test consisting of 42 items (Loopbanen in het Secundair Onderwijs test; Van den Branden et al., 2019). The test, consisting of a mixture of multiple-choice and open questions, was developed by the Center for School Feedback based on the mathematics curricula used in Flemish secondary education. The test was primarily aimed at students from programs with a strong mathematical component and covered different mathematical domains (i.e., algebra, number theory, geometry, analysis, statistics, and data processing). Large-scale prior research on 1,626 students (Dockx & Denies, 2020) showed that a factor model with one underlying mathematics proficiency dimension fitted the data well, comparative fit index (CFI) = .92, standardized root-mean-square residual (SRMR) = .03, root-mean-square error of approximation (RMSEA) = .03. In addition, the test was shown to have a balanced difficulty level (i.e., one item had a share of correct answers P_{correct} above .90; 14 items had P_{correct} between .60 and .90; 11 items had P_{correct} between .40 and .60; 13 items had P_{correct} between .10 and .40; 3 items had P_{correct} below .10; Van den Branden et al., 2019). Hence, the test adequately measures mathematics ability at different ability levels.

In the present study, for each item, it was determined whether the answer was correct (Value 1) or not (Value 0), and values were summed over all items. Sum scores were then converted into the percentage of maximum score (POMP) and standardized within each grade level. The test showed good reliability ($\alpha = .84$).

Plan of Analysis

To answer RQ1 and RQ2, multilevel analyses were performed predicting student momentary engagement scores as a function of student-perceived difficulty of the class (both linear and squared). Measurements were nested in students, which were nested in classes, with the multilevel models including at the individual level both random intercepts (i.e., variation in students' engagement levels) and random slopes (i.e., variation in the intraindividual associations between perceived difficulty and engagement), and a random intercept at the classroom level.

The resulting multilevel equation for RQ1 and RQ2 thus was:

$$\begin{aligned}\text{Eng}_{ijk} = {} & z_0 + z_1{*}S_{jk} + z_2{*}A_{jk} + z_3{*}G_{jk} + \alpha_{b,l}\,\overline{\text{Dif}}_{jk} \\ & + \alpha_{b,s}\,\overline{\text{Dif}}^2_{jk} + \alpha_{w,l}\,(\text{Dif}_{ijk} - \overline{\text{Dif}}_{jk}) \\ & + \alpha_{w,s}\,(\text{Dif}_{ijk} - \overline{\text{Dif}}_{jk})^2 + c_k + u_{jk} \\ & + w_{jk}\,(\text{Dif}_{ijk} - \overline{\text{Dif}}_{jk}) + v_{jk}\,(\text{Dif}_{ijk} - \overline{\text{Dif}}_{jk})^2 \\ & + \varepsilon_{ijk},\end{aligned} \tag{1}$$

with the engagement rating Eng_{ijk} at time i for student j in class group k predicted by a set of time-invariant controls (students' sex S_{jk}, mathematics ability A_{jk} and grade level G_{jk}), the time-invariant mean perceived difficulty rating reported by the student over all measurement occasions $\overline{\text{Dif}}_{jk}$ and its square, and the time-variant perceived difficulty at time i centered around that student mean $(\text{Dif}_{ijk} - \overline{\text{Dif}}_{jk})$ and its square. Hence, in this equation, $\alpha_{b,l}$ and $\alpha_{b,s}$ capture the between-student effects and $\alpha_{w,l}$ and $\alpha_{w,s}$ capture the within-student effects. The equation included a set of normally distributed random components: a random intercept at the classroom level r_k, a random intercept at the individual level u_{jk}, the random slopes w_{jk} and v_{jk} and the residual error term ε_{ijk}.

To answer RQ3, students' mathematics-specific Need for Cognition and its interactions with student-perceived difficulty of the class (both linear and squared) were added to the model. That is, Equation 1 was extended with the following terms:

$$\begin{aligned}\text{Eng}_{ijk} = {} & (\text{Equation 1}) \\ & + \beta\,\text{NFC}_{jk} + \gamma_{b,l}\,\overline{\text{Dif}}_{jk} \times \text{NFC}_{jk} + \gamma_{b,s}\,\overline{\text{Dif}}^2_{jk} \\ & \times \text{NFC}_{jk} + \gamma_{w,l}\,(\text{Dif}_{ijk} - \overline{\text{Dif}}_{jk}) \times \text{NFC}_{jk} \\ & + \gamma_{w,s}\,(\text{Dif}_{ijk} - \overline{\text{Dif}}_{jk})^2 \times \text{NFC}_{jk},\end{aligned} \tag{2}$$

with NFC_{jk} indicating students' mathematics-specific Need for Cognition. In this equation, $\gamma_{b,l}$ and $\gamma_{b,s}$ capture the (student-level) interactions at the between-student level and $\gamma_{w,l}$ and $\gamma_{w,s}$ capture the (cross-level) interactions at the within-student level. To facilitate interpretation of interaction effects, interacting variables were grand-mean centered.

In complex multilevel models, it is often difficult to interpret the practical magnitude of estimates, as there is no generally agreed-upon measure of effect size (Rights & Sterba, 2019; Selya et al., 2012). To give an indication of the relative importance of predictors, all continuous variables were put on a common metric (POMP), which is the percentage of the theoretically maximum score (Cohen et al., 1999). Furthermore, this study adopted a novel approach to assess the practical significance of the models, which consists of calculating a series of R-squared measures that have been developed to decompose the total explained outcome variance in multilevel models (Rights & Sterba, 2019; Shaw et al., 2023). For ease of interpretation, and because the default algorithm to calculate these measures is confined to two levels (Rights & Sterba, 2019), only two levels were considered. In particular, as only a small share of the variance in outcomes was located at the

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classroom level (see below), only the between-student and within-student levels were considered in the calculation. The procedure developed by Rights and Sterba (2019) then yielded five important indications of the practical significance of a model (i.e., shares of explained variance at different levels). First, $R^2_W(f_1)$ captures the share of within-student outcome variance which is explained by the fixed effects of within-student predictors (i.e., how much of the within-student variance in student engagement is explained by within-student variation in perceived class difficulty). Similarly, $R^2_B(f_2)$ captures the share of between-student outcome variance which is explained by the fixed effects of between-student predictors (i.e., how much of the between-student variance in student engagement is explained by between-student differences in perceived class difficulty, together with student characteristics such as grade level, sex, mathematics ability, and Need for Cognition). Hence, both $R^2_W(f_1)$ and $R^2_B(f_2)$ give an indication of how well the included predictors predict the outcome, either at the within-student or at the between-student level. Third, $R^2_T(f)$ then summarizes how much of the total outcome variance is explained by the within- and between-student-level predictors. Finally, the procedure by Rights and Sterba (2019) yields an indication of how much of the outcome variance can be explained by letting the mean levels and the effects of predictors vary between individuals, that is, by random intercepts and slopes. In particular, $R^2_T(m)$ represents the share of variance attributable to random intercepts (i.e., the degree to which students randomly differ in engagement, beyond the included predictors). Similarly, $R^2_W(v)$ represents the share of within-student variance attributable to random slope variation (i.e., how much better the model explains this variance by letting the association between perceived difficulty and engagement differ between students).

Hence, to capture the practical significance of Need for Cognition for student responses to class difficulty, R^2 measures were compared between a model including perceived difficulty and control variables, but not yet Need for Cognition (i.e., Equation 1), and a model which additionally included Need for Cognition and its interactions with perceived difficulty (i.e., adding Equation 2). The practical importance of Need for Cognition for student engagement is then indicated in the increase, between these models, in $R^2_W(f_1)$ (variance explained at the within-student level), $R^2_B(f_2)$ (variance explained at the between-student level), and $R^2_T(f)$ (total outcome variance explained). To illustrate the interaction effects, figures were created displaying associations between perceived difficulty and student engagement outcomes for two profiles of Need for Cognition, that is, with Need for Cognition either 1 *SD* below the sample mean or 1 *SD* above the sample mean.

Missing Data

During the ESM, 456 beeps were delivered to the teachers, 12 of which were neglected by the teacher (e.g., because of technical problems with the teacher app, or because class could not be interrupted because students were taking an exam). This led to 444 activated beeps. An average class group hosted 16.6 students, leading to a theoretical number of $444 \times 16.6 = 7{,}568$ ESM surveys (with each of these surveys measuring students' perceptions of class difficulty and the five engagement components). In the end, 6,332 ESM surveys were completed, with 1,236 ESM surveys (16.33%) missing. This missingness was related to a variety of reasons, such as the absence of students due to illness or technical problems with the student app. However, this missingness was found to be not systematically related to student characteristics (i.e., students' sex, grade level, mathematics ability, and Need for Cognition), nor to students' mean ratings of class difficulty or engagement. On average, each student thus completed $6.332/414 = 15.29$ ESM surveys ($SD = 5.52$).

Results

Descriptive Statistics

Table 1 reports the means, standard deviations, and correlations of all study measures; for the ESM measures, both between-student correlations (i.e., based on individual averages over all measurements; below diagonal) and within-student correlations (i.e., correlations between measurements, centered around each student mean; above diagonal) were included. Bivariately, perceived difficulty of the mathematics class was weakly negatively related to momentary engagement measures, and positively to boredom. Need for Cognition was moderately to strongly positively associated with engagement outcomes and negatively with boredom.

As the ESM measures were measured on a scale ranging from 0 to 100, the mean values indicated that students felt, on average, that their mathematics classes were of medium difficulty (average value = 51.98). Perceived difficulty did not strongly depend on the teacher practices (mean levels during classes with whole-class instruction = 51.89, with independent work = 52.60, with group work = 53.60, and with classroom discussion = 52.99). Similarly, on average, students moderately enjoyed their classes, were moderately interested in them, felt moderately concentrated, and participated moderately, as all mean scores fell within the 50–60 range (on a 0–100 scale). The average boredom rating was somewhat below the midpoint of the scale, but still indicated a substantial degree of boredom during mathematics classes.

Table 2 reports the results from empty multilevel models decomposing the total variance in difficulty ratings and engagement components between the within-student, student, and classroom level (i.e., the intraclass correlation coefficients). Overall, the largest part of the variance (typically around 50%) was located at the within-student level (i.e., variability within students over time), with another major part (typically around 40%) located at the student level (i.e., variability between students) and a minor part (typically below 10%) at the classroom level (i.e., variability between classrooms).

Associations Between Student-Perceived Class Difficulty and Engagement

Table 3 reports the results from a multilevel model predicting enjoyment, interest, concentration, active participation, and boredom as a result of student-perceived difficulty of the class. To make coefficients more readable and to aid the interpretation of these quadratic associations, Figure 3 plots the outcomes as a function of perceived difficulty, with endpoints for all scales ranging between 0 and 100.

First, for enjoyment and interest, the linear and squared terms of perceived difficulty were significantly negatively related to engagement outcomes both at the between and within levels. For concentration and active participation, associations were in the same direction, but smaller and only significant at the within-student level. Figure 3

Table 1
Descriptive Statistics: Means, Standard Deviations, and Correlations Between Study Variables

Measure	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
Individual characteristics														
1. Math-specific Need for Cognition	55.27	19.61	—											
2. Sex (0 = *male*)			−.10	—										
3. Mathematics ability	41.59	14.84	.37*	−.22*	—									
4. Grade level (0 = *Grade 11*, 1 = *Grade 12*)			.10	−.03	−.09	—								
ESM measures														
5. Perceived difficulty	51.98	16.17	−.20*	.01	−.06	.08	—	.03*	−.11*	−.05*	−.03*	−.02	.09*	
6. Perceived difficulty-squared			.00	.03	−.02	−.05	−.19*	—	−.12*	−.12*	−.08*	−.07*	.10*	
7. Enjoyment	54.23	23.66	.50*	−.10	.22*	.05	−.15*	−.15*	—	.74*	.53*	.56*	−.49*	
8. Interest	54.80	22.96	.51*	−.10	.21*	.04	−.09	−.20*	.90*	—	.58*	.53*	−.47*	
9. Concentration	60.29	22.74	.41*	.03	.13*	−.04	−.01	−.06	.70*	.72*	—	.62*	−.44*	
10. Active participation	57.29	25.06	.38*	.03	.11*	.00	−.04	−.01	.69*	.66*	.80*	—	−.43*	
11. Boredom	37.46	25.53	−.38*	−.03	−.14*	−.04	.15*	.07	−.61*	−.60*	−.61*	−.57*	—	
Interaction terms														
12. Perceived Difficulty × Math-Specific Need for Cognition			−.16*	.01	−.07	.00	−.06	−.48*	.09	.07	.02	−.01	−.04	—
13. Perceived Difficulty-Squared × Math-Specific Need for Cognition			.46*	−.01	.18*	−.04	−.46*	.15*	.30*	.32*	.25*	.27*	−.25*	−.16*

Note. All continuous measures defined as POMP scores. For the ESM measures (i.e., Measures 6–12), correlations below the diagonal are based on between-student variables (i.e., student averages over all measurements, $n = 414$), and correlations above the diagonal are based on all ESM measurements ($n = 6{,}332$). ESM = experience sampling method; POMP = percentage of maximally possible.
* $p < .05$.

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clarifies that for these five outcomes, associations with perceived difficulty followed an inverse U-shape; this shape was more pronounced for enjoyment and interest than for concentration or active participation. In addition, overall, student engagement was more strongly reduced at the upper end of the perceived difficulty scale than at the lower end. Hence, whereas very difficult mathematics classes were clearly linked to lower engagement, very easy mathematics classes were still associated with a relatively high level of student engagement. Hence, the "optimal" level of class difficulty was typically below the midpoint of the scale; for example, enjoyment was highest among students who rated the difficulty of their mathematics classes to be 37.70 on the 0–100 scale. For boredom, the linear and squared terms of perceived difficulty were significantly positively related to boredom both at the between and within level, leading to a U-shaped association between perceived difficulty and boredom.

Regarding the R^2 measures proposed by Rights and Sterba (2019), the multilevel models were found to explain a small but substantial part of the variance in most outcomes. In particular, the models explained 5.85%, 4.34%, and 2.89% of the total variance in enjoyment, interest, and boredom; for these outcomes, the models explained variance particularly at the between-student level (7.47%, 5.99%, and 5.09%, respectively) and more modestly at the within-student level (3.40%, 1.29%, and 1.29%, respectively). Hence, differences between students in how they experienced their mathematics classes were somewhat easier to predict than fluctuations in ratings within students over time. For concentration and active participation, the total degree of explained variance was fairly limited (1.26% and 0.88%, respectively), and the algorithm to further decompose this explained variance between the between- and within-student level did not converge.

Table 2
Decomposition of the Variance in Difficulty and Engagement Components Between the Within-Student, Student, and Classroom Levels

Measure	Within-student level	Student level	Classroom level
Perceived difficulty	0.57	0.37	0.07
Enjoyment	0.49	0.42	0.08
Interest	0.46	0.46	0.08
Concentration	0.55	0.39	0.05
Active participation	0.53	0.42	0.05
Boredom	0.58	0.37	0.05

Between-Student Differences in Difficulty–Engagement Associations

Importantly, in all models, substantial variance was attributed to the random components (i.e., significant random intercepts and slopes). First, over all engagement outcomes, between 40.04% and 60.88% of the variance in outcomes was related to unexplained differences between students, that is, to random intercepts, $R^2_B(m)$. Second, the models indicated considerable heterogeneity between students in the association between perceived difficulty and engagement outcomes at the within-student level (i.e., random slopes). In particular, for enjoyment, $R^2_W(v) = 12.55\%$, and interest, $R^2_W(v) = 13.40\%$, differences between students in difficulty–engagement associations accounted for a substantial degree of variance in outcomes. For concentration, active participation, and boredom, the degree of variance associated with the random slopes was more modest, that is, $R^2_W(v)$ between 3.96% and 6.36%.

Need for Cognition as a Moderator of Difficulty–Engagement Associations

Table 4 reports the results from the multilevel model predicting engagement in terms of the interaction between perceived class

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Table 3

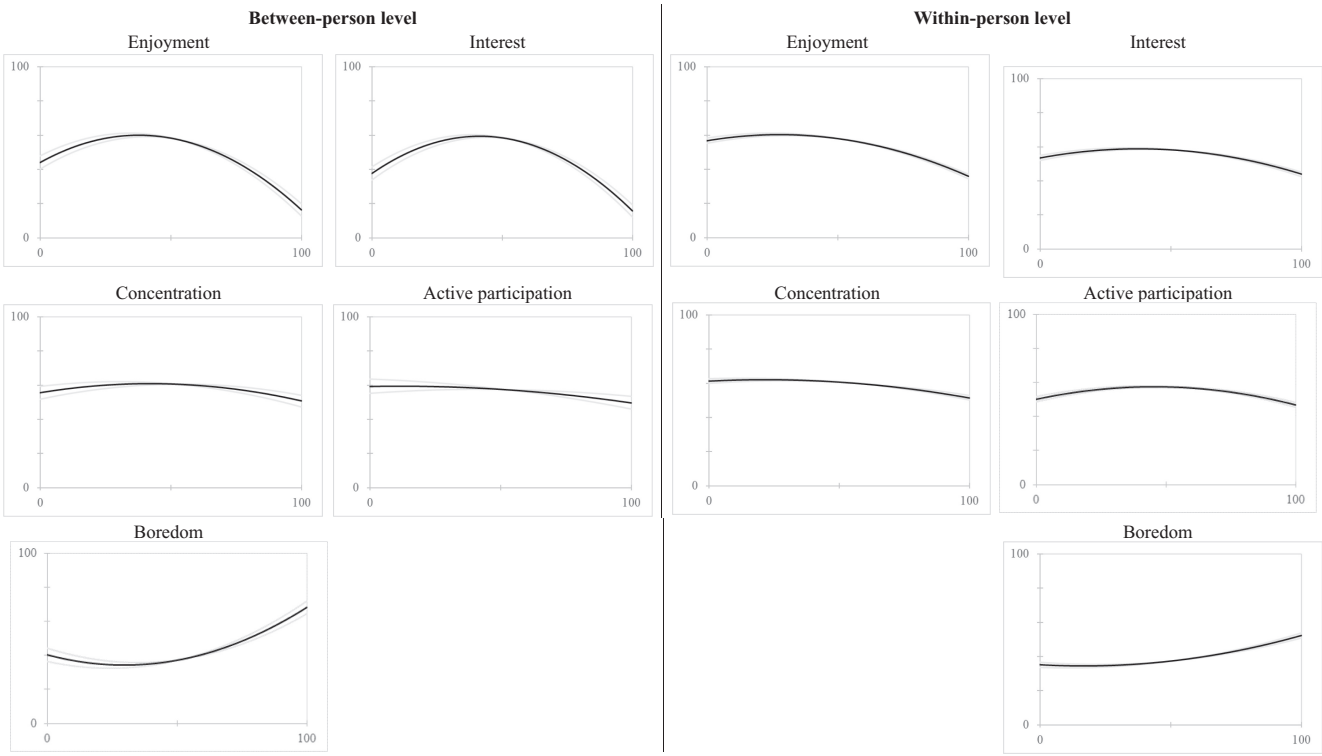
Multilevel Model Predicting Student Engagement as a Function of Perceived Difficulty

Predictor	Enjoyment			Interest			Concentration			Active participation			Boredom		
	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Intercept	57.68	2.03		58.08	2.00		60.57	1.79		57.46	1.98		37.67	1.93	
Sex (0 = *male*)	**−3.37**	**1.64**	**.039**	−2.87	1.65	.082	0.33	1.59	.836	0.45	1.78	.799	−1.21	1.68	.472
Mathematics ability	**0.15**	**0.07**	**.027**	0.13	0.07	.058	0.08	0.07	.203	0.09	0.07	.199	−0.11	0.07	.112
Grade level (ref: Grade 11)	2.02	3.55	.570	1.81	3.47	.602	−1.79	3.02	.553	−0.35	3.32	.916	−1.92	3.28	.558
Between-student level															
Perceived difficulty	**−0.32**	**0.07**	**<.001**	**−0.27**	**0.07**	**<.001**	−0.06	0.07	.402	−0.10	0.08	.212	**0.31**	**0.08**	**<.001**
Perceived difficulty-squared	**−0.011**	**0.003**	**<.001**	**−0.013**	**0.003**	**<.001**	−0.003	0.003	.250	−0.001	0.003	.674	**0.007**	**0.003**	**.013**
Within-student level															
Perceived difficulty	**−0.23**	**0.03**	**<.001**	**−0.11**	**0.03**	**<.001**	**−0.11**	**0.03**	**<.001**	−0.05	0.03	.113	**0.18**	**0.03**	**<.001**
Perceived difficulty-squared	**−0.005**	**0.001**	**<.001**	**−0.004**	**0.001**	**.001**	−0.002	0.001	.156	**−0.004**	**0.001**	**.004**	**0.003**	**0.001**	**.032**
Number of measurements	6,332			6,332			6,332			6,332			6,332		
Number of individuals	414			414			414			414			414		
Number of classes	25			25			25			25			25		
−2 log likelihood	54,105			53,472			54,533			55,487			56,230		
Variance components															
Student level															
Random intercept	212.98		<.001	219.73		<.001	200.14		<.001	254.67		<.001	219.89		<.001
Random slope perceived difficulty	0.15		<.001	0.14		<.001	0.14		<.001	0.13		<.001	0.13		<.001
Random slope perceived difficulty-squared	1.31		<.001	1.08		<.001	1.12		<.001	0.92		<.001	0.67		<.001
Classroom level															
Random intercept	42.15		.006	39.20		.008	27.06		.011	32.02		.018	32.68		.010
Residual	236.53		<.001	212.07		<.001	257.70		<.001	301.21		<.001	346.13		<.001
Explained variance (%)															
R^2_W (f_1)	3.40			1.29									1.29		
R^2_B (f_2)	7.47			5.99									5.09		
R^2_T (f)	5.85			4.34			1.26			0.88			2.89		
Variance attributable to random components (%)															
R^2_W (v)	12.55			13.40			5.45			3.96			6.36		
R^2_B (m)	55.71			60.88			44.71			47.53			40.04		

Note. Estimates significant at the .05 level are given in bold. ref = reference group.

Figure 3

Student Engagement (y-Axis) as a Function of Perceived Difficulty (x-Axis)



Note. Estimated values for a male 11th-grade student with average mathematics ability. Gray lines indicate 95% confidence intervals.

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difficulty and students' mathematics-specific Need for Cognition. To aid interpretation of the quadratic and interaction effects, Figure 4 plots the engagement outcomes as a function of perceived difficulty, with endpoints for all scales ranging between 0 and 100, for two profiles of mathematics-specific Need for Cognition (i.e., for students with Need for Cognition either 1 *SD* below the sample mean or 1 *SD* above the sample mean).

First, the main effects of perceived difficulty were similar to the results discussed in the previous section. In particular, for enjoyment and interest, there were significant negative linear and quadratic associations with perceived difficulty, both at the between-student and the within-student level, whereas for concentration, active participation, and boredom, associations were smaller and mainly significant at the within-student level.

Second, importantly, there were significant interactions between perceived difficulty and students' Need for Cognition, in particular, at the between-student level. These interactions were positive for enjoyment, interest, concentration and active participation, and negative for boredom. As Figure 4 (left panel) illustrates, this means that the negative quadratic association with perceived difficulty (i.e., inverse U-shape) was "flattened off" or even reversed for students with high Need for Cognition. That is, starting from the middle point of the difficulty axis (i.e., medium levels of perceived class difficulty), higher class difficulty corresponded to considerably lower engagement for students with low Need for Cognition, but to roughly equal and sometimes even higher levels of engagement for students with high Need for Cognition. As a result, the "optimal" level of class difficulty among students with high Need for Cognition was quite high. For example, for enjoyment, optimal difficulty equaled 70.63 on the 0–100 scale, and enjoyment remained high for higher values of perceived difficulty. Similarly, for students with high Need for Cognition, concentration and active participation reached their highest levels at the maximal difficulty score.

At the within-student level, interactions generally were smaller and failed to reach statistical significance, with the exception of boredom. However, as Figure 4 (right panel) illustrates, the gist of findings at the within-student level was similar to those at the between-student level. In particular, whereas students with low Need for Cognition reported substantially lower engagement at times when students' felt their classes to be above-average difficult, students with high Need for Cognition reported relatively high levels of engagement also when classes were above-average difficult.

Considering the R^2 measures proposed by Rights and Sterba (2019), including Need for Cognition sizably increased the shares of variance explained by the multilevel models. The models in particular succeeded in explaining variance at the between-student level; for example, including domain-specific Need for Cognition increased the explained between-student variance in interest during mathematics classes from 5.99% to 31.84%. At the within-student level, the additionally explained variance by including Need for Cognition was more modest.

Finally, a number of robustness tests were performed. First, models were estimated using a domain-general instead of a

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Table 4

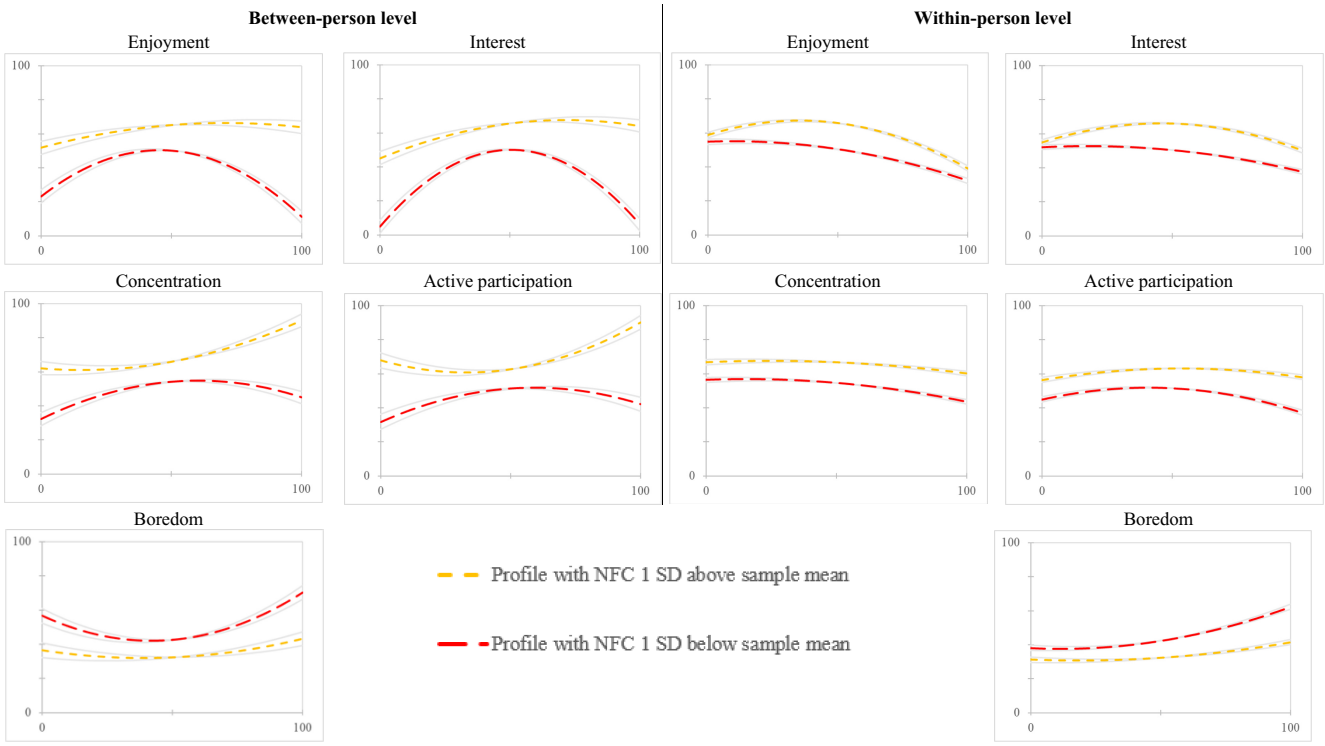
Multilevel Model Predicting Student Engagement as a Function of Perceived Difficulty, Mathematics-Specific Need for Cognition, and Their Interactions

Predictor	Enjoyment			Interest			Concentration			Active participation			Boredom		
	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Intercept	57.659	1.758		58.105	1.677		60.483	1.440		57.334	1.642		37.712	1.687	
Sex (0 = *male*)	−2.479	1.453	.088	−1.878	1.427	.188	0.979	1.455	.501	1.114	1.657	.501	−1.655	1.608	.303
Mathematics ability	−0.012	0.064	.854	−0.046	0.062	.462	−0.054	0.059	.367	−0.048	0.068	.477	0.007	0.067	.920
Grade level (ref: Grade 11)	−0.500	3.067	.871	−0.785	2.893	.786	−3.868	2.294	.092	−2.310	2.618	.378	−0.150	2.773	.957
Need for Cognition	**0.392**	**0.044**	**<.001**	**0.405**	**0.044**	**<.001**	**0.312**	**0.044**	**<.001**	**0.298**	**0.050**	**<.001**	**−0.264**	**0.049**	**<.001**
Between-student level															
Perceived difficulty	−0.032	0.076	.671	0.058	0.074	.432	**0.200**	**0.075**	**.008**	0.165	0.085	.053	0.125	0.083	.133
Perceived difficulty-squared	**−0.008**	**0.003**	**.005**	**−0.011**	**0.003**	**<.001**	−0.001	0.003	.709	0.000	0.003	.900	0.006	0.003	.069
Perceived Difficulty × NFC	**0.007**	**0.003**	**.016**	**0.006**	**0.003**	**.046**	0.005	0.003	.102	0.004	0.003	.213	−0.002	0.003	.491
Perceived Difficulty-Squared × NFC	**0.0003**	**0.0001**	**<.0013**	**0.0001**	**0.000**	**.001**	**0.0003**	**0.0001**	**.010**	**0.0003**	**0.0001**	**.007**	−0.0001	0.0001	.221
Within-student level															
Perceived difficulty	**−0.231**	**0.029**	**<.001**	**−0.113**	**0.028**	**<.001**	**−0.104**	**0.029**	**<.001**	−0.044	0.029	.128	**0.182**	**0.030**	**<.001**
Perceived difficulty-squared	**−0.004**	**0.001**	**<.001**	**−0.004**	**0.001**	**.001**	−0.002	0.001	.193	**−0.003**	**0.001**	**.006**	**0.002**	**0.001**	**.042**
Perceived Difficulty × NFC	0.000	0.001	.735	0.002	0.001	.111	0.002	0.001	.239	0.003	0.001	.067	**−0.004**	**0.001**	**.012**
Perceived Difficulty-Squared × NFC	−0.0001	0.0001	.086	−0.0000	0.0000	.119	0.0000	0.0000	.803	0.0000	0.0000	.395	−0.0000	0.0000	.475
Number of measurements	6.488			6.488			6.488			6.488			6.488		
Number of individuals	414			414			414			414			414		
Number of classes	25			25			25			25			25		
−2 log likelihood	53,747			53,066			54,175			55,152			55,913		
Variance components															
Student level															
Random intercept	161.21		<.001	157.76		<.001	166.11		<.001	218.88		<.001	198.98		<.001
Random slope perceived difficulty	0.15		<.001	0.14		<.001	0.14		<.001	0.12		<.001	0.12		<.001
Random slope perceived difficulty-squared	1.30		<.001	1.04		<.001	1.12		<.001	0.86		.001	0.60		.013
Classroom level															
Random intercept	30.52		.007	26.23		.010	11.44		.042	14.97		.075	19.76		.025
Residual	236.59		<.001	211.36		<.001	256.82		<.001	301.30		<.001	346.39		<.001
Explained variance (%)															
R^2_W (f_1)	3.47			1.45									1.57		
R^2_B (f_2)	29.52			31.84									16.60		
R^2_T (f)	16.51			17.63			9.69			8.55			7.87		
Variance attributable to random components(%)															
R^2_W (v)	11.88			12.11									6.14		
R^2_B (m)	35.29			36.29			35.77			39.32			34.95		
Difference in explained variance (relative to Table 3), %															
ΔR^2_W (f_1)	0.06			0.16									0.28		
ΔR^2_B (f_2)	22.05			25.85									11.51		
ΔR^2_T (f)	10.66			13.30			8.43			7.71			4.98		

Note. Estimates significant at the .05 level are given in bold. ref = Reference group; NFC = Need for Cognition.

Figure 4

Student Engagement (y-Axis) as a Function of Perceived Difficulty (x-Axis), for Two Profiles of Students' Math-Specific Need for Cognition



Note. Left panel: Associations at the between-person level. Right panel: Associations at the within-person level. Estimated values for a male 11th-grade student with average mathematics ability. Gray lines indicate 95% confidence intervals. NFC = Need for Cognition. See the online article for the color version of this figure.

mathematics-specific measure of Need for Cognition. Models including the domain-general measure, reported in Table A1, yielded roughly similar results regarding the main and interaction effects of Need for Cognition as models with the mathematics-specific measure. Second, models were estimated in which interactions between student mathematics ability and student-perceived class difficulty were included, on top of the interactions between students' Need for Cognition and student-perceived class difficulty. The results, reported in Table A2, showed that interactions between mathematics ability and perceived difficulty were very small; importantly, the main pattern of results (i.e., the effects of Need for Cognition and the interactions between Need for Cognition and perceived difficulty in predicting engagement) remained roughly similar when interactions with mathematics ability were controlled for. Only when predicting boredom at the within-student level, the linear interaction between Need for Cognition and perceived difficulty was no longer significant after controlling for mathematics ability. Hence, it seems that the observed interactions between Need for Cognition and perceived difficulty were not driven by mathematics ability. Finally, models were estimated controlling for measurement period (measurement period was defined as 0 when data were collected in May 2022 and as 1 when data were collected in October/November 2022), and controlling for the number of days since the start of the ESM measurement. The resulting models, available from the author, yielded an identical pattern of significant results as the models without these controls.

Discussion

In this study, we investigated how students' Need for Cognition moderated real-time associations between student-perceived difficulty of mathematics classes and five indicators of student engagement, that is, enjoyment, interest, concentration, active participation, and boredom. Data were collected in an ESM study among 414 students from the academic track in Grades 11 and 12, in which student-perceived class difficulty and the five engagement outcomes were assessed twice during each mathematics class over a period of 10 consecutive school days.

First, we found a negative quadratic association between perceived difficulty and student engagement, indicating that, on average, students were most engaged when classes were neither too easy nor too difficult, supporting H1a. Student engagement was particularly low in very difficult classes, more than in very easy classes, supporting H1b. However, there was a considerable degree of between-student variability in how class difficulty was associated with student engagement, which supported H2. Importantly, beyond having a main effect on student engagement (supporting H3a), students' mathematics-specific Need for Cognition explained a substantial part of this between-student heterogeneity, as students with high Need for Cognition were more engaged in highly difficult

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classes than students with low Need for Cognition (positive interaction effect), supporting H3b.

Associations Between Student-Perceived Class Difficulty and Engagement

Substantial variability between students was observed in their level of mathematics engagement (i.e., the standard deviations across engagement components were typically around 23–25 points on a 0–100 scale). Hence, even within a selective sample from the academic track, students differed substantially in how much they engaged with their schoolwork, evoking the question of how these differences can be explained.

Flow theory predicts that people tend to be most engaged when confronted with tasks of intermediate difficulty (Csikszentmihalyi, 1997). In line with this prediction, our study showed that in real-life classrooms, associations between perceived class difficulty and student engagement generally followed an inverse U-shape. However, too-easy schoolwork appeared to be far less detrimental for student engagement than too-difficult schoolwork. The relatively high engagement levels in easy classes have been observed before (e.g., Norsworthy et al., 2021), and have been explained by the nature of the school setting, which involves mandatory performance tasks. Students might be reluctant to invest much effort in schoolwork they feel obliged to do, or they might be concerned about the possibility of not performing well. In such cases, students may find easy classes comfortable and relaxing, leading them to prefer easy classes above more challenging ones. Unfortunately, students arguably do not learn much in easy classes (Vygotsky, 1980), which invokes the question of how students may become more attracted to classes with a higher level of difficulty.

Between-Student Differences in Difficulty–Engagement Associations: The Moderating Role of Need for Cognition

Importantly, there were considerable between-student differences in the associations between perceived class difficulty and student engagement. Apparently, whereas some students tend to enjoy easy classes the most, others tend to be more engaged when classes are perceived as challenging. Within flow theory, interindividual heterogeneity in the appreciation of challenge was already recognized, with so-called "autotelic personalities" being more attracted to challenges (Tse et al., 2020).

Interindividual differences in how individuals approach cognitively challenging situations, in particular, have been described by intellectual investment theories (Ackerman, 1996; Cattell, 1987). These theories posit that people vary in how they want to invest time and effort in cognitive activities, with investment traits such as Need for Cognition regulating these individual tendencies (Von Stumm & Ackerman, 2013).

Indeed, we found that students' Need for Cognition moderated the association between class difficulty and student engagement. Specifically, for students with high Need for Cognition, higher class difficulty was less detrimental for student engagement than for students with low Need for Cognition. In fact, even fairly difficult classes seemed to motivate rather than disengage students with high Need for Cognition. In addition, Need for Cognition was positively associated with all engagement outcomes. This emphasizes the importance of applying investment theory in educational research. In particular, this study established that investment traits such as Need for Cognition matter in the everyday classroom, where it affects how students appreciate their schoolwork, particularly when it becomes cognitively demanding.

In this way, this study may help to understand why Need for Cognition has been shown to be a strong asset for students' academic development (see, e.g., recent studies by Colling et al., 2022; Lavrijsen et al., 2023; Liu & Nesbit, 2024; Steinmayr et al., 2023). Students are known to learn the most in classes that slightly exceed their current skill level (i.e., zone of proximal development; Vygotsky, 1980). In this study, we found that higher Need for Cognition predicted higher student engagement, particularly in such cognitively challenging classes. Hence, a high Need for Cognition would lead students to engage in (e.g., be interested in, concentrate in, and participate actively in) precisely the classes that offer students the largest learning opportunities, thus substantially improving their academic performance.

Similarly, this study may exemplify the theoretical mechanism of how investment traits have been proposed to influence cognitive development throughout the life course. Intellectual investment theory posits that cognitive capacities (e.g., reasoning abilities) translate into cognitive outcomes (e.g., knowledge acquisition) to the extent that individuals want to invest time and effort in expanding these capacities. That is, investment traits are supposed to benefit cognitive development because these traits determine how people are attracted to the kind of activities in which these capacities can be expanded (Von Stumm & Ackerman, 2013). This study exemplified how this mechanism may work in youth; by getting more interested in material when this material becomes more challenging, students with high investment traits may engage more in acquiring knowledge, thus advancing their intellect.

Between- and Within-Student Effects

This study distinguished between between-student effects (i.e., how students' average evaluation of the difficulty of mathematics classes related to their average level of engagement) and within-student effects (i.e., how students' difficulty ratings and engagement were associated within students across different measurement points). In general, the pattern of findings was consistent between both levels of analysis; for example, interactions between Need for Cognition and perceived difficulty in predicting engagement were generally positive at both levels. Still, findings were somewhat more pronounced at the between-student level. A possible explanation for the more modest effects (sometimes not reaching significance) at the within-student level might be that some of the motivational benefits associated with difficult learning activities, such as the feeling of self-efficacy originating from having successfully expended effort to master challenges (Bandura, 1997; Nuutila et al., 2021), are not yet immediately salient to students at the very moment they are confronted with difficult classes.

Educational Implications

This study showed that students are most engaged when classes are perceived as neither too difficult nor too easy. This may suggest that teachers could support their students' engagement by aligning the difficulty level of their classes to students' skill levels (Lavrijsen et al., 2021). In addition, this study demonstrated the

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heterogeneity in how students engage in difficult classes, showing that this heterogeneity could be meaningfully explained by students' Need for Cognition. For teachers, this may suggest that students' Need for Cognition could be taken into account when designing instructional approaches. Indeed, for students with high Need for Cognition, the "optimal" level of schoolwork difficulty might be particularly elevated, that is, these students would benefit most from being provided with tasks above the regular level of difficulty (Meier et al., 2014). Of note, teachers, in particular in mathematics, have sometimes been found to refrain from giving students difficult tasks as they believe this would make the subject only more frightening to students (Dowker et al., 2016; Strati et al., 2017). The current study underlined that such a well-intentioned attempt to keep students engaged would backfire, particularly for students with high Need for Cognition who long for cognitive challenge.

More generally, an implication of this study is that it might be important to try to raise the level of students' Need for Cognition. Indeed, we showed that students with high Need for Cognition report higher engagement in difficult classes, which might further support their academic and cognitive development (Liu & Nesbit, 2024). This evokes the question of whether and how Need for Cognition then could be nurtured in students. Theoretically, it has been suggested that Need for Cognition could be fostered by letting children repeatedly experience that engagement in cognitive activities is rewarding and enjoyable (Cacioppo et al., 1996). However, to date, little is yet known about these developmental underpinnings of Need for Cognition. Hence, future research should investigate how the appreciation of cognitive challenge may be nurtured in youth.

Strengths and Limitations

This study was the first to explore the role of student Need for Cognition in student engagement using an ESM design, that is, with repeated assessments capturing students' fluctuating engagement during real-life classrooms (Dirk & Nett, 2022). Assessing student engagement semirandomly twice within each class allowed us to capture engagement as a state rather than a trait. Indeed, we observed a substantial degree of within-student variation in engagement, which indicates that a single student may find, for example, one mathematics class to be fairly engaging, but the next one much less so. Accordingly, the ESM design allowed to distinguish interindividual differences in engagement (i.e., the between-student level) from within-student fluctuations in engagement over time (Pekrun & Marsh, 2022). In addition, using momentary assessments limited retrospective biases commonly associated with survey research. Beyond exploiting the benefits of the ESM design, this study also controlled for a set of student characteristics that might also affect student engagement, such as sex, grade level, and mathematics ability, which was assessed with a standardized mathematics test.

Of course, the study also had its limitations. First, all participants were recruited from the academic (i.e., college-bound) track from Flemish education, with an oversampling of students from mathematics-oriented study programs. As the sample thus was selective on mathematics ability, participants may have, on average, appreciated mathematics better than students from other programs. On the other hand, as the academic track may be quite demanding to students, concerns about failure may also have led students in this track to particularly favor easier schoolwork. Hence, it remains to be investigated whether the associations between perceived difficulty and engagement generalize to other programs and tracks, in particular those catering for students with lower average mathematics ability. Similarly, students were recruited from the final two grades of secondary education; future research could examine engagement in other age groups. In addition, future studies could further unravel findings for students according to social origin or language status. Finally, sex was assessed as a binary variable, although this view has recently been challenged (e.g., nonbinary gender identifications; Hyde et al., 2019).

Second, the study only considered mathematics classes. Mathematics is often considered to be an important but difficult subject (Brown et al., 2008; Dowker et al., 2016); moreover, performance in mathematics is often believed to be more intrinsically tied to innate ability in other subjects (Asbury et al., 2023). Further research is thus needed to see whether the observed findings would also apply to other subjects.

Third, it has been argued that whereas the ESM design mitigates certain biases associated with self-report surveys (e.g., recall biases), ESM studies can still be affected by self-report biases such as social desirability (Pekrun & Marsh, 2022). To address this shortcoming, future studies could involve external reports of key constructs, such as teacher or observer ratings of class difficulty. In general, however, how students subjectively experience classes is often more decisive for their motivational adjustment than external reports (Lauermann & Berger, 2021; Stroet et al., 2013). Of note, there was substantial variability in difficulty ratings of a single class between students, emphasizing the subjectivity of difficulty ratings. In addition, future research could consider how Need for Cognition affects not just (self-reported) student engagement, but also more objective outcomes such as student performance. Cross-sectionally, associations between Need for Cognition and student performance have been repeatedly documented (Liu & Nesbit, 2024), particularly in challenging learning environments (Colling et al., 2022).

Fourth, students' subjective states during mathematics class were captured with single-item measures. Previous research has supported the use of single-item measures to capture affective and motivational states in intensive longitudinal studies (Cloos et al., 2023). Indeed, when multiple constructs need to be assessed repeatedly and within a limited amount of time, long surveys have been shown to lead to higher perceived participant burden, lower compliance rates, and increased careless responding (Eisele et al., 2022; Morren et al., 2009). By inducing fatigue, annoyance, and irritation in respondents, long surveys might thus obscure the motivational states that were intended to be measured. By contrast, with short sets of single-item measures, respondents may answer more conscientiously and carefully, thus improving the validity of the results (Cloos et al., 2023; Krannich et al., 2022). Hence, single-item measures are an efficient low-burden assessment tool of momentary states and thus standard in ESM studies (Cloos et al., 2023).

Still, some limitations related to this reliance on single-item measures need to be acknowledged. In particular, every measurement is subject to random measurement error. When using composite scales, these errors may be partially canceled out by averaging across multiple items. As a result, single-item measures capture the underlying latent construct often with somewhat less precision than a longer scale (Gogol et al., 2014). This potential lower precision of single-item measures might have deflated the observed associations between study variables. All in all, ESM researchers hold that this reduced precision is preferred over jeopardizing data quality due

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to participant overburden, claiming that in ESM studies single-item measures typically do not underperform compared to combined scales when it comes to data validity.

In the present study, single items were selected based on face validity for the construct. Future research could do well in selecting single items on the basis of their psychometric properties, for example, based on factor analyses on larger sets of items.

Fifth, all measures in the multilevel models, including Need for Cognition and mathematics ability, were treated as manifest variables, thus not accommodating for measurement error. Future research could also consider a single engagement outcome as indexed by several items, instead of single items each capturing a different component of engagement.

Sixth, data were collected in two separate time periods (May 2022; October/November 2022). Whereas the average levels of student-perceived difficulty were highly similar between both periods, it could be that there were unobserved differences between mathematics classes in each period (e.g., on the topic covered). Moreover, the present study did not systematically collect information on the specific subdomain covered during the mathematics classes (e.g., geometry, calculus). It might be possible that some subdomains of mathematics were perceived by some students as more difficult than others, or that some students enjoyed a specific domain more than another one. Future research could distinguish between different subdomains of mathematics when investigating relationships between perceived difficulty and student mathematics engagement. The mathematics ability test assessed mathematics performance in terms of a single underlying mathematics proficiency dimension, thus aggregating performance in multiple subdomains of mathematics. This was supported by the high reliability of the mathematics ability test.

Finally, beyond its many assets, the ESM design is still fundamentally observational in nature (Zirkel et al., 2015). That is, in this study, we could not disentangle any causal influences nor establish the temporal precedence of perceived difficulty and student engagement, calling for caution when interpreting results.

Conclusion

In this ESM study, associations between student-perceived class difficulty and student engagement and the role of Need for Cognition in moderating these associations were examined, both at the between-student and within-student level. On average, there was a quadratic association between student-perceived class difficulty and student engagement, with engagement being particularly low in highly difficult classes. However, there were clear between-student differences in the associations between class difficulty and engagement, and these differences were found to be related to students' Need for Cognition. In particular, students with high Need for Cognition reported more favorable engagement outcomes when confronted with difficult mathematics classes than students with low Need for Cognition.

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(*Appendix follows*)

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Appendix

Additional Analyses

Table A1

Multilevel Model Predicting Student Engagement as a Function of Perceived Difficulty, Domain-General Need for Cognition, and Their Interactions

Predictor	Enjoyment			Interest			Concentration			Active participation			Boredom		
	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Intercept	57.736	1.930		58.162	1.847		60.594	1.564		57.510	1.750		37.564	1.801	
Sex (0 = *male*)	−2.508	1.546	.105	−1.829	1.514	.227	0.980	1.491	.511	1.160	1.672	.488	−1.546	1.640	.346
Mathematics ability	0.071	0.067	.289	0.032	0.065	.622	0.000	0.061	.995	0.004	0.069	.958	−0.043	0.069	.527
Grade level (ref: Grade 11)	−0.024	3.410	.994	−0.524	3.240	.871	−3.817	2.580	.139	−2.360	2.885	.413	−0.513	3.035	.866
Need for Cognition	**0.284**	**0.055**	**<.001**	**0.327**	**0.054**	**<.001**	**0.264**	**0.053**	**<.001**	**0.250**	**0.059**	**<.001**	**−0.171**	**0.058**	**.003**
Between-student level															
Perceived difficulty	−0.073	0.082	.373	0.027	0.080	.734	**0.202**	**0.078**	**.010**	**0.198**	**0.088**	**.024**	0.131	0.086	.128
Perceived difficulty-squared	**−0.018**	**0.003**	**<.001**	**−0.014**	**0.003**	**<.001**	−0.002	0.003	.423	−0.001	0.003	.807	**0.008**	**0.003**	**.012**
Perceived Difficulty × NFC	0.002	0.004	.582	0.001	0.004	.812	0.002	0.004	.502	0.002	0.004	.596	0.002	0.004	.534
Perceived Difficulty-Squared × NFC	**0.0004**	**0.0001**	**.003**	**0.0005**	**0.0001**	**<.001**	**0.0004**	**0.0001**	**.001**	**0.0005**	**0.0001**	**<.001**	**−0.0003**	**0.0001**	**.024**
Within-student level															
Perceived difficulty	**−0.231**	**0.029**	**<.001**	**−0.113**	**0.028**	**<.001**	**−0.104**	**0.029**	**<.001**	−0.045	0.029	.124	**0.183**	**0.030**	**<.001**
Perceived difficulty-squared	**−0.005**	**0.001**	**<.001**	**−0.004**	**0.001**	**.001**	−0.001	0.001	.172	**−0.003**	**0.002**	**.004**	**0.003**	**0.001**	**.029**
Perceived Difficulty × NFC	0.000	0.002	.901	0.002	0.002	.255	0.002	0.002	.365	0.002	0.002	.150	**−0.005**	**0.002**	**.011**
Perceived Difficulty-Squared × NFC	−0.0001	0.0000	.103	−0.0001	0.0000	.088	0.0000	0.0000	.822	0.0001	0.0000	.180	−0.0001	0.0000	.205
Number of measurements	6.488			6.488			6.488			6.488			6.488		
Number of individuals	414			414			414			414			414		
Number of classes	25			25			25			25			25		
−2 log likelihood	53,796			53,114			54,193			55,159			55,927		
Variance components															
Student level															
Random intercept	184.77		<.001	178.92		<.001	173.34		<.001	220.60		<.001	206.42		<.001
Random slope perceived difficulty	0.15		<.001	0.14		<.001	0.14		<.001	0.12		<.001	0.12		<.001
Random slope perceived difficulty-squared	1.29		<.001	1.05		<.001	1.11		<.001	0.84		.001	0.56		.016
Classroom level															
Random intercept	38.71		.005	34.17		.007	16.95		.020	21.08		.032	25.78		.015
Residual	236.55		<.001	211.25		<.001	256.73		<.001	301.18		<.001	346.47		<.001
Explained variance (%)															
R^2_W (f_1)	3.50			1.43									1.56		
R^2_B (f_2)	19.51			22.33									11.98		
R^2_T (f)	11.58			12.62			7.30			7.21			5.94		
Variance attributable to random components (%)															
R^2_W (v)	11.90			12.15			5.53			3.99			6.10		
R^2_B (m)	40.59			41.58			38.32			40.73			36.99		
Difference in explained variance (relative to Table 3), %															
ΔR^2_W (f_1)	0.10			0.14									0.27		
ΔR^2_B (f_2)	12.05			16.34									6.90		
ΔR^2_T (f)	5.73			8.28			6.04			6.37			3.05		

Note. Estimates significant at the .05 level are given in bold. ref = reference group; NFC = Need for Cognition.

(*Appendix continues*)

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Table A2

Multilevel Model Predicting Student Engagement as a Function of Domain-Specific NFC in Interaction with Perceived Difficulty and Mathematics Ability

Predictor	Enjoyment			Interest			Concentration			Active participation			Boredom		
	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Intercept	**57.755**	**1.756**	**<.001**	**58.220**	**1.675**	**<.001**	**60.665**	**1.411**	**<.001**	**57.433**	**1.626**	**<.001**	**37.578**	**1.671**	**<.001**
Sex (0 = *male*)	−2.573	1.450	.076	−2.016	1.422	.156	0.788	1.444	.585	0.931	1.653	.574	−1.399	1.597	.381
Mathematics ability	0.013	0.068	.847	−0.019	0.066	.771	−0.009	0.064	.884	−0.042	0.073	.565	−0.006	0.072	.937
Grade level (ref: Grade 11)	−0.435	3.063	.887	−0.683	2.892	.813	−3.750	2.229	.093	−2.171	2.578	.400	−0.347	2.741	.899
Domain-general Need for Cognition	**0.383**	**0.045**	**<.001**	**0.395**	**0.044**	**<.001**	**0.298**	**0.045**	**<.001**	**0.295**	**0.051**	**<.001**	**−0.260**	**0.050**	**<.001**
Between-student level															
Perceived difficulty	−0.021	0.076	.781	0.072	0.074	.328	**0.223**	**0.075**	**.003**	**0.181**	**0.085**	**.034**	0.105	0.083	.205
Perceived difficulty-squared	**−0.879**	**0.294**	**.003**	**−1.179**	**0.289**	**<.001**	−0.218	0.294	.459	0.020	0.336	.953	0.586	0.324	.070
Perceived Difficulty × NFC	0.005	0.003	.098	0.003	0.003	.300	0.002	0.003	.635	0.001	0.004	.738	0.002	0.004	.599
Perceived Difficulty-Squared × NFC	**0.031**	**0.012**	**.011**	**0.037**	**0.012**	**.002**	**0.032**	**0.012**	**.008**	**0.030**	**0.014**	**.029**	−0.010	0.013	.438
Perceived Difficulty × Mathematics Ability	0.006	0.005	.302	0.008	0.005	.112	**0.011**	**0.005**	**.043**	0.011	0.006	.081	**−0.015**	**0.006**	**.009**
Perceived Difficulty-Squared × Mathematics Ability	−0.011	0.021	.611	−0.007	0.021	.755	−0.014	0.021	.504	0.006	0.025	.794	−0.015	0.024	.525
Within-student level															
Perceived difficulty	**−0.231**	**0.029**	**<.001**	**−0.113**	**0.028**	**<.001**	**−0.104**	**0.029**	**<.001**	−0.045	0.029	.126	**0.183**	**0.030**	**<.001**
Perceived difficulty-squared	**−0.478**	**0.124**	**<.001**	**−0.388**	**0.115**	**.001**	−0.159	0.122	.193	**−0.341**	**0.120**	**.005**	**0.244**	**0.117**	**.038**
Perceived Difficulty × NFC	<0.001	0.002	.977	0.001	0.001	.323	0.001	0.002	.665	0.002	0.002	.141	−0.003	0.002	.088
Perceived Difficulty-Squared × NFC	−0.010	0.006	.104	−0.008	0.006	.148	0.002	0.006	.780	0.002	0.006	.685	−0.003	0.006	.577
Perceived Difficulty × Mathematics Ability	0.002	0.002	.469	0.003	0.002	.208	0.004	0.002	.090	0.001	0.002	.622	−0.004	0.002	.105
Perceived Difficulty-Squared × Mathematics Ability	<0.001	0.010	.970	−0.001	0.009	.927	−0.002	0.010	.816	0.010	0.009	.297	−0.002	0.009	.829
Number of measurements	6.488			6.488			6.488			6.488			6.488		
Number of individuals	414			414			414			414			414		
Number of classes	25			25			25			25			25		
−2 log likelihood	53,744			53,060			54,164			55,148			55,903		
Variance components															
Student level															
Random intercept	160.04			155.91			163.18			217.02			195.13		
Random slope perceived difficulty	0.15			0.14			0.13			0.12			0.12		
Random slope perceived difficulty-squared	1.30			1.03			1.12			0.86			0.59		
Classroom level															
Random intercept	30.45			26.28			10.29			14.11			19.18		
Residual	236.61			211.40			256.78			301.18			346.48		
Explained variance (%)															
R^2_W (f_1)	3.46			1.48									1.64		
R^2_B (f_2)	29.82			32.41									17.96		
R^2_T (f)	16.67			17.98			10.62			8.97			8.49		
Variance attributable to random components (%)															
R^2_W (v)	11.94			12.09			5.55			4.02			6.11		
R^2_B (m)	35.18			36.06			35.02			39.01			34.43		

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Table A2 (*continued*)

Predictor	Enjoyment			Interest			Concentration			Active participation			Boredom		
	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Difference in explained variance (relative to Table 4), %															
ΔR^2_W (f_1)	−0.01			0.03									0.07		
ΔR^2_B (f_2)	0.30			0.57									1.36		
ΔR^2_T (f)	0.16			0.35			0.93			0.43			0.62		
Reduction in variance attributable to random components (relative to Table 4; absolute; relative reduction), %															
ΔR^2_W (v)	0.06	0.53		−0.02	−0.12								−0.03	−0.42	
ΔR^2_B (m)	−0.11	−0.31		−0.23	−0.64		−0.75	−2.10		−0.31	−0.78		−0.51	−1.47	

Note. Estimates significant at the .05 level are given in bold. NFC = Need for Cognition; ref = reference group.

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