



HAL
open science

Adolescent well-being and school engagement as a function of teacher and peer relatedness: The more (relatedness) is not always the merrier

Fernando Núñez-Regueiro, Ming-Te Wang

► To cite this version:

Fernando Núñez-Regueiro, Ming-Te Wang. Adolescent well-being and school engagement as a function of teacher and peer relatedness: The more (relatedness) is not always the merrier. *Journal of Educational Psychology*, 2024, 117 (3), pp.466-484. 10.1037/edu0000910 . hal-04920252v2

HAL Id: hal-04920252

<https://hal.science/hal-04920252v2>

Submitted on 6 Mar 2026

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Copyright - All rights reserved

Adolescent Well-Being and School Engagement as a Function of Teacher and Peer Relatedness: The More (Relatedness) Is Not Always the Merrier

Fernando Núñez-Regueiro¹ and Ming-Te Wang²

¹ Contextual Learning Research Laboratory (LaRAC), Université Grenoble Alpes

² Crown Family School of Social Work, Policy, and Practice, University of Chicago

It is often assumed that relatedness with peers and teachers are two developmental factors whose effects are independent of each other. Preliminary research nevertheless suggests that the combined effects of peer and teacher relationships may manifest in various ways, resulting in positive or negative outcomes based on the degree and direction of imbalance in relatedness levels across social partners. Relatedly, complex social ecology models have underlined the importance of analyzing such combined effects; however, there has been limited research proposing operationalizations of such processes. The present research aims to address the substantive issue of how peer and teacher relatedness intersect in influencing well-being and school engagement by introducing a novel methodological framework for operationalizing complex social ecology, specifically cubic response surface analysis. The validity of this substantive-methodological synergy was examined in Study 1 ($N = 643$ students, 75% female, aged 15–18) and cross-validated in Study 2 ($N = 493$ students, 66% female, aged 10–18) with a focus on various combinatory processes related to school relatedness. Overall, results suggested that peer relatedness was beneficial to student well-being and engagement when accompanied by teacher relatedness. However, there was limited support for the positive effects of peer relatedness in the absence of teacher relatedness. Conversely, teacher relatedness was sufficient to foster school engagement, yet it did not contribute to well-being in the absence of peer relatedness. The implications highlight the interdependency of both peer and teacher relatedness in fundamental research and interventions and emphasize the added value of cubic response surface analysis for investigating intricate dynamics within complex social ecologies.


Educational Impact and Implications Statement

Educational theories commonly posit that a sense of relatedness to others, involving feeling supported and valued, is essential for optimal adolescent development. While existing evidence suggests that relatedness to at least one school partner (i.e., teachers or peers) may be sufficient for this purpose, our research found that peer and teacher relatedness work in tandem to support student well-being, but that peer relatedness does not contribute to school engagement in the absence of teacher relatedness. These new insights are facilitated by a novel technique, cubic response surface analysis, which is introduced in the field to investigate socialization processes across multiple partners. Overall, peer and teacher relatedness appear to be interdependent factors of positive development, which changes the way psychological needs for relatedness are conceived in educational theories and opens new avenues for interventions aiming to foster healthy socialization processes at school.

Keywords: peer relatedness, teacher relatedness, well-being, school engagement, cubic response surface analysis

Supplemental materials: <https://doi.org/10.1037/edu0000910.supp>

Erika A. Patall served as action editor.

Fernando Núñez-Regueiro  <https://orcid.org/0000-0003-4784-2021>

Ming-Te Wang  <https://orcid.org/0000-0002-6170-5448>

This research was partly supported by a grant from the French National Research Agency in the framework of the Initiative d'excellence formation (project "Make a link!"). The authors report no conflicts of interest. This study was not preregistered. Materials and analysis code for this study are available on the Open Science Framework (<https://osf.io/z5jec/>), or by emailing the corresponding author. Part of this research was presented at the European Association for Research on Learning and Instruction

(Núñez-Regueiro et al., 2023).

Fernando Núñez-Regueiro served as lead for conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, software, validation, visualization, and writing—original draft. Ming-Te Wang served in a supporting role for conceptualization, validation, and writing—review and editing.

Correspondence concerning this article should be addressed to Fernando Núñez-Regueiro, Contextual Learning Research Laboratory (LaRAC), Université Grenoble Alpes, Bâtiment Michel Dubois, 1251, rue des Universités, 38400 Saint Martin d'Hères, France. Email: fernando.nunez-regueiro@univ-grenoble-alpes.fr

During adolescence, social relationships act as valuable coping resources as youth undergo changes in physical and psychosocial functioning (Smetana et al., 2015), including identity development (Smetana et al., 2015). Adolescents who feel connected to their peers (Ragelienė, 2016) and share reflective experiences with their teachers (Verhoeven et al., 2019) are more likely to have a stronger sense of identity. As such, researchers have concluded that socialization processes and, in particular, affective relations denoting feelings of relatedness (e.g., feeling accepted, connected, understood, close, included) are essential for adolescents' motivation at school, life satisfaction, and prosocial behavior (Núñez-Regueiro, 2017; Pitzer & Skinner, 2017; Ryan & Deci, 2020; Wang et al., 2019).

Adolescence is also characterized by a reconfiguration of socialization processes whereby adolescents distance themselves from the family system while becoming socioemotional closer with peers (Smetana et al., 2015). At the same time, social activities with peers (i.e., making new friends, integrating cliques, exploring romantic relationships) help adolescents define their role in the social hierarchy. Conflicts that arise within peer relationships have the potential to evoke personal disappointment or moral conundrums (Opatow, 1991), the consequences of which include spillover effects on conflicts with teachers (Pakarinen et al., 2018). Accordingly, qualitative studies have found that adolescents view conflicts with peers and teachers as major sources of stress in their lives (Núñez-Regueiro & Núñez-Regueiro, 2021).

These cumulative conflicts have the potential to undermine adolescents' feelings of relatedness and their capacity to cope with developmental changes; hence, it is critical that scholars better understand how relatedness with teachers and peers contributes to adolescents' well-being and engagement. With the two-study approach ($N_{\text{Study1}} = 643$, $N_{\text{Study2}} = 493$), we use cubic response surface analysis (RSA), a novel technique that allows the description of patterns of congruence or incongruence between peer and teacher relatedness and relates these patterns to the analysis of developmental processes.

Links Between Teacher and Peer Relatedness, Adolescents' Well-Being, and School Engagement

Relatedness is generally defined as a sense of belonging and connection to a community, assessed through students' self-reports of their feelings of acceptance, understanding, or support from specific social partners such as peers, teachers, and parents (Pitzer & Skinner, 2017; Ryan & Deci, 2020; Serie et al., 2021). Particularly during adolescence, teachers and peers serve as significant sources of relatedness, offering social support through caring relationships, expressions of affection, and appreciation for individuals (Smetana et al., 2015). The social support provided by these relationships and the resulting sense of relatedness have consistently shown positive associations with students' engagement in school and subjective well-being. According to systematic reviews and meta-analyses, youth's sense of peer camaraderie ($r = .32$, 95% confidence interval [CI] [0.28, 0.36]; Serie et al., 2021) and teacher support ($r = .209$, 90% CI [0.204, 0.213]; Chu et al., 2010) are positively related to indicators of psychological well-being (e.g., psychological and social adjustment, self-concept or self-esteem, happiness, life satisfaction), and negatively related to depressive symptoms (Gariépy et al., 2016). Similarly, affectionate teacher–student relationships ($r = .40$, 95% CI [0.35, 0.45]; Roorda et al., 2011) and feelings of belonging and acceptance from classmates (Mikami et al., 2017) have been associated with higher levels of emotional

and behavioral engagement (e.g., involvement in school work, motivation to learn, school liking, persistence; for a review, see Vollet, 2017). It appears, then, that both teacher and peer relatedness contribute to psychological and scholastic adjustment during adolescence, as also postulated by theories of self-determination of student motivation and well-being (Ryan & Deci, 2020) and self-system processes of school engagement and resilience (Núñez-Regueiro, 2017; Pitzer & Skinner, 2017; Wang et al., 2019).

Yet, this general conclusion leaves unanswered questions regarding the joint impact of peer and teacher relatedness on youth's engagement and well-being. First, it is unknown whether peer and teacher relatedness have cumulative effects on adolescents' well-being and engagement at school. This question has been addressed from a variable-centered approach via multivariate regression modeling with studies showing that both variables had additive, positive effects on task-focused behavior in class (Kiuru et al., 2014), emotional and behavioral engagement at school (Van Ryzin et al., 2009), school compliance and identification (Wang & Eccles, 2012), psychological well-being (Sarkova et al., 2014), and positive affects (King, 2015). These results can be interpreted as evidence that all sources of school relatedness (i.e., peers, teachers) matter for adolescents' development. However, a limitation of the variable-centered approach is that it provides no information on the impact of unbalanced levels of relatedness (e.g., high peer relatedness vs. low teacher relatedness, low peer relatedness vs. high teacher relatedness), as such configurations are not accounted for in the modeling strategy. One exception to the latter critique found that interaction effects between teacher and peer relatedness processes on student engagement were not significant (Wang & Eccles, 2012), which could indeed suggest that relatedness processes are independent. Simultaneously, another study demonstrated a positive relationship between the engagement levels of one's peer group and changes in one's own engagement, particularly when the level of teacher relatedness is initially low (Vollet et al., 2017). Although the study did not explicitly explore peer relatedness but rather focused on peers' levels of engagement, it suggests the potential existence of a peer-specific compensatory mechanism (see the next section).

Questions also remain as to whether different profiles of school relatedness exist during adolescence and how these profiles relate to indicators of well-being and engagement. These questions align with a person-centered approach that estimates profiles of students based on their levels of teacher relatedness, peer relatedness, and developmental outcomes, but very few studies have provided definitive answers. For example, Furrer and Skinner's (2003) engagement study classified children and early adolescents as a function of their rankings on indicators of relatedness with peers, teachers, and parents. Students with low levels of relatedness bestowed less behavioral and emotional engagement at school, and those with strong relatedness with adults (e.g., teachers, parents) were able to compensate for having low levels of relatedness with peers, although the reverse compensatory mechanism was not observed (Furrer & Skinner, 2003). While Furrer and Skinner's study investigated adolescents' school engagement, León and Liew's (2017) latent profile analysis examined the links between four relatedness profiles and students' psychological well-being (i.e., life satisfaction, vitality, self-esteem). The analysis revealed that students experiencing high levels of frustration (low peer and teacher relatedness) exhibited the lowest levels of psychological well-being, whereas highly satisfied students (high peer and teacher relatedness) demonstrated the highest levels of well-being. Results also revealed that

students with high peer relatedness but low teacher relatedness had significantly higher levels on certain well-being indicators (i.e., life satisfaction) than students with average relatedness levels. This finding indicated that peer relatedness had a compensatory effect on well-being in the absence of teacher relatedness, suggesting the presence of a “peer-specific compensatory process.” No evidence was found to support the “teacher-specific compensatory process” identified in Furrer and Skinner (2003) for engagement (León & Liew, 2017).

Although informative, the person-centered approach used in these studies is limited by the fact that the inferences made about relations between school relatedness profiles and outcome variables (engagement, well-being) were based on descriptive statistics dependent on a clustering solution (i.e., differences in means between the obtained profiles). The evidence on the impact of relatedness discrepancies (i.e., differing levels in peer and teacher relatedness) is therefore indirect. At best, these findings have provided a glimpse of the complex processes linking school relatedness patterns (peer-driven vs. teacher-driven) and youth development; however, it is possible that extant findings present an oversimplified picture of these processes. A novel theoretical and methodological approach is needed to overcome the limitations of variable-centered and person-centered approaches in understanding school relatedness processes.

Toward a School Relatedness Model of Adolescent Well-Being and Engagement: A Complex Social Ecology Approach

Building on Bronfenbrenner’s bioecological model (Bronfenbrenner, 1979), the complex social ecology model (Skinner et al., 2022) was developed to provide a conceptualization of the “collective influences” that social partners (e.g., parents, peers, teachers) may have on youth development and academic functioning (see Figure 1A). This model comprised three microsystems (i.e., family, peer, school), each containing specific “proximal processes” between the youth and the social partners involved. Of relevance to the present research, the school microsystem encompasses relationships with school-based peers and teachers and these relationships work together to jointly influence developmental and academic outcomes. Thus, this model provides an appropriate theoretical framework for school relatedness processes arising from the collective effects of peer and teacher relatedness on well-being and engagement at school.

The originality of the complex social ecology model lies in its delineation of the collective effects of social partners on youth’s academic development. Figure 1B offers an illustration of this approach, by portraying how the degree of relatedness provided by school-based peers and teachers can affect adolescents’ well-being and school engagement. In its current version, the complex social ecology model assumes collective effects on youth outcomes in the form of additive (b_1 , b_2) and interactive effects (b_4 ; Figure 1B). In the present research, we extend the mathematical operationalization of collective effects to include high-order effects in the form of cubic polynomial regression models. This extension increases the flexibility of the modeling approach and enables the identification of complexities beyond main or interactive effects.

Analyzing Complex School Relatedness Processes Using RSA: On Five Hypothetical Congruence Processes

The present research explores school relatedness processes within the school microsystem using cubic RSA, a modeling technique

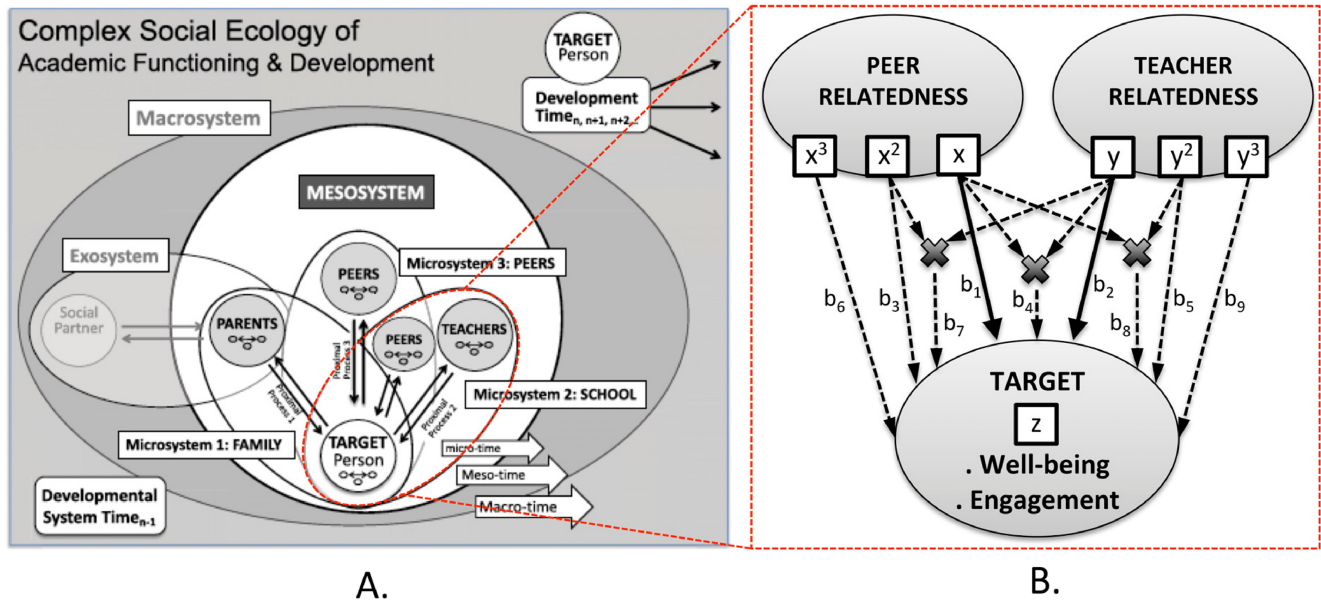
that allows school relatedness variables (e.g., x = peer relatedness, y = teacher relatedness) to have additive, interactive, quadratic, cubic, and interactive-quadratic effects on adolescent adjustment (e.g., z = psychological well-being or school engagement; Núñez-Regueiro & Juhel, 2022, 2024a, 2024b). The cubic polynomial model, which is composed of nine regression parameters (i.e., b_1 to b_9 in the model: $z = b_0 + b_1x + b_2y + b_3x^2 + b_4xy + b_5y^2 + b_6x^3 + b_7x^2y + b_8xy^2 + b_9y^3$; Figure 1B), can be set to different constraints to accommodate specific relatedness processes (for an illustration of specific processes and their respective constraints, see Figure 2), thus allowing for flexible structural relations between the predictor and outcome variables that are projected in the form of flat or curved surfaces. These surfaces represent how variations in the response variable depend on patterns of predictor values along the lines of congruence (LOC; $x = y$) or incongruence (LOIC, $x = -y$). From the perspective of school relatedness research, RSA can be seen as a mixed analytical approach that combines the structural relations of variable-oriented approaches (i.e., predictive effects of peer and teacher relatedness) with the typological characterization of person-oriented approaches (i.e., patterns of congruence or incongruence between peer and teacher relatedness). This novel approach allows for a nuanced analysis of the interplay between peer and teacher relatedness—that is, “congruence processes” in the RSA literature, or “collective effects” in the complex social ecology model. In two studies with distinct samples and comparable measures, we test five evidence-based congruence hypotheses regarding the relations between school relatedness and adolescent well-being or school engagement (for details on model specifications, see Table 1 and Appendix).

Based on the empirical evidence of univariate (i.e., meta-analyses) and multivariate (i.e., variable-centered approach) analyses, the first congruence hypothesis (Hypothesis 1 [H1]; Figure 2) assumes that (a) peer and teacher relatedness have additive positive effects on well-being or engagement ($b_1 > 0$, $b_2 > 0$) and (b) the effect of peer relatedness on well-being is slightly stronger than the effect of teacher relatedness (e.g., $b_1 = 0.32 > b_2 = 0.21$; Chu et al., 2010; Serie et al., 2021). Because high-order effects are ignored in this kind of evidence, H1 also assumes that these effects are null ($b_3 = \dots = b_9 = 0$). Collectively, these assumptions give rise to a response surface in the form of a positively inclined plane along the LOC represented by the solid line in Figure 2 (H1). Additionally, there is a slight positive tilt along the LOIC denoted by the dashed line in Figure 2H1. An alternative version of H1 could propose that the impact of teacher (vs. peer) relatedness on school engagement is more substantial, leading to a negative tilt along the LOIC. Yet, to our knowledge, meta-analytic evidence for the effect size of peer relatedness on engagement is absent within the extant literature. More generally, H1 can be viewed as a loose interpretation of developmental theories that conceptualize school relatedness as a cumulative process whose aggregate effects across multiple sources (i.e., peers, teachers)—as opposed to the isolated effect of a single source—matter most. In complex social ecology terms, H1 represents a process of “cumulative coaction” between peer and teacher relatedness (Skinner et al., 2022). Thus, students experiencing high levels of relatedness on one factor of relatedness (e.g., peers) and low levels on another (e.g., teachers) should have a similar motivational impact as those who have average levels on both factors.

The second hypothesis (Hypothesis 2 [H2]; Figure 2) can be viewed as a stricter interpretation of developmental theories. Instead of focusing on aggregate levels, this hypothesis asserts that

Figure 1

Cubic Polynomial Operationalization of Complex Social Ecology: Focus on the Collective Effects of Peers and Teachers on Well-Being and Engagement



Note. Complex social ecology (A; Skinner et al., 2022) meets cubic polynomial regression modeling (B; Núñez-Regueiro & Juhel, 2022, 2024a, 2024b) to obtain a mathematical operationalization of school microsystem's collective effects (peers, teachers) on youth development and academic functioning (well-being, student engagement). Solid arrows in Figure 1B represent additive or independent effects investigated in the literature, whereas dashed arrows represent complex, collective effects (nonlinearities, interdependencies). Specific hypotheses for RSA are presented in Figure 2. RSA = response surface analysis. See the online article for the color version of this figure.

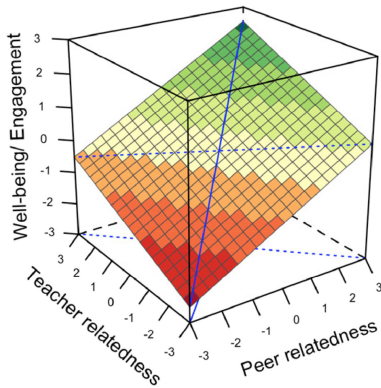
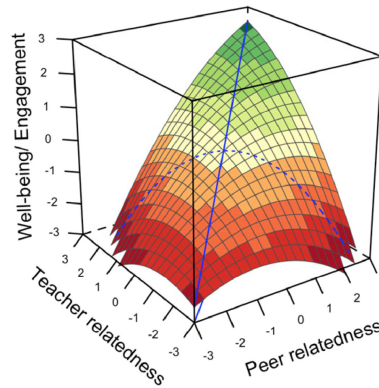
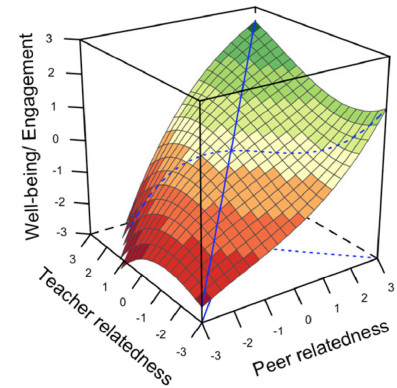
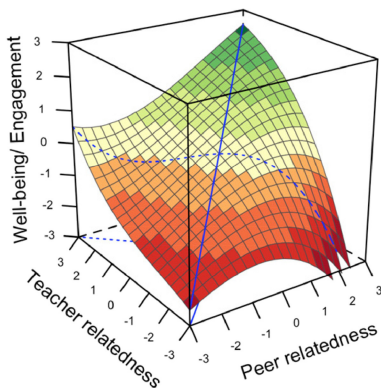
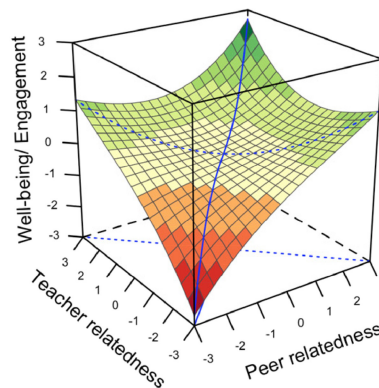
specific levels of relatedness matter for well-being and engagement. Although H2 assumes the same positive main effects of peer and teacher relatedness as H1 (i.e., $b_1 > 0, b_2 > 0$), it also assumes that these positive effects cumulate with each other when both factors of relatedness are present, but reverse in sign and become negative when one of the two factors is absent. Visually, this hypothesis is represented by an inverted-U relationship between relatedness levels along the LOIC where these levels oppose each other (i.e., $x = -y$). While no evidence exists on this process, developmental theories have postulated that deficiencies in at least one psychological need or resource (e.g., autonomy, competence, relatedness; Pitzer & Skinner, 2017; Ryan & Deci, 2020) or life good (e.g., excellence in agency, inner peace, community, pleasure, creativity; Serie et al., 2021) have the potential to compromise youth development, even when other needs or goods are satisfied. Following the same rationale, H2 assumes that being frustrated with one social partner at school (e.g., peer relatedness) can offset the beneficial effect of being satisfied with another social partner (e.g., teacher relatedness). This process—referred to as an interdependent needs (or resources) model of school relatedness (see Figure 2) or disabling effects in complex social ecology (Skinner et al., 2022)—is visually represented as a concave curvature with its ridge rising over the LOC, which corresponds to a negative congruence effect (Humberg et al., 2022; Núñez-Regueiro & Juhel, 2022, 2024a).

The next two hypotheses are more resonant with the person-oriented (vs. variable-centered) research on school relatedness and imply complex congruence processes over and above the positive additive effects of teacher and peer relatedness within H1. Both

Hypothesis 3 (H3) and Hypothesis 4 (H4) can be considered “asymmetric” in their postulation of disabling effects, positing that either peers or teachers play specialized roles, uniquely contributing to specific outcomes even if the relatedness with the other social partner is thwarted. However, the frustration of relatedness with one social partner will hinder the beneficial effects of satisfaction with the other (Skinner et al., 2022). More precisely, the third congruence hypothesis (H3; Figure 2) aligns with findings on peer-specific compensatory processes (León & Liew, 2017) in which high levels of peer relatedness can have a protective role on well-being in the absence of teacher relatedness, but the reverse is not true (i.e., high teacher relatedness is detrimental in the absence of peer relatedness). This hypothesis implies a positive asymmetric congruence effect (Humberg et al., 2022; Núñez-Regueiro & Juhel, 2022, 2024a). Because the peer-specific compensatory effect appears to be less adaptive than enjoying high levels on both relatedness factors (León & Liew, 2017), H3 also assumes that this positive asymmetric congruence effect is attenuated by a negative congruence effect, according to a combination of second- and third-order polynomial parameters (Núñez-Regueiro & Juhel, 2022, 2024b). In doing so, we effectively situate well-being levels (and presumably engagement levels) of students high in peer (but not teacher) relatedness, a bit lower than those of students high in both peer and teacher relatedness (see Figure 2, H3). The contrary formulation of this hypothesis aligns with H4 (Figure 2). In this context, the teacher-specific compensatory process observed in the analysis of student engagement implies the same parametric constraints as H3, but with the

Figure 2

Five Hypotheses About School Relatedness Processes Undergirding Adolescent Well-Being and School Engagement

H1**H2****H3****H4****H5**

Note. Hypotheses projected: (H1) cumulative risks or benefits process, (H2) interdependent needs (or resources) process, (H3) peer-specific compensatory process, (H4) teacher-specific compensatory process, (H5) complete (or nonspecific) compensatory process. Dashed and solid lines describe the response surface above the LOC ($x = y$) and LOIC ($x = -y$), respectively. Parameters are defined as in Table 1. H = Hypothesis; LOC = line of congruence; LOIC = line of incongruence. See the online article for the color version of this figure.

distinction of a negative sign in the asymmetric congruence process. Finally, Hypothesis 5 (H5; Figure 2) assumes that both peer and teacher relatedness have compensatory effects, thereby allowing for sustained levels of well-being and engagement if at least one relatedness factor is satisfied. For terminological coherence with H3 and H4, this process shall be called complete (or nonspecific) compensatory process; however, it should be noted that some have categorized this phenomenon as fully substitutive collective effects (Skinner et al., 2022). In terms of modeling, H5 can be viewed as the inverse of H2 in the sense that single-source relatedness is associated with higher adaptive levels (vs. lower adaptive levels in H2), as instantiated by a positive congruence effect (instead of negative in H2). Because H5 also assumes that high levels of relatedness on both factors (i.e., peers and teachers) are more adaptive than high levels on a single factor (Furrer & Skinner, 2003), a positive asymmetric incongruence process is assumed (Núñez-Regueiro & Juhel, 2022, 2024a). This specification yields a school relatedness model of well-being or engagement, where the fulfillment of any psychological

need or resource (i.e., peer or teacher relatedness) guarantees adequate youth adaptation. The optimal adaptation is observed in adolescents experiencing high relatedness with both peers and teachers.

Study 1: Test of Congruence Processes of School Relatedness Among High School Students

In Study 1, we tested five hypotheses on congruence processes underlying the relationship between school relatedness and adolescent outcomes (i.e., well-being, school engagement; Figure 2) in a sample of high school adolescents. Based on developmental theories, the empirical literature on variable-oriented and person-oriented research, and the complex social ecological model (Figure 1), it was expected that at least one of the five hypotheses would be confirmed. However, RSA has never been applied in this context; hence, the possibility remained that unexpected congruence processes would fit the data better. To account for both possibilities, we used a mixed

Table 1
Overview of Parametric Constraints and Polynomial Families of Study Hypotheses

Hypothesis	Parametric constraints	Polynomial family
H1. Cumulative risks or benefits process	$b_1 > b_2 > 0; b_3 = \dots = b_5 = 0; b_6 = \dots = b_9 = 0$	Additive effects
H2. Interdependent needs (or resources) process	$b_1 > b_2 > 0; b_3 = \frac{b_4}{-2} = b_5 < 0; b_6 = \dots = b_9 = 0$	Congruence effect
H3. Peer-specific compensatory process	$b_1 > b_2 > 0; b_3 = \frac{b_4}{-2} = b_5 < 0; b_6 = \frac{b_7}{-3} = \frac{b_8}{3} = -b_9 > 0$	Asymmetric congruence effect
H4. Teacher-specific compensatory process	$b_1 > b_2 > 0; b_3 = \frac{b_4}{-2} = b_5 < 0; b_6 = \frac{b_7}{-3} = \frac{b_8}{3} = -b_9 < 0$	Asymmetric congruence effect
H5. Complete compensatory process	$b_1 > b_2 > 0; b_3 = \frac{b_4}{-2} = b_5 > 0; b_6 = \frac{b_7}{3} = \frac{b_8}{3} = b_9 > 0$	Asymmetric incongruence effect

Note. First-order (b_1, b_2), second-order (b_3, b_4, b_5), and third-order (b_6, b_7, b_8, b_9) polynomial parameters describe the effects of peer relatedness (x) and teacher relatedness (y) on well-being or school engagement (z), according to the cubic polynomial model defined by $z = b_0 + b_1x + b_2y + b_3x^2 + b_4xy + b_5y^2 + b_6x^3 + b_7x^2y + b_8xy^2 + b_9y^3$. Polynomial families are predefined by nonzero constraints of higher order polynomials (for a list of 37 families and their constraints, see Núñez-Regueiro and Juhel (2022, 2024a). H = hypothesis.

modeling strategy to examine both confirmatory and exploratory congruence hypotheses (Núñez-Regueiro & Juhel, 2022, 2024a).

Method

Participants

Data were collected from 662 high school students (15–18 years old) living in the city of Grenoble and its suburbs, in the French Alps. The participants were evenly distributed across school grades, with 204 in Grade 10, 228 in Grade 11, and 230 in Grade 12. They exhibited similarity to the national population in both socioeconomic and academic demographics, as indicated in Table S1 in the online supplemental materials. Additionally, the majority (90.2%) followed an academic curriculum, while a smaller portion (9.8%) pursued a vocational curriculum. The sample had a disproportionately high level of female adolescents (75%) as compared to the national population (51%). Preliminary data inspection revealed the existence of careless respondents (3%), discerned through excessively rapid and inconsistent responses (Ward & Meade, 2023), and were subsequently excluded from the analyses. The final sample comprised 643 students.

Procedure

Prior to data collection, consent for the study was obtained from headmasters of participating schools. The data were then collected in April 2021 through an online questionnaire containing 47 items and the questionnaire was distributed using the schools' administrative mailing lists. In total, 662 adolescents agreed to participate, with 25% attending School 1, 37% attending School 2, and 38% attending School 3. Participation in the study was strictly voluntary and anonymous. On median, participants completed the questionnaire in 10 min.

Measures

Peer and Teacher Relatedness. The acceptance dimension of the perceived relatedness scale (*Echelle du sentiment d'appartenance sociale*; Richer & Vallerand, 1998) was used to measure adolescents' feelings of school relatedness with regard to peers and teachers. This scale contains five items measuring feelings of support, understanding, attention, valuing, and trust on a 7-point scale (1 = *not at all* to 7 = *very much*) in daily interactions with social partners, and these items were similar in content with relatedness scales used in previous studies. The scale was adapted so that

adolescents answered the scale twice, first with regard to peers (e.g., *In my relations with my other students, I feel understood*) and then with regard to teachers (e.g., *In my relations with my teachers, I feel understood*). Both scales showed excellent reliability in the present sample ($\omega_{\text{peers}} = .88, \omega_{\text{teachers}} = .91$).

Well-Being. Adolescent well-being was measured using the 12-item version of the General Health Questionnaire, validated among adolescents (Baksheev et al., 2011). This scale measures positive (e.g., happiness, pleasure, determination, efficacy, utility) and negative feelings about the self in daily life (reverse-coded, e.g., anxiety, low self-worth, pressure, depression, loss of confidence) on a 4-point scale. In the present sample, the scale showed good internal consistency ($\omega = .75$).

School Engagement. Adolescents' school engagement was measured using the four-item student engagement scale from the dropout prediction index (Archambault & Janosz, 2009). Using 4-point and 5-point Likert scales, this measure assesses the extent to which students appreciate school, value their school-related competencies, place importance on their academic achievements, and express a desire to pursue further education. Consequently, it embodies a comprehensive measurement approach concentrating on students' overall adaptation and commitment to the schooling process. This approach aligns with previous studies on relatedness (Roorda et al., 2011; Wang & Eccles, 2012) and conforms to widely used school engagement scales (e.g., Identification with School Questionnaire, Motivation and Engagement Scale, School Success Profile, Student Engagement Instrument; Fredricks & McColskey, 2012). To augment the scale's validity in the French high school context where curriculum tracking is an important issue (i.e., academic, technical, or vocational tracking), an item was added that inquired about students' satisfaction with their track (5-point scale). After reduction to common 4-point scores, these items provided a reliable measure of school engagement ($\omega = .69$) that accounted for multiple facets of the school experience.

Covariates. The questionnaire also measured confounding factors of well-being and engagement, including adolescents' gender (1 = *female adolescent*), parental socioeconomic status (SES) (1 = *low SES* to 4 = *high SES*), school grade (i.e., Grades 10 through 12), grade retention (0 = *no*, 1 = *yes*), academic ability as measured by results on national examinations (21-point scale, with higher scores indicating better achievement), and school track (0 = *academic or technical*, 1 = *vocational*). Other measures pertaining to school life, such as delegated status and assistance received during the middle school tracking process, were deemed irrelevant and consequently excluded from consideration.

Analytic Strategy

RSA. Using a general framework for RSA, school relatedness congruence processes were identified empirically via a three-step identification strategy (Núñez-Regueiro & Juhel, 2022, 2024a, 2024b). This general framework is based on the comparison of families of congruence processes (37 to date) that are implemented by imposing specific parametric constraints on polynomial parameters of the cubic model $z = b_0 + b_1x + b_2y + b_3x^2 + b_4xy + b_5y^2 + b_6x^3 + b_7x^2y + b_8xy^2 + b_9y^3$. More precisely, each family of congruence is characterized by constraints applied on first- (b_1, b_2), second- (b_3, b_4, b_5), or third-order polynomial parameters. Thus, higher order families (third-order and second-order) can be combined with lower order families (i.e., first- and second-order, respectively) to generate thousands of complex congruence processes. One of these processes will provide a best fit to the data, either expectedly (confirmatory hypothesis, as H1 through H5) or unexpectedly (exploratory hypothesis).

After integrating background covariates into the model, Step 1 of the identification strategy consisted in finding the best-fitting family based on tests of absolute fit against the saturated cubic model (to select candidate families), their relative degree of parsimony as indicated by Akaike information criterion (AIC) and Bayesian information criterion (BIC) weights¹ (wAIC and wBIC, respectively, to select most parsimonious solutions among candidates), explained variance (i.e., R^2 adjusted for model complexity), and fit indices, for example, comparative fit index (CFI) ≥ 0.95 , Tucker–Lewis index (TLI) ≥ 0.95 , root-mean-square error of approximation (RMSEA) ≤ 0.06 , standardized root-mean-square residual (SRMR) ≤ 0.08 . Step 2 then identified the best-fitting variant within the best-fitting family, by imposing constraints on lower order polynomial parameters in that family. This step was conducted by first gauging the presence of equality or zero constraints in the best-fitting family from Step 1, before evaluating their relevance by observing that the likelihood ratio test between models with and without these constraints was not significant ($p > .05$). Finally, Step 3 proved the robustness of results of the model-selection process conducted in Steps 1 and 2 using 1,000 bootstrapped samples to verify that the obtained 95% CI of nonnull parameters in the best-fitting variant did not contain the value zero.

The best-fitting variant was then interpreted by probing the curvatures of the response surface, using rationales for combining cubic polynomials (Núñez-Regueiro & Juhel, 2024b). These rationales facilitate the characterization of response behavior in congruence (LOC, peer relatedness = teacher relatedness) and incongruence patterns of relatedness (LOIC, peer relatedness = –teacher relatedness; see Appendix). This is achieved notably by identifying reversal processes, where the behavior changes sign (e.g., from increasing to decreasing), and acceleration processes, where the response undergoes significant changes in behavior (e.g., from gradually increasing to strongly increasing; Núñez-Regueiro & Juhel, 2024b). Accelerations were identified for rates of change reflecting moderate effect sizes, that is, $\left|\frac{\partial z}{\partial x}\right| = 0.30$ (or large effect sizes, i.e., $\left|\frac{\partial z}{\partial x}\right| = 0.50$ when the main effect was already above 0.30; Cohen, 1988), whereas reversals were identified by extrema where the acceleration is null, that is, $\frac{\partial^2 z}{\partial x^2} = 0.0$.

For ease of interpretation and to ensure commensurability between predictors (Núñez-Regueiro & Juhel, 2024d), all main variables (peer and teacher relatedness, well-being, school engagement) were standardized to zero means and unit variance prior to analysis. A maximum likelihood estimator with robust standard errors was

used to ensure the robustness of the analyses against deviations from normality and the presence of outliers (Maydeu-Olivares, 2017; Yuan & Zhong, 2013). However, data clustering was not taken into consideration due to the absence of information on student class membership (but see Study 2).

Treatment of Missing Data. Missing data (12% teacher relatedness; 25% parent SES) were accounted for using full information maximum likelihood (Graham, 2012). All student background characteristics (i.e., grade, gender, parent SES, grade retention, academic ability, school track) were included in the estimation algorithm to recover relevant information on the missing data. By using this strategy, all data were retained for data analysis, thus providing more valid results on congruence processes than strategies involving listwise deletion.

Models were estimated on *lavaan* (Rosseel, 2012), using the comparative framework for polynomial regression modeling and RSA implemented in the R package *RSATools* (Núñez-Regueiro & Juhel, 2024c; R Core Team, 2024).

Transparency and Openness

The design and analyses of this study were not preregistered. We provide details on data collection, all data exclusions, and the complete set of measures used in the study. Analyses code and data can be accessed on the Open Science Framework (<https://osf.io/z5jec/>), or by contacting the corresponding author.

Results

Descriptive Statistics

On average, adolescents reported high levels of relatedness to peers ($M = 4.9$), relatedness to teachers ($M = 4.6$), well-being ($M = 2.3$), and school engagement ($M = 3.1$; Table 2). Correlations between variables were significant at 5% and ranged from small ($r = .261$) to moderate for most variables ($r = .387$), but were trivial for the two outcome variables ($r = .130$). Although adolescents experiencing high levels of relatedness at school also tended to experience high levels of well-being and engagement, those with better mental health were not systematically more engaged at school.

School Relatedness Congruence Models of Adolescent Well-Being

The baseline model containing all covariates explained 6% of the variance in well-being, with significant negative effects evident for female adolescents and older students (in Grade 11 or 12; Table S2 in the online supplemental materials). Next, the comparison of families of congruence models (Step 1) showed that the family of congruence effect provided the best-fitting candidate, by passing the test of absolute fit ($\chi^2_6 = 5.9, p = .436$), showing the strongest parsimony (wAIC = .191, wBIC = .741) as well as excellent fit indices (CFI = 1.000, TLI = 1.003, RMSEA = 0.000, SRMR = 0.005), and explaining 17.1% of the variance in well-being (Table 2). An inspection of this model (Step 2) suggested that the effect of peer

¹ AIC (or BIC) weights represent conditional probabilities of parsimony, relative to the most parsimonious solution with the lowest AIC (or BIC) value. They provide the probability that a specific model is the most suitable among the candidate models, given the available data (Wagenmakers & Farrell, 2004).

Table 2
Descriptive Statistics

Variable	Theoretical range	<i>M</i>	<i>SD</i>	1	2	3
Study 1						
1. Peer relatedness	(1, 7)	4.96	1.26	—		
2. Teacher relatedness	(1, 7)	4.62	1.36	.387***	—	
3. Well-being	(1, 4)	2.28	0.51	.299***	.261***	—
4. School engagement	(1, 4)	3.08	0.52	.304***	.282***	.130**
Study 2						
1. Peer relatedness	(1, 5)	3.43	0.97	—		
2. Teacher relatedness	(1, 5)	3.43	1.18	.094*	—	
3. Well-being	(1, 5)	3.41	0.87	.376***	.203***	—
4. School engagement	(1, 5)	3.40	0.86	.181***	.439***	.349***

Note. *N* = 643 high school students (Study 1) and 493 middle and high school students (Study 2).

* $p < .10$. ** $p < .01$. *** $p < .001$.

relatedness ($b_1 = 0.233$) was twice as large as the effect of teacher relatedness ($b_2 = 0.122$; Table 5). Imposing this constraint provided a best-fitting variant for this family ($\chi^2_1 = 0.008$, $p = .930$) and produced a model with excellent fit (Table 3). Finally, bootstrapping procedures (Step 3) showed that the 95% CI of the obtained parameters from this best-fitting variant did not contain zero values; therefore allowing for valid postmodel-selection inferences (Table S5 in the online supplemental materials). Aligning with a process of interdependent needs (H2), the best-fitting model of well-being showed a concave response surface with its ridge rising over the LOC that had a negligible, positive shift toward the LOIC (i.e., at the reversal point, $\text{peer}_{\text{relatedness},r1} = 0.173$; red line [dark gray], Figure 3A1). This finding indicates that students with high levels of relatedness showed higher levels of well-being, but only when both sources of relatedness were equally provided for (i.e., positive trend on the LOC where peer relatedness = teacher relatedness, $b_1 + b_2 = 0.353$, $p < .001$; Table 5 and Figure 3A2). On the contrary, unequal

levels of relatedness (i.e., peer relatedness \neq teacher relatedness) were associated with significantly lower levels of well-being (Figure 3A3). A visual inspection of data points shows that realistic observations (i.e., nonoutliers) were observed across all relevant features of the surface (i.e., over and above the ridge, at low and high predictor values; see fence of the bagplot in Figure 3A1), thus providing full empirical support for the identified congruence process.

School Relatedness Congruence Models of School Engagement

Preliminary analyses of covariates indicated that female adolescents and adolescents with a more favorable social background and higher academic ability were more engaged than their peers. Together these covariates explained 18% of the variance (Table S2 in the online supplemental materials). Moreover, Step 1 of the identification strategy indicated that the model of asymmetric congruence effect showed excellent fit to the data ($\chi^2_3 = 1.9$, $p = .586$, CFI = 1.000, TLI = 1.031, RMSEA = 0.000, SRMR = 0.003) explaining 28% of the variance in school engagement and providing the most parsimonious model according to AIC weights (wAIC = .369; Table 4). A second family (i.e., the quadratic effect of *Y*) provided the most parsimonious solution according to BIC weights (wBIC = .318), but this model showed a poorer fit to the data (e.g., TLI = 0.872) and differed significantly from the saturated cubic model ($\chi^2_3 = 14.8$, $p = .022$). The first family (asymmetric congruence) was therefore retained as more valid.

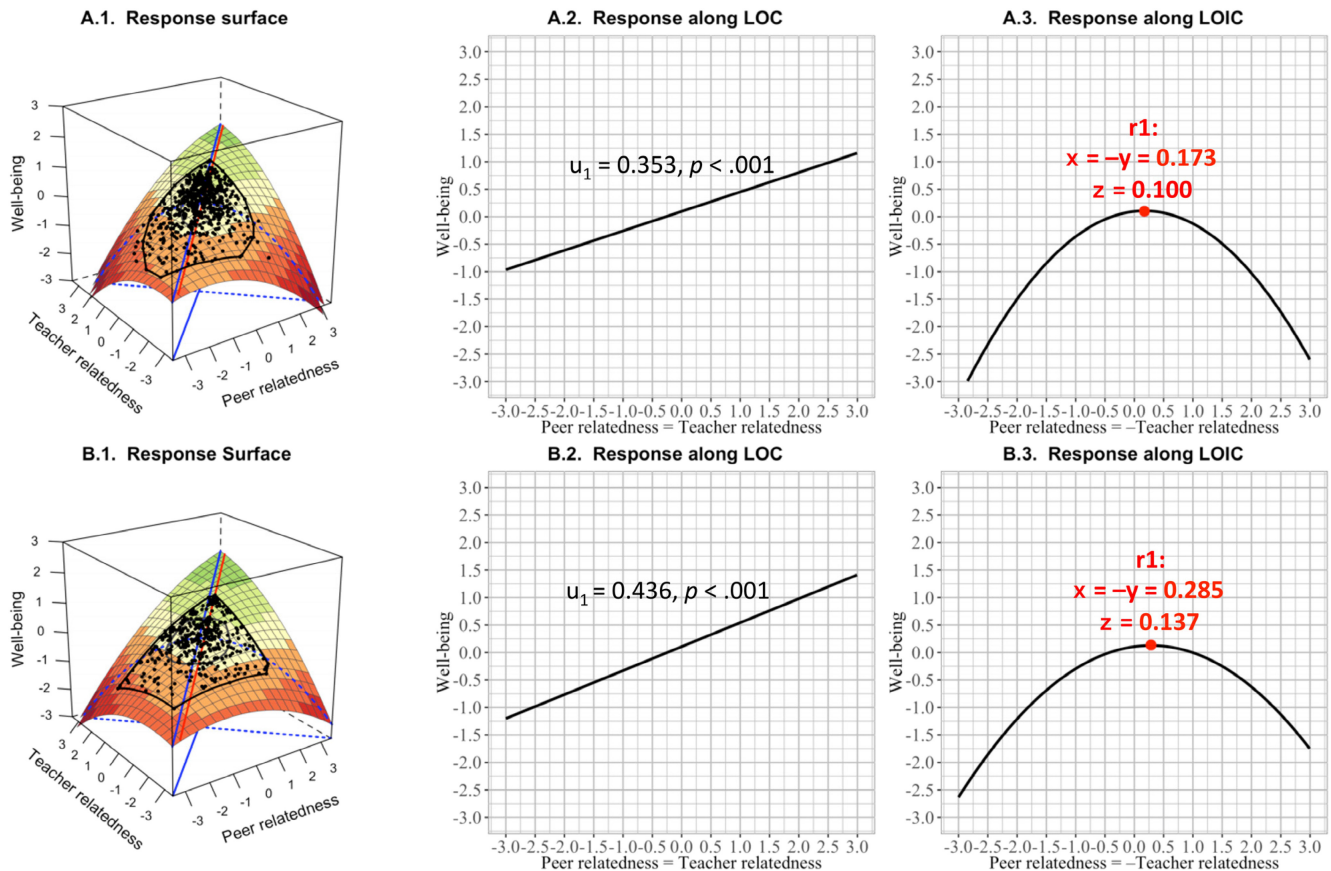
In Step 2, an inspection of lower order parameters in this model (i.e., b_1 to b_5) suggested that the effect of peer relatedness was thrice as large as the effect of teacher relatedness ($b_1 = 0.336$, $b_2 = 0.075$). The quadratic effect of peer relatedness ($b_3 = 0.016$, $p = .653$) and the interaction effect were null ($b_4 = -0.057$, $p = .212$; Table 5). Constraining these assumptions to be true obtained a variant of asymmetric congruence processes that did not differ significantly from the best-fitting family ($\chi^2_3 = 1.8$, $p = .608$), showed excellent fit to the data (Table 4), and was robust to postmodel-selection biases

Table 3
Fit Indices of Congruence Models of Well-Being

Model	χ^2	<i>df</i>	<i>p</i>	wAIC	wBIC	<i>R</i> ²	CFI	TLI	RMSEA	SRMR
Study 1										
Cubic model (saturated model)	0.0	0		.009	.000	.176	1.000	1.000	.000	.000
Congruence effect	5.9	6	.436	.191	.741	.171	1.000	1.003	.000	.005
Best-fitting variant (Step 2)	5.9	7	.552			.173	1.000	1.023	.000	.005
Nonparallel, asymmetric congruence and incongruence effects	0.8	3	.852	.122	.001	.176	1.000	1.105	.000	.001
Rotated congruence effect	5.5	5	.360	.086	.036	.170	0.995	0.986	.012	.005
Nonparallel, asymmetric weak congruence and strong incongruence	2.2	3	.537	.061	.000	.175	1.000	1.039	.000	.002
Study 2										
Cubic model (saturated model)	0.0	0		.008	.000	.325	1.000	1.000	.000	.000
Congruence effect	5.7	6	.454	.182	.534	.318	1.000	1.006	.000	.006
Best-fitting variant of 7 (Step 2)	5.8	7	.568			.319	1.000	1.023	.000	.006
Rotated congruence effect	5.6	5	.344	.071	.026	.316	0.994	0.984	.016	.006
Level-dependent incongruence effect rotated by <i>Y</i>	0.0	2	.993	.058	.000	.328	1.000	1.131	.000	.001
Congruence effect curved by <i>Y</i>	8.1	6	.229	.055	.161	.306	0.979	0.954	.027	.009

Note. *N* = 643 (Study 1) and 493 (Study 2). In plain characters, models correspond to families of fundamental models of congruence, which are compared in Step 1 of the identification strategy (for complete lists, see the online supplemental materials). Congruence models in bold and italic characters correspond to the best-fitting family (Step 1) and the best-fitting variant within the family (Step 2), respectively. wAIC = AIC weight; wBIC = BIC weight; CFI = comparative fit index; TLI = Tucker–Lewis index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual; AIC = Akaike information criterion; BIC = Bayesian information criterion.

Figure 3
Identified Response Surfaces for School Relatedness Models of Well-Being



Note. Interpretation of results from Study 1 (Line A) and Study 2 (Line B). For each outcome, graphs project the response surface (Column 1), the response along the LOC (Column 2), and the response along the LOIC (Column 3). The metaparameter $u_1 = b_1 + b_2$ corresponds to the slope of the response along the LOC. When curvatures exist, lines in green (light gray) and red (dark grey) intersect reversal (“r”) or acceleration points (“a”) on the LOC and LOIC, respectively. Coordinates are provided for reversal or acceleration points on the LOC and LOIC. The fence around data points corresponds to the fourth quartile of the bivariate boxplot delimiting realistic observations for inference. LOC = line of congruence; LOIC = line of incongruence. See the online article for the color version of this figure.

based on bootstrapped CIs (Table S5 in the online supplemental materials). According to the response surface of this best-fitting variant (Figure 3A1), the data were partly compatible with a peer-specific compensatory process for relatedness values near the mean (H3). For more extreme values (H4), the data were more compatible with a teacher-specific compensatory process. This finding was evident from the negative cubic effect along the LOIC and the rising, slightly curved trend on the LOC.

More precisely, for close-to-average values of peer relatedness, adolescents experiencing higher levels of peer relatedness than teacher relatedness tended to experience higher levels of school engagement (rising trend on the LOIC, $b_1 - b_2 = 0.208$, $p < .001$; Table 5), but this effect reversed in sign when reaching extreme points (see red lines [dark gray], Figure 4A3). When moving beyond the relative maxima on the LOIC ($\text{peer}_{\text{relatedness},r2} = -\text{teacher}_{\text{relatedness},r2} = 0.600$ SD, or a $0.600 \times 2 = 1.2$ SD excess in peer relatedness), reporting more peer than teacher relatedness was associated with lower levels of school engagement (Figure 4A3). Conversely, when moving below the relative minima on the LOIC ($\text{peer}_{\text{relatedness},r1} = -\text{teacher}_{\text{relatedness},r1} = -0.362$ SD, or a $0.362 \times 2 = 0.724$ SD excess in teacher

relatedness), the negative effect of experiencing higher levels of teacher relatedness (vs. peer relatedness) reversed in sign and became positive, eventually raising engagement levels (Figure 4A3). Moreover, students experiencing equivalent amounts of relatedness with peers and teachers (i.e., with predictor values near the LOC) experienced high levels of school engagement with increased amounts of relatedness (rising trend on the LOC, $b_1 + b_2 = 0.417$, $p < .001$; Table 3), but this positive effect became weaker when reaching the minima of the quadratic effect along the LOC ($\text{peer}_{\text{relatedness},r1} = -1.829$ SD; green line, Figure 3A1) and slowly reversed in sign for relatedness levels below this threshold (Figure 4A2). A visual inspection of data points indicated that these various characteristics of the response surface were contained within the bagplot of realistic predictor values, including all surfaces above or below extreme points.

Discussion

Study 1 confirmed that experiencing high levels of relatedness at school is important for students’ well-being and school engagement;

Table 4
Fit Indices of Congruence Models of School Engagement

Model	χ^2	df	p	wAIC	wBIC	R ²	CFI	TLI	RMSEA	SRMR
Study 1										
Cubic model (saturated model)	0.0	0		.049	.000	.284	1.000	1.000	.000	.000
Asymmetric congruence effect	1.9	3	.586	.369	.012	.284	1.000	1.031	.000	.003
Best-fitting variant (Step 2)	3.7	6	.722			.284	1.000	1.034	.000	.004
Asymmetric congruence effect rotated by X	0.8	2	.685	.244	.001	.285	1.000	1.054	.000	.002
Asymmetric congruence effect rotated by Y	1.9	2	.391	.140	.000	.283	1.000	1.005	.000	.003
Level-dependent incongruence effect rotated by Y	4.4	2	.113	.040	.000	.278	0.986	0.897	.043	.004
Study 2										
Cubic model (saturated model)	0.0	0		.019	.000	.310	1.000	1.000	.000	.000
Nonparallel, asymmetric congruence and incongruence effects	2.0	3	.576	.139	.003	.311	1.000	1.029	.000	.003
Best-fitting variant (Step 2)	3.9	6	.690			.312	1.000	1.029	.000	.007
Asymmetric incongruence effect	2.7	3	.440	.097	.002	.310	1.000	1.008	.000	.003
Asymmetric incongruence effect rotated by Y	0.9	2	.633	.087	.000	.311	1.000	1.046	.000	.002
Level-dependent congruence effect rotated by Y	1.0	2	.610	.084	.000	.311	1.000	1.043	.000	.002

Note. $N = 643$ (Study 1) and 493 (Study 2). In plain characters, models correspond to families of fundamental models of congruence, which are compared in Step 1 of the identification strategy (for complete lists, see the online supplemental materials). Congruence models in bold and italic characters correspond to the best-fitting family (Step 1) and the best-fitting variant within the family (Step 2), respectively. wAIC = AIC weight; wBIC = BIC weight; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual; AIC = Akaike information criterion; BIC = Bayesian information criterion.

however, experiencing school relatedness was not always adaptive when the source of relatedness was confined to a single actor (i.e., peers or teachers). This finding was particularly true for psychological well-being, which was most strongly related to school relatedness (in terms of explanatory power): Aligning with a process of interdependent needs (H2), the data showed that being low on one source of relatedness was detrimental to the beneficial effect of high relatedness from the other source. Moreover, the average student's engagement levels seemed to benefit from the experience of more peer (vs. teacher) relatedness (as seen in León & Liew, 2017), but the process reversed in valence for students experiencing higher levels of discrepancy

between peer and teacher relatedness. More precisely, when this difference was high (reaching approximately a 1 *SD* difference), experiencing high relatedness with teachers compensated for the absence of relatedness with peers so as to support high engagement levels (teacher-specific compensatory process), whereas low teacher relatedness was associated with low engagement.

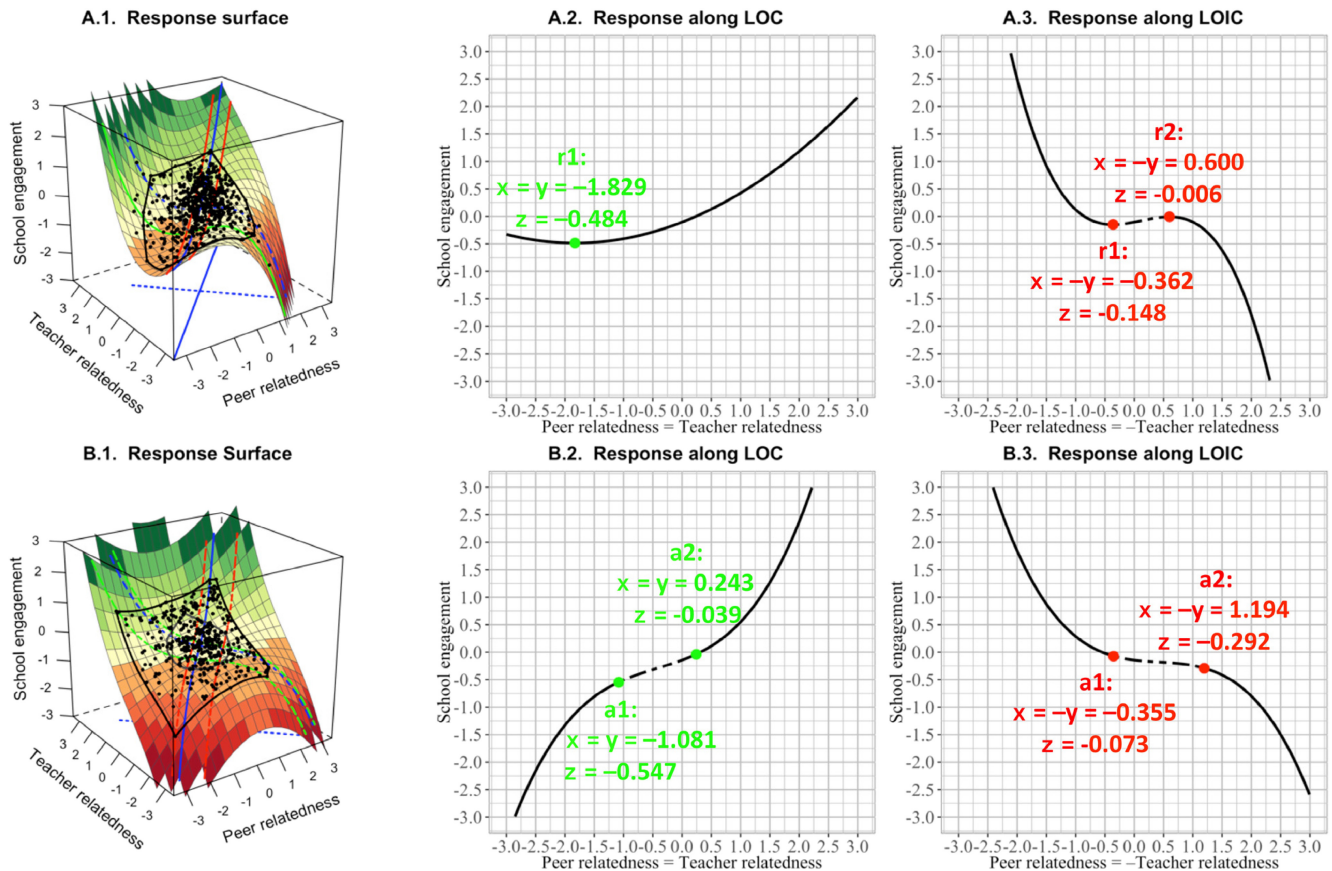
Although promising, these findings are limited by the fact that the type of analysis used (i.e., RSA) was the first of its kind in the area and some findings were original with regard to previous studies (i.e., process of interdependent needs for well-being). There is therefore a need to replicate these findings to verify that

Table 5
Polynomial Parameters of Selected Congruence Models

Model	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	$b_1 + b_2$	$b_1 - b_2$
Well-being (Study 1)											
Congruence effect	0.233	0.122	-0.085	0.169	-0.085	0.000	0.000	0.000	0.000	0.354	0.111
<i>p</i>	.000	.016	.000	.000	.000	Fixed	Fixed	Fixed	Fixed	.000	.173
Best-fitting variant	0.236	0.118	-0.085	0.170	-0.085	0.000	0.000	0.000	0.000	0.353	0.118
<i>p</i>	.000	.000	.000	.000	.000	Fixed	Fixed	Fixed	Fixed	.000	.000
Well-being (Study 2)											
Congruence effect	0.295	0.137	-0.064	0.128	-0.064	0.000	0.000	0.000	0.000	0.452	0.148
<i>p</i>	.000	.000	.028	.028	.028	Fixed	Fixed	Fixed	Fixed	.000	.072
Best-fitting variant	0.291	0.145	-0.064	0.128	-0.064	0.000	0.000	0.000	0.000	0.436	0.145
<i>p</i>	.000	.000	.028	.028	.028	Fixed	Fixed	Fixed	Fixed	.000	.000
School engagement (Study 1)											
Asymmetric congruence effect	0.336	0.075	0.016	-0.057	0.135	-0.045	0.135	-0.135	0.045	0.411	0.261
<i>p</i>	.000	.270	.653	.212	.000	.000	.000	.000	.000	.000	.042
Best-fitting variant	0.313	0.104	0.000	0.000	0.114	-0.040	0.120	-0.120	0.040	0.417	0.208
<i>p</i>	.000	.000	Fixed	Fixed	.003	.000	.000	.000	.000	.000	.000
School engagement (Study 2)											
Nonparallel asymmetric congruence and incongruence effect	0.138	0.285	0.047	-0.002	0.152	0.000	0.058	0.000	0.058	0.424	-0.147
<i>p</i>	.003	.000	.245	.946	.007	Fixed	.019	Fixed	.019	.000	.142
Best-fitting variant	0.132	0.264	0.000	0.000	0.166	0.000	0.066	0.000	0.066	0.396	-0.132
<i>p</i>	.000	.000	Fixed	Fixed	.001	Fixed	.001	Fixed	.001	.000	.000

Note. Cubic polynomial parameters are defined as in Table 1 and Figure 1.

Figure 4
Identified Response Surfaces for School Relatedness Models of Engagement



Note. See Figure 3 for an explanation of graphical features. LOC = line of congruence; LOIC = line of incongruence. See the online article for the color version of this figure.

these new contributions to relatedness research are not merely artifacts of the data used in Study 1 and can be observed in different research designs (i.e., independent sample, alternative measures of predictors and outcomes).

Study 2: Replication of Study 1

The aim of Study 2 was to replicate the findings from Study 1 by testing the five hypotheses on congruence processes (Figure 2) in a convenience sample of secondary school students. This replication aimed to use alternative measures of relatedness, well-being, and engagement while employing the same analytic strategy. This conceptual replication approach offers the advantage of assessing whether the earlier findings in Study 1 were influenced by unintended idiosyncrasies in the measurement of latent constructs, such as differences in item wording or the level of specificity of the construct. By replicating prior findings using alternative measures, greater confidence can be placed in the understanding that the observed processes are indeed associated with the intended constructs, rather than being influenced by idiosyncrasies in the constructs themselves (Fabrigar & Wegener, 2016). Based on Study 1, it was expected that the congruence hypothesis would provide the best fit to the data on adolescent well-being (Hypothesis 6

[H6]) and that a negative asymmetric congruence process would explain school engagement variations (Hypothesis 7 [H7]).

Method

Participants

Participants were 516 middle and high school students (age = 10–18 years old) from the same region as Study 1, but attending three different schools. The sample covered all grade levels of secondary school (i.e., Grades 6–12; $n = 54\text{--}116$), presented a slight overrepresentation of female adolescents (66%), and showed diversity in terms of social makeup (School 1: predominantly low or intermediate SES, $n = 120$; School 2: intermediate SES, $n = 221$; School 3: high SES, $n = 175$). Following the removal of careless respondents (4%), the final sample comprised 493 participants from 36 classes.

Procedure

The same data collection procedure from Study 1 was used for Study 2. The protocol was first validated by competent authorities before being launched in March 2023 using schools' administrative mailing lists of their students. The questionnaire, which was voluntary and anonymous, contained over 50 items and was completed in 9 min (median).

Measures

All measures reflected the same latent constructs as in Study 1, but different measures were used during data collection. This approach was chosen to test the robustness of previous findings to alternative measures.

Peer and Teacher Relatedness. School relatedness variables were measured using a needs-supplies fit framework that asked student about their ideal experience of relatedness (needs dimension), before asking them about actual experiences (supplies dimension). The present study focused on the latter. More precisely, peer relatedness was measured using the same scale as Study 1 (i.e., social acceptance from peers; Richer & Vallerand, 1998), but was adapted by substituting the item stem “In my relations with other students” by “In reality, when I am at school with my peers at school” (five items, $\omega_{\text{peers}} = .90$, sample item = “In reality, when I am at school with my peers at school, I feel understood”). Teacher relatedness was measured through two items that gauge the feelings of being understood and supported by the teacher. These items were drawn from the short version of the autonomy support scale within the Learning Climate Questionnaire (Williams & Deci, 1996) and were tailored for one of two disciplines (language arts or mathematics, assigned randomly; i.e., $\omega_{\text{teachers}} = .79$, sample item = “My <discipline> teacher makes me feel understood, my <discipline> conveys confidence in my ability to do well”). Both scales were measured using 5-point response scales (1 = *do not agree at all* to 5 = *very strongly agree*).

Well-Being. Aligning with the positive and negative dimensions of the General Health Questionnaire (Study 1), students’ well-being was operationalized as a compound measure of adolescent happiness (four items, $\omega_{\text{happy}} = .88$, sample item = *I feel happy*; Kern et al., 2016) and adolescent burnout at school (five items, $\omega_{\text{burnout}} = .81$, sample item = “I feel a lack of motivation for my schoolwork and often thing of giving up”; Salmela-Aro et al., 2009). Both scales measured items on a 5-point response scale (1 = *do not agree at all* to 5 = *very strongly agree*). To obtain a second-order construct of well-being, burnout items were reverse-coded. The measurement model for this second-order construct showed good fit to the data ($\chi^2_{27} = 86.5$, $p < .001$, CFI = 0.952, TLI = 0.937, RMSEA = .071, SRMR = .044) and good reliability ($\omega_{\text{well-being}} = .83$).

School Engagement. While Study 1 used a global measure of school engagement, Study 2 employed a specific measure grounded in the behavioral and emotional dimensions of the Engagement With Learning scale (Skinner et al., 2009). This scale evaluated students’ attitudes and behaviors toward learning activities in class, aligning with the approach in previous relatedness studies (Furrer & Skinner, 2003; Salmela-Aro et al., 2009; Van Ryzin et al., 2009) and other well-established school engagement measures in the literature (e.g., School Engagement Measure, School Engagement Scale, Engagement versus Disaffection with Learning scale; Fredricks & McColskey, 2012). Additionally, the scale was condensed in length and tailored to a specific discipline (three-item scales of behavioral and emotional engagement; Núñez & León, 2019). As a result, both the engagement items and teacher relatedness items focused on experiences within the same academic discipline (i.e., language arts or mathematics). Items for both facets of behavioral and emotional engagement were measured on a 5-point scale (1 = *do not agree at all* to 5 = *very strongly agree*). Scales were combined to obtain a general measure of classroom engagement with satisfactory reliability (six items, sample item = “In class of <discipline>, I work as hard as I can”; $\omega_{\text{engagement}} = .81$).

Covariates. Control variables included adolescents’ age, gender (1 = *female adolescent*), parental education level (1 = *primary school* to 4 = *higher education*), academic ability measured by grade point average (21-point scale), and education level (0 = *middle school*, 1 = *high school*).

Analytic Strategy

The same analytic strategy as in Study 1 was used for Study 2, including the general framework for RSA, the inclusion of covariates in the identification of congruence processes, and the treatment of missing data (1%–16%) using full information maximum likelihood (for details, see the Method section in Study 1). Final results accounted for 100% (well-being) and 95% (engagement) of the sample. To account for data clustering (students nested within classes), models were estimated using a “complex” sandwich estimator that corrects standard errors for class-level variance. This method has been shown to perform effectively in structural equation models (Muthén & Satorra, 1995).

Transparency and Openness

See Transparency and Openness statement in Study 1.

Results

Descriptive Statistics

Mean levels of relatedness, well-being, and engagement in class were moderately high, being just above the midpoint of scales (Table 2). Intercorrelations were similar to those seen in Study 1, that is, small to moderate in size and positive for all constructs. Two noteworthy differences from Study 1 were observed in Study 2. Firstly, peer and teacher relatedness were weakly correlated instead of strongly correlated ($r = .094$, $p = .066$). Conversely, well-being and engagement exhibited a stronger correlation ($r = .349$, $p < .001$). Despite these variations, the descriptive statistics indicated that the alternative operationalization of constructs in Study 2 maintained a similar, positive correlational structure between the major constructs.

School Relatedness Congruence Models of Adolescent Well-Being

Covariates explained 19% of the variance in well-being. According to this model, being a female and older student had negative effects on predicted levels of well-being (as in Study 1), whereas being academically able had a positive effect (Table S7 in the online supplemental materials). Polynomial models were then compared (Step 1), showing that the family of congruence effect provided the best-fitting candidate in terms of explained variance, parsimony, and fit indices (Table 3). As this family showed excellent fit to the data while also replicating the family observed in Study 1, it was retained as a best-fitting candidate with strong external validity.

In Step 2, a best-fitting variant was obtained by constraining the effect of peer relatedness ($b_1 = 0.295$) to be twice as large as the effect of teacher relatedness ($b_2 = 0.137$). This constraint did not induce significant decrements in model fit ($\chi^2_1 = 0.04$, $p = .846$) and produced a model with excellent fit indices ($\chi^2_1 = 5.8$, $p = .568$, CFI = 1.000, TLI = 1.023, RMSEA = 0.000, SRMR = 0.006) that explained

31.9% of the variance in well-being (see Table 3). The model was also robust to bootstrapping procedures (Step 3; Table S10 in the online supplemental materials). Regarding H6, an inspection of the response surface (see Figure 3B1) showed that the model fully replicated the congruence process seen in Study 1 (Figure 3A1) that corresponded to the process of interdependent needs of teacher and peer relatedness (Figure 2; H2). More precisely, this model of well-being showed a concave response surface with its ridge rising over the LOC, as well as positively shifted over the LOIC (i.e., at the maxima, $\text{peer}_{\text{relatedness},r1} = 0.285$; red line, Figure 3B1). Therefore, as in Study 1, high (low) levels of well-being were observed among adolescents experiencing high (low) relatedness with both peers and teachers (Figure 3B2), but these levels decreased significantly when one or the other source of relatedness was frustrated (Figure 3B3).

School Relatedness Congruence Models of School Engagement

Academic ability had a positive effect on levels of engagement that explained 9% of the variance (other covariates were nonsignificant; Table S7 in the online supplemental materials). Whereas the family of asymmetric congruence effect provided the best-fitting family in Study 1, the comparison of families (Step 1) showed that this family did not provide a good fit to Study 2's data, ranking 19th out of 37 families (Table S9 in the online supplemental materials). Based on this observation, an alternative best-fitting family was explored in the form of a nonparallel, asymmetric congruence and incongruence effects (i.e., a cubic model constraining interactive quadratic and cubic effects of peer and teacher relatedness on engagement to be equal, following the constraints: $b_7 = b_9$, $b_6 = b_8 = 0$). This family was the most parsimonious in terms of AIC weight ($w_{\text{AIC}} = .139$), had the greatest explanatory power ($R^2 = .311$), and showed excellent fit to the data ($\chi^2_1 = 2.0$, $p = .576$, CFI = 1.000, TLI = 1.029, RMSEA = 0.000, SRMR = 0.003; Table 4). A best-fitting variant of this family was then obtained ($\chi^2_1 = 1.9$, $p = .588$) by constraining the effect of peer relatedness ($b_1 = 0.138$) to be twice smaller than the effect of teacher relatedness ($b_2 = 0.285$), and the quadratic effect of peer relatedness ($b_3 = 0.047$, $p = .245$) as well as the first-order interaction effect to be null ($b_4 = -0.002$, $p = .946$). This final model showed excellent fit to the data, was robust to postmodel select inferences (i.e., bootstrapping; Table S10 in the online supplemental materials), and explained 31% of the variance in school engagement (Table 4).

The response surface of the final model (Figure 4B1) showed some similarities with the final model from Study 2 (Figure 4A1), notably in the form of a teacher-specific compensatory effect (Furrer & Skinner, 2003). More precisely, the negative trend along the LOIC ($b_1 - b_2 = -0.132$, $p < .001$; Table 5) mimicked the reversal effects (i.e., negative effects) of the asymmetric congruence process beyond extreme points in Study 1. According to this negative trend, students experienced significantly more engagement when they perceived more teacher than peer relatedness (Figure 4B3). Moreover, according to the asymmetric congruence effect of the model, this negative trend accelerated (i.e., became stronger) upon reaching more extreme levels of discrepancy in peer and teacher relatedness (Figure 4B3). More precisely, experiencing relative excess in teacher relatedness became particularly beneficial (of moderate effect size) to school engagement for a 1 *SD* difference (i.e., first acceleration point situated at $\text{peer}_{\text{relatedness},a1} = -\text{teacher}_{\text{relatedness},a1} = -0.355$ *SD*, or a $0.355 \times 2 = 0.710$ *SD* excess in teacher relatedness), whereas experiencing relative excess in peer

relatedness became particularly detrimental to school engagement for a 2 *SD* difference (i.e., second acceleration point situated at $\text{peer}_{\text{relatedness},a2} = 1.194$ *SD*, or a $1.194 \times 2 = 2.388$ *SD* excess in peer relatedness). Similarly, the positive trend on the LOC ($b_1 - b_2 = 0.396$, $p < .001$; Table 5) showed acceleration points (see Figure 4B2), indicating that the positive effect of experiencing equivalent amount of peer and teacher relatedness became substantial (i.e., large effect size) at extreme values situated below -1 *SD* (first acceleration point situated at $\text{peer}_{\text{relatedness},a1} = -1.081$) and above $1/4$ *SD* (second acceleration point situated at $\text{peer}_{\text{relatedness},a2} = 0.243$). In summary, the model of school engagement in Study 2 did not exactly replicate the process from Study 1, but it shared strong similarities regarding the shape (asymmetric curvature) of the teacher-specific compensatory process undergirding school engagement levels, and in the positive effect of congruent values (peer relatedness = teacher relatedness) on school engagement (partial validation of H7).

Discussion

Using alternative measures and an independent sample, Study 2 partially replicated the findings from Study 1. Study 2 also confirmed the importance of considering the source of relatedness that students experience at school rather than examining aggregated levels of relatedness across social partners. Fully replicating the congruence effect observed in Study 1, it was found that adolescent well-being was highest when relatedness was experienced with both peers and teachers, and well-being decreased significantly when one (or both) sources of relatedness were frustrated. Partially replicating the asymmetric congruence process in Study 1 and aligning with previous findings on student engagement (Furrer & Skinner, 2003), it was also found that higher teacher (vs. peer) relatedness was associated with increased levels of engagement in class, even at low levels of peer relatedness. However, the reverse pattern (i.e., high peer relatedness, low teacher relatedness) was associated with lower engagement levels. Thus, teacher relatedness provided a compensatory motivational resource to engage in class, whereas peer relatedness did not. As seen in Study 1, experiencing high levels of both peer and teacher relatedness was beneficial to well-being and engagement alike.

General Discussion

This study sought to understand how feelings of relatedness at school are associated with psychological well-being and school engagement. Moving beyond the consensual finding that experiencing more relatedness at school has beneficial effects on development, this research delved into whether these benefits are evident when the sources of relatedness are diversified and balanced (i.e., peers and teachers) or if some sources of relatedness (i.e., peers or teachers) are more advantageous than others in promoting optimal outcomes. The results from two independent studies converged, emphasizing the significance of experiencing balanced sources of relatedness at school. This extends prior research that primarily analyzed the developmental impact of peer or teacher relatedness in isolation from one another.

Peer and Teacher Relatedness Have Interdependent Effects on Well-Being

Peer and teacher relatedness had interdependent effects on well-being (validation of H2), indicating that (a) frustration on one source

of relatedness (e.g., teachers) compromised the benefits of experiencing high relatedness on the other source (e.g., peers), and (b) only equivalent and moderate to high amounts of relatedness on both sources supported well-being. Although adolescence is often associated with exploration of relationships with peers (Smetana et al., 2015), the present study shows that satisfying this need (i.e., feeling understood, supported, appreciated by peers) does not fully support one's well-being, especially in the absence of teacher relatedness. The fact that this process of interdependent needs provided the best fit to the data in two independent samples suggests strong external validity; yet, previous studies have reported the existence of a peer-specific compensatory process (H3) in which high levels of peer relatedness supported well-being (León & Liew, 2017). These contrasting results could be due to several factors. First, the latter study employed a clustering approach that analyzed well-being levels as a function of fixed patterns of relatedness (i.e., clusters). This approach does not necessarily reflect the complex structural relations revealed by polynomial models (i.e., RSA). Second, the cited study measured well-being at 5-month intervals whereas the present study measured well-being at the same time as relatedness. Given that these are dynamic processes, this time-lapse could have disrupted underlying structural relations. Third, it could be that the relations observed in the present context (France) differed from those cited in the literature (Spain). Therefore, future research using a similar research design (contemporaneous measures, cubic RSA) within different contexts is needed to probe the external validity of the present findings.

Teacher Relatedness Matters Most for Student Engagement

School engagement was found to be responsive to a teacher-specific compensatory process, validating H4. This process indicated that elevated levels of relatedness with teachers were adequate to sustain engagement levels, even when there was an absence of relatedness with peers. Conversely, experiencing high levels of peer relatedness did not contribute to optimal engagement when not accompanied by concomitant high levels of teacher relatedness. This finding strongly supports the notion that establishing a connection with teachers is pivotal for the development of emotions and behaviors reflecting a sense of belonging and connection with school activities, irrespective of the level of relatedness with peers (Furrer & Skinner, 2003). However, our findings partly contradict those of many variable-centered studies indicating that peer and teacher relatedness have independent effects on student engagement. On the one hand, our findings are in line with research demonstrating nonsignificant interaction effects between peer and teacher relatedness on engagement (Wang & Eccles, 2012). On the other hand, cubic polynomials in Study 1 and Study 2 revealed the presence of teacher-specific compensatory processes in the data, suggesting the involvement of higher level effects. However, structural disparities in the cubic processes, such as the asymmetric congruence effect versus nonparallel asymmetric congruence and incongruence effects, indicate the necessity for additional research to gain a better understanding of the nature of this process.

To our knowledge, these findings are the first to replicate the patterns reported by Furrer and Skinner (2003) and challenge the claim that relationships with peers are central to the quality of engagement in school activities (Mikami et al., 2017). A more nuanced assertion

is that the positive effects of peer relatedness on engagement are contingent on students also establishing a connection with teachers. This is not universally applicable to all students who experience relatedness with their peers. Moreover, these findings attest to the importance of operationalizing complex social processes using more comprehensive model specifications that move beyond main and interactive effects. In particular, they show that the extension of complex social ecology models (Skinner et al., 2022) to cubic polynomial modeling (Núñez-Regueiro & Juhel, 2022, 2024a, 2024b) is especially valuable to grasp the full complexity of collective effects within school microsystems.

Both Peer and Teacher Relatedness Are Needed for Optimal Youth Development

The extent to which adolescents establish connections with social partners at school matters for their psychological well-being and engagement in the educational process, and the complexity of these associations requires a thorough analysis of the configurations of the involved actors. While theoretical models and meta-analyses have generally concluded that feeling connected to peers or teachers is beneficial for youth development, this premise appears to hold true primarily when both sources of relatedness are simultaneously satisfied. For instance, the present data suggested that some adolescents were engaged in learning due to their connection with a single social partner at school (i.e., teacher relatedness without peer relatedness), and this imbalance exposed them to a risk of poor mental health. On the contrary, balanced levels of relatedness across social sources (peers and teachers) were systematically associated with optimal well-being and engagement. Such insights were facilitated by the simultaneous examination of academic and mental health outcomes, thereby validating a theoretical approach that contextualizes both types of outcomes within the same developmental framework, aligning with the complex social ecological model of development and academic functioning (Skinner et al., 2022).

This discovery sheds new light on theories of youth development by demonstrating that the psychological needs (Ryan & Deci, 2020), resources (Pitzer & Skinner, 2017), and primary goods of relatedness at school (Serie et al., 2021) are interdependent rather than merely complementary. The recognition of interdependencies served as a key motivation in developing the complex social ecological model, driven by the understanding that research should transcend the examination of isolated effects of social partners at school (Skinner et al., 2022). From this standpoint, the present study provides one of the first illustrations of how collective effects from both peers and teachers synergize to determine major developmental outcomes during adolescence.

Cubic RSA Offers a Powerful Framework for Investigating Complex Social Ecology

Methodologically, the present research also contributes to the field of research on complex social ecology by introducing cubic RSA as a powerful operational framework (see Figure 1). Whereas combinatory effects of social partners or learning contexts on learning and engagement processes had previously been conceptualized (Núñez-Regueiro, 2017; Skinner et al., 2022) and investigated (Fraser & Fisher, 1983; Núñez-Regueiro, 2018; Núñez-Regueiro & Leroy, 2024; Núñez-Regueiro, Jamain, et al., 2022; Wang &

Eccles, 2012) in the form of additive and interactive effects, the current study extended these approaches by augmenting the analytical framework to include higher order effects of the predictor variables (quadratic and cubic effects, parameters b_3 , b_5 , b_6 , b_9) and high-order interactive effects (quadratic interaction, parameters b_7 and b_8 ; Figure 1B; Núñez-Regueiro & Juhel, 2022, 2024a, 2024b).

Our approach considerably increased the flexibility of the resulting response surface, thus allowing for more precise hypotheses (Figure 2) and data modeling (i.e., increased fit to the real data). More precisely, the fact that the identification strategy allowed us to jointly test hypothesized and nonhypothesized processes was a strength of our approach as it guaranteed that best-fitting solutions were accounted for, at least for this degree of complexity (i.e., third-order polynomials). In combination with graphical projections, cubic RSA also enabled visualizing the processes at stake with great clarity and transparency. These numerous extensions (i.e., higher order parameters, precise hypotheses, mixed confirmatory-exploratory framework, graphical projections) proved essential to the analyses of both outcomes of interest (well-being, engagement), as the findings would have been quite different (and possibly misleading) without them.

In sum, cubic RSA seems to be particularly appropriate for those looking to investigate the proximal processes undergirding academic functioning and development. Future applications of the complex social ecology model may therefore prioritize this technique as a reliable and potent method for comprehending collective effects arising from multiple microsystems (parents, peers, teachers). This is particularly relevant when compared to simpler approaches, including quadratic RSA, which may not offer sufficient tests of nonlinearities when cubic processes are present in the data, as evidenced in engagement processes in the present study, but also in other investigations of complex interactive processes (e.g., needs-supplies fit processes at school, autonomous-controlled motivational effects; Núñez-Regueiro, 2024; Núñez-Regueiro, Juhel, & Wang, 2024; Núñez-Regueiro, Santana-Monagas, & Juhel, 2024). In such instances, limiting the analysis to quadratic RSA will overlook relevant nonlinearities in the data and obtain possibly misleading results.

Limitations

Interpretation of the current findings should be approached with consideration of several limitations. First, the data were measured concurrently; as a result, they do not provide insights into processes of change over time or illuminate causal relationships between the involved constructs. The complex relationships highlighted in the present findings suggest that achieving optimal development is highly improbable when the needs for relatedness with either peers or teachers remain unfulfilled. Yet, the data themselves could be driven by diverse causalities such as relatedness processes causing well-being/engagement or vice versa, as well as potential mediation processes linking teacher relatedness, student behavior, and peer relatedness (Endedijk et al., 2022). To identify the causalities at stake, conducting analyses of longitudinal relations between relatedness and developmental outcomes using the appropriate modeling techniques (e.g., random-effects cross-lagged panel models; Hamaker et al., 2015; Núñez-Regueiro, Juhel, et al., 2022; Núñez-Regueiro, Fayol, et al., 2024) are needed.

Moreover, it is important to note that our study did not account for relatedness with parents, which has been demonstrated to be nearly as crucial as teacher relatedness in fostering student engagement

(Furrer & Skinner, 2003). Furthermore, we did not explore how the academic adaptation of one's peer group might influence individual engagement in class, beyond the impact of relatedness to peers or teachers (Vollet et al., 2017). Future research with a complementary methodological approach should investigate whether and how parental relatedness could serve as a compensatory factor for deficiencies in relatedness at school. Additionally, it would be valuable to examine how relatedness processes (with peers, teachers, parents) are contingent upon the nature of the peer groups to which individuals relate.

This study was also the first to apply RSA in the relatedness research. Cubic RSA offers a powerful framework for understanding the interplay between psychological constructs, but we must first thoroughly probe this emerging technique to fully grasp its added value for understanding developmental processes. In the present study, we probed the robustness of cubic RSA findings using a convenience sample and a conceptual replication approach. This enabled us to exclude the possibility that replicated congruence patterns (e.g., of well-being processes) were due to "irrelevancies" in the measures (vs. effects of targeted constructs; Fabrigar & Wegener, 2016), but did not allow us to conclude whether the differences observed across Study 1 and Study 2 (e.g., of engagement processes) are due to the different operationalization of measures or, alternatively, to weaknesses in the identification strategy. In the future, it is crucial to conduct "exact" replication studies employing the same measures and identification techniques (three-step strategy) to validate whether the findings of this study can be replicated across both similar and dissimilar student populations. This includes exploring younger children or adolescents in countries other than France.

Finally, all measures in our study were self-reported by students, providing the advantage of richer information regarding personal experiences of relatedness and individual behavior, such as engagement with the schooling process or classroom activities. However, it is essential to acknowledge potential response biases, including consistency seeking, self-enhancement, and self-presentation (Paulhus & Vazire, 2007). While past studies have demonstrated convergent findings when using either teacher or student reports of engagement processes (Furrer & Skinner, 2003; Wang et al., 2016), future research could enhance methodological rigor by incorporating measures from independent observers to assess the robustness of findings across alternative measurement methods.

Implications and Conclusions

To establish balanced sources of relatedness and promote beneficial synergies, the current research proposes that interventions targeting healthy socialization processes at school should prioritize strategies that simultaneously address both peers and teachers. For example, brief interventions that train teachers to use autonomy-supportive teaching behaviors (Cheon et al., 2022), deliver engaging messages in class (León et al., 2023), or foster strong student relationships (Kincade et al., 2020) have been shown to increase students' perceived quality of relationships with peers and teachers, motivation to learn in class, and prosocial behavior. As such, these types of interventions should be considered robust and cost-effective measures to bolster school relatedness. Concurrently, the acknowledgment that positive synergies are contingent on the composition of the peer group should prompt practitioners to not only focus on individual students but also

consider the collective behavior of the peer group. This approach is particularly relevant in addressing students who associate with peers exhibiting lower levels of adjustment (Vollet et al., 2017).

In a broader context, future studies and interventions could incorporate various diversity factors, such as gender, race, ethnicity, culture, and age, to address the heterogeneity of relatedness experiences and their respective effects on engagement or well-being. For example, research suggests that peer relatedness may have more positive effects on youth development for some ethnic groups (e.g., European Americans) than for others (e.g., African Americans). These effects may be also more pronounced among younger students who are less advanced in their pubertal development, as they are more likely to accept parents' legitimate authority over peer socialization processes (Smetana et al., 2015). Similarly, positive teacher relationships appear to be more beneficial to student engagement and achievement among older youth and among female adolescents, who might benefit more from this source of social support (Roorda et al., 2011). Considering these diversity factors has the potential to provide insights into specific groups of adolescents who may be more sensitive to positive or negative socialization processes at school. This information can be valuable in prioritizing interventions among adolescents who may benefit the most from targeted support.

From a more fundamental perspective, it is critical to acknowledge the interdependency of peer and teacher relatedness effects in theoretical models of development. This recognition can pave the way for more comprehensive and nuanced conceptualizations that better capture the intricate dynamics of socialization processes in educational contexts. Further research is essential to explore the factors influencing the development of peer and teacher relatedness, along with investigating the reciprocal influences between these social actors throughout childhood and adolescence (Wang & Eccles, 2012). Additionally, there is a need for investigations into intermediate behavioral processes that might elucidate these influences (Endedijk et al., 2022). Theoretical frameworks that underscore the complexity of social ecologies (Skinner et al., 2022) can provide valuable resources to steer and shape this research agenda.

References

- Archambault, I., & Janosz, M. (2009). Fidélité, validité discriminante et prédictive de l'indice de prédiction du décrochage [Fidelity, discriminant and predictive validity of the Dropout Prediction Index]. *Canadian Journal of Behavioural Science/Revue Canadienne Des Sciences Du Comportement*, 41(3), 187–191. <https://doi.org/10.1037/a0015261>
- Bakshiev, G. N., Robinson, J., Cosgrave, E. M., Baker, K., & Yung, A. R. (2011). Validity of the 12-item General Health Questionnaire (GHQ-12) in detecting depressive and anxiety disorders among high school students. *Psychiatry Research*, 187(1–2), 291–296. <https://doi.org/10.1016/j.psychres.2010.10.010>
- Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Harvard University Press.
- Cheon, S. H., Reeve, J., Marsh, H. W., & Song, Y.-G. (2022). Intervention-enabled autonomy-supportive teaching improves the PE classroom climate to reduce antisocial behavior. *Psychology of Sport and Exercise*, 60, Article 102174. <https://doi.org/10.1016/j.psychsport.2022.102174>
- Chu, P. S., Saucier, D. A., & Hafner, E. (2010). Meta-analysis of the relationships between social support and well-being in children and adolescents. *Journal of Social and Clinical Psychology*, 29(6), 624–645. <https://doi.org/10.1521/jscp.2010.29.6.624>
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.
- Endedijk, H. M., Breeman, L. D., van Lissa, C. J., Hendrickx, M. M. H. G., den Boer, L., & Mainhard, T. (2022). The teacher's invisible hand: A meta-analysis of the relevance of teacher–student relationship quality for peer relationships and the contribution of student behavior. *Review of Educational Research*, 92(3), 370–412. <https://doi.org/10.3102/003465432111051428>
- Fabrigar, L. R., & Wegener, D. T. (2016). Conceptualizing and evaluating the replication of research results. *Journal of Experimental Social Psychology*, 66, 68–80. <https://doi.org/10.1016/j.jesp.2015.07.009>
- Fraser, B. J., & Fisher, D. L. (1983). Student achievement as a function of person-environment fit: A regression surface analysis. *British Journal of Educational Psychology*, 53(1), 89–99. <https://doi.org/10.1111/j.2044-8279.1983.tb02538.x>
- Fredricks, J. A., & McColskey, W. (2012). The measurement of student engagement: A comparative analysis of various methods and student self-report instruments. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 763–782). Springer. https://doi.org/10.1007/978-1-4614-2018-7_37
- Furrer, C. J., & Skinner, E. (2003). Sense of relatedness as a factor in children's academic engagement and performance. *Journal of Educational Psychology*, 95(1), 148–162. <https://doi.org/10.1037/0022-0663.95.1.148>
- Gariépy, G., Honkaniemi, H., & Quesnel-Vallée, A. (2016). Social support and protection from depression: Systematic review of current findings in Western countries. *The British Journal of Psychiatry*, 209(4), 284–293. <https://doi.org/10.1192/bjp.bp.115.169094>
- Graham, J. W. (2012). *Missing data: Analysis and design*. Springer Science & Business Media.
- Hamaker, E. L., Kuiper, R. M., & Grasman, R. P. (2015). A critique of the cross-lagged panel model. *Psychological Methods*, 20(1), 102–116. <https://doi.org/10.1037/a0038889>
- Humberg, S., Schönbrodt, F. D., Back, M. D., & Nestler, S. (2022). Cubic response surface analysis: Investigating asymmetric and level-dependent congruence effects with third-order polynomial models. *Psychological Methods*, 27(4), 622–649. <https://doi.org/10.1037/met0000352>
- Kern, M. L., Benson, L., Steinberg, E. A., & Steinberg, L. (2016). The EPOCH measure of adolescent well-being. *Psychological Assessment*, 28(5), 586–597. <https://doi.org/10.1037/pas0000201>
- Kincade, L., Cook, C., & Goerdt, A. (2020). Meta-analysis and common practice elements of universal approaches to improving student-teacher relationships. *Review of Educational Research*, 90(5), 710–748. <https://doi.org/10.3102/0034654320946836>
- King, R. B. (2015). Sense of relatedness boosts engagement, achievement, and well-being: A latent growth model study. *Contemporary Educational Psychology*, 42, 26–38. <https://doi.org/10.1016/j.cedpsych.2015.04.002>
- Kiuru, N., Pakarinen, E., Vasalampi, K., Silinskas, G., Aunola, K., Poikkeus, A.-M., Metsäpelto, R.-L., Lerkkanen, M.-K., & Nurmi, J.-E. (2014). Task-focused behavior mediates the associations between supportive interpersonal environments and students' academic performance. *Psychological Science*, 25(4), 1018–1024. <https://doi.org/10.1177/0956797613519111>
- León, J., & Liew, J. (2017). Profiles of adolescents' peer and teacher relatedness: Differences in well-being and academic achievement across latent groups. *Learning and Individual Differences*, 54, 41–50. <https://doi.org/10.1016/j.lindif.2017.01.009>
- León, J., Núñez-Regueiro, F., & Santana-Monagas, E. (2023). *Longitudinal relations between teacher engaging messages and student motivation to learn* [Manuscript submitted for publication]. Department of Education, Universidad Las Palmas de Gran Canaria.
- Maydeu-Olivares, A. (2017). Maximum likelihood estimation of structural equation models for continuous data: Standard errors and goodness of fit. *Structural Equation Modeling: A Multidisciplinary Journal*, 24(3), 383–394. <https://doi.org/10.1080/10705511.2016.1269606>

- Mikami, A. Y., Ruzek, E. A., Hafen, C. A., Gregory, A., & Allen, J. P. (2017). Perceptions of relatedness with classroom peers promote adolescents' behavioral engagement and achievement in secondary school. *Journal of Youth and Adolescence*, *46*(11), 2341–2354. <https://doi.org/10.1007/s10964-017-0724-2>
- Muthen, B. O., & Satorra, A. (1995). Complex sample data in structural equation modeling. *Sociological Methodology*, *25*, 267–316. <https://doi.org/10.2307/271070>
- Núñez, J. L., & León, J. (2019). Determinants of classroom engagement: A prospective test based on self-determination theory. *Teachers and Teaching*, *25*(2), 147–159. <https://doi.org/10.1080/13540602.2018.1542297>
- Núñez-Regueiro, F. (2017). Dropping out of school as a stress process: Heterogeneous profiles in the form of boredom and burnout. *L'orientation Scolaire et Professionnelle*, *46*(46/1), Article 1. <https://doi.org/10.4000/osp.5353>
- Núñez-Regueiro, F. (2018). *High school dropout: Analyzing the effects of stress processes and tracking, and dropout profiles* [Doctoral dissertation]. Université Grenoble Alpes.
- Núñez-Regueiro, F. (2024). Cubic relations of autonomous and controlled motivation to achievement: A cross-national validation of self-determination theory using response surface analysis. *Educational Psychology Review*, *36*(3), Article 71. <https://doi.org/10.1007/s10648-024-09905-x>
- Núñez-Regueiro, F., Fayol, M., Massonnié, J., Potocki, A., Hanner, C., Bianco, M., & Lima, L. (2024). *How reading and spelling co-develop over time* [Submitted for publication]. Department of Education, Université Grenoble Alpes.
- Núñez-Regueiro, F., Jamain, L., Laurent-Chevalier, M., & Nakhili, N. (2022). School engagement in times of confinement: A stress process approach. *Journal of Youth and Adolescence*, *51*(7), 1257–1272. <https://doi.org/10.1007/s10964-022-01621-5>
- Núñez-Regueiro, F., & Juhel, J. (2022). *Model-building strategies in response surface analysis* [Submitted for Publication]. <https://osf.io/ym32c>
- Núñez-Regueiro, F., & Juhel, J. (2024a). *Response surface analysis for the social sciences I: Identifying best-fitting polynomial solutions* [Submitted for publication]. Department of Education, Université Grenoble Alpes.
- Núñez-Regueiro, F., & Juhel, J. (2024b). *Response surface analysis for the social sciences II: Combinatory rationales for complex polynomial models* [Submitted for Publication].
- Núñez-Regueiro, F., & Juhel, J. (2024c). *RSAtools: Tools for advanced response surface analysis on R (0.1.0)* [R CRAN]. <https://CRAN.R-project.org/package=RSAtools>
- Núñez-Regueiro, F., & Juhel, J. (2024d). *Standardizing predictors in response surface analysis* [Manuscript in preparation].
- Núñez-Regueiro, F., Juhel, J., Bressoux, P., & Nurra, C. (2022). Identifying reciprocities in school motivation research: A review of issues and solutions associated with cross-lagged effects models. *Journal of Educational Psychology*, *114*(5), 945–965. <https://doi.org/10.1037/edu0000700>
- Núñez-Regueiro, F., Juhel, J., & Wang, M.-T. (2024). *Does needs satisfaction reflect positive needs-supplies-fit or misfit? A new look at autonomy supportive contexts using cubic response surface analysis* [Submitted for publication]. Department of Education, Université Grenoble Alpes.
- Núñez-Regueiro, F., & Leroy, N. (2024). Exploring the joint effects of stressors and resources on student engagement in teacher education: A French study. *Teaching Education*, *35*(3), 332–351. <https://doi.org/10.1080/10476210.2023.2286356>
- Núñez-Regueiro, F., & Núñez-Regueiro, S. (2021). Identifying salient stressors of adolescence: A systematic review and content analysis. *Journal of Youth and Adolescence*, *50*(12), 2533–2556. <https://doi.org/10.1007/s10964-021-01492-2>
- Núñez-Regueiro, F., Santana-Monagas, E., & Juhel, J. (2024). How needs-supplies fit processes with teachers, peers, and parents relate to youth outcomes: A theoretical and methodological extension of Self-Determination Theory. *Journal of Youth and Adolescence*. <https://doi.org/10.1007/s10964-024-02049-9>
- Núñez-Regueiro, F., Santana-Monagas, E., & León, J. (2023). *Are peer and teacher relatedness always adaptive? An analysis of (a)symmetric congruence processes* [Poster presentation]. Poster presented at the European Association for Research on Learning and Instruction (EARLI), Thessaloniki, Greece.
- Opatow, S. (1991). Adolescent peer conflicts: Implications for students and for schools. *Education and Urban Society*, *23*(4), 416–441. <https://doi.org/10.1177/0013124591023004005>
- Pakarinen, E., Silinskas, G., Hamre, B. K., Metsäpelto, R.-L., Lerkkanen, M.-K., Poikkeus, A.-M., & Nurmi, J.-E. (2018). Cross-lagged associations between problem behaviors and teacher-student relationships in early adolescence. *The Journal of Early Adolescence*, *38*(8), 1100–1141. <https://doi.org/10.1177/0272431617714328>
- Paulhus, D. L., & Vazire, S. (2007). The self-report method. In R. W. Robins, R. C. Fraley, & R. F. Krueger (Eds.), *Handbook of research methods in personality psychology* (Vol. 1, pp. 224–239). Guilford Press.
- Pitzer, J., & Skinner, E. A. (2017). Predictors of changes in students' motivational resilience over the school year: The roles of teacher support, self-appraisals, and emotional reactivity. *International Journal of Behavioral Development*, *41*(1), 15–29. <https://doi.org/10.1177/0165025416642051>
- Ragelienė, T. (2016). Links of adolescents identity development and relationship with peers: A systematic literature review. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, *25*(2), 97–105. <https://pubmed.ncbi.nlm.nih.gov/27274745/>
- R Core Team. (2024). *R: A language and environment for statistical computing (4.4)* [Computer software]. <https://www.R-project.org>
- Richer, S. F., & Vallerand, R. J. (1998). Construction et validation de l'échelle du sentiment d'appartenance sociale (ÉSAS) [Construction and validation of the ÉSAS the relatedness feelings scale]. *Revue Européenne de Psychologie Appliquée*, *48*(2), 129–138.
- Roorda, D. L., Koomen, H. M. Y., Spilt, J. L., & Oort, F. J. (2011). The influence of affective teacher–student relationships on students' school engagement and achievement: A meta-analytic approach. *Review of Educational Research*, *81*(4), 493–529. <https://doi.org/10.3102/0034654311421793>
- Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling and more. Version 0.5–12 (BETA). *Journal of Statistical Software*, *48*(2), 1–36. <https://doi.org/10.18637/jss.v048.i02>
- Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology*, *61*, Article 101860. <https://doi.org/10.1016/j.cedpsych.2020.101860>
- Salmela-Aro, K., Kiuru, N., Leskinen, E., & Nurmi, J.-E. (2009). School Burnout Inventory (SBI): Reliability and validity. *European Journal of Psychological Assessment*, *25*(1), 48–57. <https://doi.org/10.1027/1015-5759.25.1.48>
- Sarkova, M., Bacikova-Sleskova, M., Madarasova Geckova, A., Katreniakova, Z., van den Heuvel, W., & van Dijk, J. P. (2014). Adolescents' psychological well-being and self-esteem in the context of relationships at school. *Educational Research*, *56*(4), 367–378. <https://doi.org/10.1080/00131881.2014.965556>
- Serie, C. M. B., Van Damme, L., Pleyssier, S., De Ruyter, C., & Put, J. (2021). The relationship between primary human needs of the Good Lives Model (GLM) and subjective well-being in adolescents: A multi-level meta-analysis. *Aggression and Violent Behavior*, *61*, Article 101651. <https://doi.org/10.1016/j.avb.2021.101651>
- Skinner, E. A., Kindermann, T. A., & Furrer, C. J. (2009). A motivational perspective on engagement and disaffection: Conceptualization and assessment of children's behavioral and emotional participation in academic activities in

- the classroom. *Educational and Psychological Measurement*, 69(3), 493–525. <https://doi.org/10.1177/0013164408323233>
- Skinner, E. A., Rickert, N. P., Vollet, J. W., & Kindermann, T. A. (2022). The complex social ecology of academic development: A bioecological framework and illustration examining the collective effects of parents, teachers, and peers on student engagement. *Educational Psychologist*, 57(2), 87–113. <https://doi.org/10.1080/00461520.2022.2038603>
- Smetana, J. G., Robinson, J., & Rote, W. M. (2015). Socialization in adolescence. In J. E. Grusec & P. D. Hastings (Eds.), *Handbook of socialization: Theory and research* (pp. 60–84). Guilford Press.
- Van Ryzin, M. J., Gravely, A. A., & Roseth, C. J. (2009). Autonomy, belongingness, and engagement in school as contributors to adolescent psychological well-being. *Journal of Youth and Adolescence*, 38(1), 1–12. <https://doi.org/10.1007/s10964-007-9257-4>
- Verhoeven, M., Poorthuis, A. M. G., & Volman, M. (2019). The role of school in adolescents' identity development: A literature review. *Educational Psychology Review*, 31(1), 35–63. <https://doi.org/10.1007/s10648-018-9457-3>
- Vollet, J. W. (2017). *Capturing peers', teachers', and parents' joint contributions to students' engagement: An exploration of models* [PhD Thesis]. Portland State University.
- Vollet, J. W., Kindermann, T. A., & Skinner, E. A. (2017). In peer matters, teachers matter: Peer group influences on students' engagement depend on teacher involvement. *Journal of Educational Psychology*, 109(5), 635–652. <https://doi.org/10.1037/edu0000172>
- Wagenmakers, E.-J., & Farrell, S. (2004). AIC model selection using Akaike weights. *Psychonomic Bulletin & Review*, 11(1), 192–196. <https://doi.org/10.3758/BF03206482>
- Wang, M.-T., Degol, J. L., & Henry, D. A. (2019). An integrative development-in-sociocultural-context model for children's engagement in learning. *American Psychologist*, 74(9), 1086–1102. <https://doi.org/10.1037/amp0000522>
- Wang, M.-T., & Eccles, J. S. (2012). Social support matters: Longitudinal effects of social support on three dimensions of school engagement from middle to high school. *Child Development*, 83(3), 877–895. <https://doi.org/10.1111/j.1467-8624.2012.01745.x>
- Wang, M.-T., Fredricks, J. A., Ye, F., Hofkens, T. L., & Linn, J. S. (2016). The math and science engagement scales: Scale development, validation, and psychometric properties. *Learning and Instruction*, 43, 16–26. <https://doi.org/10.1016/j.learninstruc.2016.01.008>
- Ward, M. K., & Meade, A. W. (2023). Dealing with careless responding in survey data: Prevention, identification, and recommended best practices. *Annual Review of Psychology*, 74(1), 577–596. <https://doi.org/10.1146/annurev-psych-040422-045007>
- Williams, G. C., & Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *Journal of Personality and Social Psychology*, 70(4), 767–779. <https://doi.org/10.1037/0022-3514.70.4.767>
- Yuan, K.-H., & Zhong, X. (2013). Robustness of fit indices to outliers and leverage observations in structural equation modeling. *Psychological Methods*, 18(2), 121–136. <https://doi.org/10.1037/a0031604.supp>

Appendix

Details On Cubic Response Surface Analysis

The cubic polynomial model $z = b_0 + b_1x + b_2y + b_3x^2 + b_4xy + b_5y^2 + b_6x^3 + b_7x^2y + b_8xy^2 + b_9y^3$ is composed of first-order (b_1 to b_2), second-order (b_3 to b_5), and third-order regression parameters (b_6 to b_9) which are responsible, respectively, for trends, curvatures, and asymmetric curvatures in the response surface z . By combining specific constraints across first-order to third-order polynomial parameters, this mathematical decomposition can generate over 2,000 congruence hypotheses grouped around families of polynomial models (37 families or FMs to date; for a list, see Núñez-Regueiro & Juhel, 2022, 2024a). In this approach, the lines of congruence (LOC; $x = y$) and incongruence (LOIC; $x = -y$) have heuristic value for hypothesis generation, because substituting y by x values rewrites the cubic model twofold:

$$\begin{aligned} z(\text{LOC}) &= b_0 + (b_1 + b_2)x + (b_3 + b_4 + b_5)x^2 \\ &\quad + (b_6 + b_7 + b_8 + b_9)x^3 \\ z(\text{LOIC}) &= b_0 + (b_1 - b_2)x + (b_3 - b_4 + b_5)x^2 \\ &\quad + (b_6 - b_7 + b_8 - b_9)x^3. \end{aligned} \quad (\text{A1})$$

By imposing constraints on these two models, one can make precise hypotheses concerning the behavior of the outcome along the LOC and LOIC, which can then be combined to generate complex congruence hypotheses. In the present study, five congruence processes were conceived based on theoretical hypotheses about the combinatory effects of peer and teacher relatedness on well-being and engagement. As is summarized in Table 1 (see the main text),

the hypothesis of cumulative risks of benefits (Hypothesis 1) was implemented by assuming that parameters responsible for curvatures were null (i.e., $b_3 = \dots = b_9 = 0$), while assuming that the effects of peer and teacher relatedness on well-being or engagement were both positive and slightly larger for the former (i.e., $b_1 > b_2 > 0$), thus obtaining a positive trend along the LOC ($b_1 + b_2 > 0$; solid line, Figure 2H1) and a slightly positive trend along the LOIC ($b_1 - b_2 > 0$; dashed line, Figure 2H1), from the family of additive effects (FM3). The hypothesis of interdependent needs or resources (Hypothesis 2) was specified by assuming that predictors have negative quadratic effects of equivalent size (i.e., $b_3 = b_5 < 0$) and a positive interactive effect two times larger than quadratic effects (i.e., $b_4 = 2 * -b_3 = 2 * -b_5 > 0$), thus creating a concave curvature along the LOIC ($b_3 - b_4 + b_5 < 0$), with its ridge rising over the LOC ($b_1 + b_2 > 0$) and slightly shifted positively over the LOIC ($b_1 - b_2 > 0$), also called “rising ridge congruence effect” (Humberg et al., 2022), from the family of congruence effects (FM7). The third hypothesis of peer-specific compensatory processes (Hypothesis 3 [H3]) implied a positive cubic effect along the LOIC specified by a positive asymmetric congruence effect (i.e., FM20; $b_6 = b_7 / -3 = b_8 / 3 = -b_9$; Humberg et al., 2022), but also an attenuation of the latter by a negative congruence effect (i.e., $b_3 = b_4 / -2 = b_5 < 0$; FM7). This effectively situated well-being levels (and, presumably, engagement levels) of students high in peer relatedness only, a bit lower than those of students high in both peer and teacher relatedness. The hypothesis of teacher-specific compensatory process (Hypothesis 4) implied the same parametric constraints as H3, and only differed with

regard to the negative sign of the asymmetric congruence process (i.e., $b_6 = b_7/-3 = b_8/3 = -b_9 < 0$). The last hypothesis of complete compensatory process (Hypothesis 5) was obtained by combining a positive congruence effect inducing convex curvature along the LOC to reflect the compensatory effects of both teacher and peer relatedness (i.e., $b_3 = b_4/-2 = b_5 > 0$; FM7), with a positive asymmetric incongruence process to induce an asymmetric curvature along the LOIC (i.e., $b_6 = b_7/3 = b_8/3 = b_9$; FM21). This specification reinforced the sensitivity of the response to extreme predictor values and, in particular, increased the standing of congruent values above the mean ($x = y > 0$) relative to the

standing of incongruence values above the mean ($x = -y > 0$ or $-x = y > 0$). Details on fundamental polynomials, rationales for their combination, a typology of complex congruence processes, dedicated software, and other illustrative examples are provided elsewhere (Núñez-Regueiro, 2024; Núñez-Regueiro & Juhel, 2022, 2024a, 2024b, 2024c; Núñez-Regueiro, Juhel, & Wang, 2024; Núñez-Regueiro, Santana-Monagas, & Juhel, 2024).

Received September 26, 2023

Revision received June 15, 2024

Accepted June 18, 2024 ■