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Students' relatedness with peers and teachers in secondary education: distinct associations with student motivation and engagement

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Abstract
Positive relationships with classmates and teachers are essential for fostering student motivation and engagement. However, existing research often fails to differentiate between these two sources of relatedness and overlooks relatedness frustration. This study addresses these gaps by adapting the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS) to distinguish between peer and teacher relatedness satisfaction and frustration in secondary physical education (PE) and investigating their unique associations with student motivation and engagement. The study involved 1043 secondary PE students (59% girls; mean age = 15.48 ± 1.65) from 76 classes. Participants completed the adapted BPNSFS and scales assessing motivation (intrinsic, identified, introjected, external, and amotivation) and engagement (behavioral, emotional, cognitive, and agentic). Factor analyses supported a four-factor model differentiating peer and teacher relatedness satisfaction and frustration. Linear mixed-effects models revealed that peer and teacher relatedness satisfaction were positively associated with beneficial outcomes, while frustration was related to adverse outcomes. Notably, teacher relatedness satisfaction had stronger associations with adaptive outcomes, such as autonomous motivation and engagement, compared to peer relatedness satisfaction. In contrast, peer relatedness frustration showed stronger links with maladaptive outcomes, such as controlled motivation and lower agentic engagement, compared to teacher relatedness frustration. These findings enhance our understanding of the distinct roles peers (i.e., classmates) and teachers play in shaping students' classroom experiences, emphasizing the importance for PE teachers to develop supportive teacher-student relationships while mitigating negative relationships between students. The modified BPNSFS provides a nuanced tool for future research.

Keywords Self-determination theory · Basic psychological needs · Student-teacher relationships · Teacher-student relationships · Peer relationships · Classroom relatedness

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1 Introduction

Relatedness, a fundamental concept in Self-Determination Theory (SDT; Deci & Ryan, 2000; Ryan & Deci, 2017), refers to the innate human need to feel connected, valued, and cared for by others. SDT posits that satisfying the need for relatedness, alongside the needs for autonomy and competence, is essential for individuals to experience intrinsic motivation and optimal functioning. In educational settings, relatedness plays a crucial role in shaping student motivation and engagement (Ladd et al., 2009; Wentzel, 2009; Xiang et al., 2017), which are key predictors of academic success and overall well-being (Fredricks et al., 2004; Ryan & Deci, 2017). However, despite the clear importance of relatedness in education, a recent meta-analysis of SDT interventions found that relatedness was the least studied of the three basic psychological needs (Wang et al., 2024a, 2024b), underscoring the need for more research in this area.

Secondary education is a critical period to study relatedness and motivation due to the significant changes students experience in their social relationships, academic motivation, and engagement. Peer relationships become increasingly complex and influential (Rubin et al., 2006; Veenstra & Dijkstra, 2011), while teacher-student relationships transform as students strive for greater independence (Eccles et al., 1993; Lynch & Cicchetti, 1997). Moreover, the decline in motivation and engagement often experienced by students during this period (Gillet et al., 2012; Wang & Eccles, 2012) emphasizes the need to understand how relatedness can support these outcomes during this transformative stage of development.

1.1 The importance of distinguishing between peer and teacher relatedness

At school, students' sense of relatedness to peers and teachers has distinct dynamics (Ladd et al., 2009; Wentzel, 2009). Peer relationships are characterized by equality, shared experiences, and mutual interests, whereas teacher-student relationships are marked by differences in authority, expertise, and responsibility (Hartup, 1989; Wentzel, 2022). Given these differences, it is crucial to examine peer and teacher relatedness separately to gain a more comprehensive understanding of their unique contributions to students' academic experiences and outcomes.

In this study, we use the terms "teacher relatedness satisfaction" and "teacher relatedness frustration" to refer to students' experiences of relatedness satisfaction and frustration in their relationships with their teachers. For example, a student with high teacher relatedness satisfaction feels that their teacher genuinely cares about them and supports their learning, while a student with high teacher relatedness frustration feels that their teacher is cold or dismissive (Ryan & Deci, 2017; Vansteenkiste & Ryan, 2013). Similarly, "peer relatedness satisfaction" and "peer relatedness frustration" refer to students' experiences of relatedness satisfaction and frustration in their relationships with their classmates. A student with high peer relatedness satisfaction feels accepted and valued by their peers, while a student with high peer

relatedness frustration feels excluded, ignored, or even bullied by their classmates (Ryan & Deci, 2017; Vansteenkiste & Ryan, 2013).

Several studies in secondary education have demonstrated that teacher and peer relatedness satisfaction are distinct constructs, each contributing independently to various student outcomes (Cox & Ullrich-French, 2010; Cox et al., 2009; Gairns et al., 2015; King, 2015; Shen et al., 2012; Wakefield, 2016; Xiang et al., 2017). However, the influence of teacher and peer relatedness satisfaction often differs depending on the specific outcome. For example, in general education, teacher relatedness satisfaction has been found to have a stronger influence on outcomes such as identified regulation (Guay et al., 2017) and overall autonomous school motivation and adjustment (Ryan et al., 1994) compared to peer relatedness satisfaction. In contrast, peer relatedness satisfaction has been shown to have a greater impact on disengagement (King, 2015). In the context of physical education (PE), findings are mixed. While one study found that teacher relatedness satisfaction was more strongly related to behavioral and emotional engagement (Shen et al., 2012), another study reported that while peer relatedness satisfaction had a positive relationship with emotional and cognitive engagement, teacher relatedness satisfaction did not (Xiang et al., 2017). These inconsistencies highlight the need for more research on how relationships with peers and teachers relate to student motivation and engagement, especially in PE.

1.2 Gaps of relatedness research in secondary education

Despite the emerging evidence supporting the importance of distinguishing between peer and teacher relatedness in secondary education, several gaps in the literature remain.

1.2.1 Limited number of studies and lack of differentiation in measures

First, the number of studies comparing the impact of peer and teacher relatedness in secondary education is relatively limited. This scarcity stems partly from the lack of differentiation between peer and teacher relatedness in some widely used measures, such as the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS; Chen et al., 2015). In general education research, the BPNSFS typically refers to "people" without specifying the source of relatedness (Buzzai et al., 2021; Krijgsman et al., 2019; Wang et al., 2024a, 2024b). Similarly, in PE research, it often refers only to "classmates," measuring peer relatedness without considering teacher relatedness (Behzadnia et al., 2018; De Meyer et al., 2016; Haerens et al., 2015; Van Doren et al., 2023). In addition to the BPNSFS, several other scales used for measuring relatedness in educational research do not distinguish between peer and teacher relatedness (e.g., Cordeiro et al., 2016; Moreno et al., 2008; Tian et al., 2014).

Although some recent studies have begun to adapt widely used measures like the BPNSFS to separately assess peer and teacher relatedness, these adaptations have primarily been conducted in higher education (e.g., Fedesco et al., 2019). The unique social dynamics and developmental challenges of secondary education

(Brown & Larson, 2009; Eccles & Roeser, 2011), however, underscore the need for validated measures that differentiate between peer and teacher relatedness in this specific context.

1.2.2 Limited examination of relatedness frustration

Second, studies comparing peer and teacher relatedness in secondary education often do not separately measure relatedness frustration (Cox & Ullrich-French, 2010; Cox et al., 2009; Gairns et al., 2015; King, 2015; Shen et al., 2012; Wakefield, 2016; Xiang et al., 2017). Scales that measure both peer and teacher relatedness often combine relatedness satisfaction and frustration into a composite score (e.g., Furrer & Skinner, 2003) or only measure relatedness satisfaction (e.g., Richer & Vallerand, 1998).

Not measuring relatedness frustration separately is a critical oversight, as need frustration has been found to be a stronger predictor of maladaptive outcomes, such as ill-being, disengagement, and oppositional defiance, compared to low need satisfaction (Costa et al., 2015; Haerens et al., 2015; Vasconcellos et al., 2020). Consequently, when relatedness frustration is not evaluated independently, studies are likely to underestimate the influence of negative peer and teacher relationships on student outcomes. Furthermore, it remains unclear whether negative relationships with teachers or peers have a greater adverse effect on students.

1.2.3 Lack of comprehensive assessment of motivation and engagement

Third, studies rarely examine the relationship of peer and teacher relatedness with a broad range of student motivation and engagement types (e.g., Guay et al., 2017; Shen et al., 2012; Xiang et al., 2017). Distinguishing between these different types of motivation and engagement is crucial because they represent distinct qualities of students' experiences and have differential implications for learning outcomes and well-being (Deci & Ryan, 2000; Skinner et al., 2008).

According to SDT, motivation types exist along a continuum from autonomous to controlled forms of motivation (Ryan, 2023). Intrinsic motivation, the most autonomous form, refers to students engaging in activities for their inherent satisfaction and enjoyment, such as a genuine interest in the subject matter. Identified regulation, a relatively autonomous form of extrinsic motivation, involves students valuing their education and perceiving it as personally important for their goals. Introjected regulation, a moderately controlled form of extrinsic motivation, involves students engaging in activities to avoid guilt or anxiety or to enhance their self-esteem, such as studying to avoid disappointing others. External regulation, the most controlled form of extrinsic motivation, refers to students engaging in activities solely to obtain rewards, like good grades, or avoid punishments, such as failing a course. Finally, amotivation represents a lack of intention to participate in educational activities and is characterized by students feeling incompetent and lacking control over their academic outcomes.

Autonomous motivation (intrinsic motivation and identified regulation combined) has been consistently associated with more adaptive outcomes, such as

deeper learning, persistence, and academic achievement (Guay et al., 2008; Koka & Hagger, 2010; Taylor et al., 2014; Vasconcellos et al., 2020). In contrast, controlled motivation (introjected regulation and external regulation combined) and amotivation have been linked to less adaptive outcomes, such as surface-level learning, lower academic performance, and higher dropout rates (Legault et al., 2006; Ntoumanis, 2001; Vallerand et al., 1997; Vasconcellos et al., 2020).

Similarly, engagement is a multidimensional construct that encompasses behavioral, emotional, cognitive, and agentic aspects of students' involvement in learning activities (Reeve, 2013; Skinner et al., 2008). Behavioral engagement refers to students' observable participation in academic tasks, such as effort and persistence (Fredricks et al., 2004). Emotional engagement involves students' affective reactions to their learning experiences, including enthusiasm and enjoyment (Pekrun & Linnenbrink-Garcia, 2012). Cognitive engagement encompasses students' psychological investment in learning, such as the use of deep learning strategies (e.g., elaboration, critical thinking) and self-regulated learning processes (e.g., goal-setting, metacognition; Greene, 2015). Agentic engagement represents students' proactive contribution to their learning environment, such as expressing opinions and making suggestions to enhance the learning experience (Reeve, 2013). Each dimension of engagement has been found to contribute uniquely and positively to students' learning and achievement (Fredricks et al., 2004; Greene, 2015; Pekrun & Linnenbrink-Garcia, 2012; Reeve, 2013).

Given the differential associations of motivation and engagement types with educational outcomes, examining how peer and teacher relatedness relate to these distinct motivational and engagement processes can provide a more nuanced understanding of the ways in which social relationships shape students' academic experiences and outcomes.

1.3 The present study

The present study aims to address the gaps in the relatedness literature in secondary education by focusing on two main objectives. First, we seek to differentiate between peer and teacher relatedness by adapting the relatedness subscale of the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS; Chen et al., 2015). We add items measuring teacher relatedness satisfaction and frustration, mirroring the original items of the PE version of the BPNSFS which only measure peer relatedness. This adaptation addresses the methodological limitations of existing measures that often fail to distinguish between peer and teacher relatedness and do not assess relatedness frustration separately. We investigate the factor structure of this adapted scale to explore and confirm not only the distinction between teacher and peer relatedness satisfaction, but also the distinction between teacher and peer relatedness frustration. Based on previous research demonstrating the distinctiveness of peer and teacher relatedness (Cox & Ullrich-French, 2010; Cox et al., 2009; Fedesco et al., 2019) and the importance of differentiating between need satisfaction and frustration (Haerens et al., 2015; Vansteenkiste & Ryan, 2013), we expect the

best solution to have four factors: teacher relatedness satisfaction, teacher relatedness frustration, peer relatedness satisfaction, and peer relatedness frustration.

Second, leveraging this modified scale, we examine the associations of peer and teacher relatedness satisfaction and frustration with a comprehensive range of student motivation types (intrinsic, identified, introjected, external regulation, and amotivation) and engagement dimensions (behavioral, emotional, cognitive, and agentic). Based on previous research, we hypothesize that teacher relatedness satisfaction will show stronger associations with autonomous forms of motivation (Guay et al., 2017; Ryan et al., 1994), compared to peer relatedness satisfaction. However, given the mixed findings regarding the relative influence of peer and teacher relatedness on engagement in PE (Shen et al., 2012; Xiang et al., 2017) and the limited research directly comparing their associations with the full range of motivation and engagement types, we do not formulate specific hypotheses for the remaining relationships. Instead, we adopt an exploratory approach to investigate these associations.

We focus on the context of PE because it presents unique challenges and opportunities for social interactions that may amplify the importance of relatedness. In PE, the impact of students' basic psychological needs, including relatedness, on their motivation is well-established (Vasconcellos et al., 2020). PE classes involve physical challenges, cooperation, and competition, which can intensify the salience of peer relationships and their impact on student experiences (Bailey, 2006; Opstoel et al., 2020). While PE can be a valuable context for fostering positive peer interactions and developing cooperation and communication skills (Bailey, 2006; Opstoel et al., 2020; Sparks et al., 2016), negative peer interactions, such as teasing and dominating behavior, can also occur, thwarting students' sense of relatedness and potentially leading to amotivation and reduced engagement (White et al., 2021). Moreover, the nature of PE often requires more visible, direct, and personal interactions between teachers and students, potentially strengthening the influence of teacher relatedness on student outcomes (Sparks et al., 2015). By investigating peer and teacher relatedness in this context, we aim to shed light on the distinct roles these social agents play in a setting where social dynamics are particularly pronounced while still providing insights that may generalize to other educational contexts.

2 Methods

2.1 Participants and procedure

This cross-sectional survey study recruited 1043 secondary PE students (59% girls; mean age = 15.48 ± 1.65 years) from 76 classes across 50 schools in Flanders, Belgium. The sample included students from general (76%) and technical (24%) educational tracks. Schools were selected using convenience sampling, starting with those closest to the university.

Researchers contacted 140 schools, primarily through in-person presentations to school leaders, followed by email communication. In some cases, researchers

directly contacted PE teachers with whom they had personal connections via social media. Of the schools approached, 50 agreed to participate (35.7% acceptance rate at the school level). The main reasons for non-participation were lack of time, being over-contacted, or not responding.

Within the participating schools, a total of 76 PE teachers took part in the study. The only inclusion criterion was being a secondary education PE teacher. There were no further exclusion criteria. Each participating teacher was asked to randomly select one of their classes for data collection. Data were collected during the first semester of each academic year over a two-year period (2021–2023).

Participating students completed an online questionnaire on their smartphones during regular PE classes under the supervision of their teacher. Students were assured that the questionnaire was anonymous and that teachers would not have access to their individual responses. They were instructed to respond honestly and individually. The study received ethical approval from the ethical committee of Ghent University Hospital, and informed consent was obtained from school leaders, PE teachers, students, and parents prior to data collection.

2.2 Measures

2.2.1 Peer relatedness satisfaction and frustration

Students' perceived relatedness satisfaction and frustration with their classmates were assessed using the relatedness subscales of the Dutch version of the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS; Chen et al., 2015), adapted for the PE context (Haerens et al., 2015). The original items of the PE version of the BPNSFS focus exclusively on relatedness with classmates (i.e., peer relatedness).

The peer relatedness satisfaction and frustration subscales each consist of four items rated on a 5-point Likert scale ranging from 1 (not at all true) to 5 (completely true). The questionnaire stem, "During the PE classes …", is followed by items assessing satisfaction and frustration. For example, an item measuring peer relatedness satisfaction is: "… I feel connected with the classmates who I care about and who care about me." In contrast, an item assessing peer relatedness frustration is: "… I feel that classmates who are important to me are cold and distant towards me." Previous research has provided evidence for the scale's reliability, validity, and measurement invariance across different cultures and languages (Chen et al., 2015; Haerens et al., 2015). In the current study, McDonald's omega (ω) was 0.72 and 0.74 for peer relatedness satisfaction and frustration, respectively.

2.2.2 Teacher relatedness satisfaction and frustration

To measure students' experiences of teacher relatedness, we adapted the items of the relatedness subscale of the BPNSFS by replacing "classmates" with "PE teacher" and making minor adjustments to ensure the items sounded natural when referring to the teacher-student relationship. The teacher relatedness satisfaction

subscale consists of three items while the teacher relatedness frustration subscale comprises four items. The reason for having only three items for teacher relatedness satisfaction is that two of the original peer relatedness satisfaction items, "… I feel closely connected with classmates who are important to me" and "… I feel connected with the classmates who I care about and who care about me," would have been essentially the same when adapted to measure relatedness with the teacher. Therefore, including both adapted items would have been redundant. The specific items for each subscale, along with their factor loadings, will be presented in the results section. In the current study, McDonald's omega for teacher relatedness satisfaction and frustration was 0.85 and 0.78, respectively.

2.2.3 Student motivation

Five types of motivation were assessed in this study: intrinsic motivation, identified regulation, introjected regulation, external regulation, and amotivation. To measure these types of motivation, we used the Behavioral Regulations in Physical Education Questionnaire (BRPEQ; Aelterman et al., 2012), which is an adapted and validated Dutch version of the Behavioral Regulations in Exercise Questionnaire (BREQ-II; Markland & Tobin, 2004). The BRPEQ has 20 items, with four items for each motivation type rated on a 5-point Likert scale (1 = not true for me, 5 = very true for me).

The questionnaire stem was "I participate during PE classes because …" Examples of items include: "… I enjoy these PE classes" (intrinsic motivation), "… I personally find these classes useful" (identified regulation), "… I would feel guilty if I didn't" (introjected regulation), "… other people pressure me during these classes" (external regulation), and "I actually find these PE classes a waste of time" (amotivation). McDonald's omega values for intrinsic motivation, identified regulation, introjected regulation, external regulation, and amotivation were 0.93, 0.86, 0.68, 0.73, and 0.85, respectively, indicating adequate internal consistency.

2.2.4 Student engagement

This study assessed four types of student engagement: behavioral engagement, emotional engagement, cognitive engagement, and agentic engagement. Each type of engagement was measured using items from validated scales, with the stem "During the PE classes …" for all items. Behavioral engagement was assessed using five items from the Engagement Versus Disaffection with Learning scale (Skinner et al., 2009), such as "… I listen very attentively to the PE teacher." Emotional engagement was also measured using five items from the same scale, with an example item being "… I am interested." Cognitive engagement was measured using four items from an adapted version of the Metacognitive Strategies scale (Wolters, 2004). An example item is "… I try to find connections between what I learn and my own experiences." Agentic engagement was assessed using five items from the Agentic Engagement Scale (Reeve, 2013), with an example item being "… I let my PE teacher know what I need and want." McDonald's omega values for behavioral

engagement, emotional engagement, cognitive engagement, and agentic engagement were 0.78, 0.88, 0.77, and 0.79, respectively.

2.3 Data analysis

2.3.1 Factor analyses of the adapted BPNSFS scale

The factor structure of the adapted BPNSFS scale was examined using both exploratory and confirmatory factor analyses to assess the distinctiveness of the relatedness constructs. To ensure equivalent subsamples for exploratory and confirmatory factor analyses, the dataset was split into two equal groups using the SOLOMON method (Lorenzo-Seva, 2022) in R version 4.4.1. An exploratory factor analysis (EFA) was conducted on the first subsample using SPSS version 29. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were used to assess the suitability of the data for factor analysis. Principal axis factoring with oblimin rotation was used, allowing for correlated factors.

To determine the optimal number of factors to retain, two methods were used: scree plot analysis and Horn's parallel analysis. The scree plot, generated by SPSS, was visually inspected to identify the point at which the eigenvalues leveled off. Horn's parallel analysis, performed using the *paran* package in R version 4.4.1, compared the eigenvalues of the observed data to those obtained from randomly generated datasets with the same number of variables and observations. Factors with eigenvalues greater than the corresponding eigenvalues from the random data were considered meaningful.

Based on the findings from the EFA, scree plot, and parallel analysis, confirmatory factor analyses (CFA) were conducted on the second subsample using the *lavaan* package in R. The CFA models were estimated using the maximum likelihood estimation with robust standard errors (MLR) to account for potential non-normality in the data. Model fit was evaluated using several goodness-of-fit indices, including the comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR).

2.3.2 Associations with motivation and engagement

First, descriptive statistics and correlations between all variables were calculated. Next, to determine the proportion of variance in the outcome variables attributable to differences between teachers, we calculated intraclass correlation coefficients (*ICC*s). Afterwards, we used linear mixed-effects models to examine how peer and teacher relatedness satisfaction and frustration were associated with each of the five types of motivation (intrinsic motivation, identified regulation, introjected regulation, external regulation, and amotivation) and each of the four types of engagement (behavioral, emotional, cognitive, and agentic engagement). In total, we used nine separate models, one for each motivation or engagement variable. The analyses were performed using the *lme4* and *lmerTest* packages in R, with the models including

random intercepts for classes to account for the nested structure of the data (students nested within classes). Students' age and gender were included as control variables, as they have been shown to influence students' motivational experiences in PE (Cairney et al., 2012; Ntoumanis et al., 2009).

To compare the strength of the associations of peer and teacher relatedness satisfaction and frustration with the student outcomes, additional analyses were conducted using the general linear hypothesis test (*glht*) from the *multcomp* package (Hothorn et al., 2008). This test allows for the comparison of regression coefficients within a model. In this study, we used it to compare the estimates for peer and teacher relatedness satisfaction with those for peer and teacher relatedness frustration.

To control the false discovery rate, we adjusted *p*-values for both the regression coefficients and the comparisons for multiple comparisons using the Benjamini-Hochberg (BH) procedure. Four separate BH corrections were performed: (1) for the motivation outcome coefficients, (2) for the engagement outcome coefficients, (3) for the comparisons between the coefficients of peer and teacher relatedness satisfaction and frustration for the motivation outcomes, and (4) for the comparisons between the coefficients of peer and teacher relatedness satisfaction and frustration for the engagement outcomes.

3 Results

3.1 Validation of the adapted BPNSFS: factor analyses

The exploratory factor analysis (EFA) conducted on the first subsample revealed that the data were suitable for factor analysis, with a Kaiser–Meyer–Olkin (KMO) value of 0.89 and a significant Bartlett's test of sphericity ($\chi 2 = 3086.79$, $p < 0.001$). The scree plot suggested a 2-factor solution, while Horn's parallel analysis indicated that four factors should be retained. The 2-factor model consisted of the following factors: teacher relatedness and peer relatedness. The 4-factor model included these factors: teacher relatedness satisfaction, teacher relatedness frustration, peer relatedness satisfaction, and peer relatedness frustration.

Based on these findings, two confirmatory factor analysis (CFA) models were specified and tested using the second subsample: a 2-factor model and a 4-factor model. The CFA results showed that the 4-factor model had a better fit to the data compared to the 2-factor model. The 4-factor model had a comparative fit index (CFI) of 0.95, a Tucker-Lewis index (TLI) of 0.94, a root mean square error of approximation (RMSEA) of 0.06 (90% CI 0.05, 0.07), and a standardized root mean square residual (SRMR) of 0.042. In contrast, the 2-factor model had a CFI of 0.90, a TLI of 0.88, an RMSEA of 0.08 (90% CI 0.07, 0.09), and an SRMR of 0.05. These findings suggest that the 4-factor model, which separates satisfaction and frustration, as well as teacher and peer relatedness, provides a better representation of the data compared to the 2-factor model, which only differentiates teacher and peer relatedness.

Table 1 Items measuring relatedness and standardized factor loadings for the 4-factor CFA model

Factor	Item (During the PE classes …)	Standardized Factor Loading
Teacher Relatedness Satisfaction	… I feel connected with my PE teacher	0.78
	… I feel that my PE teacher cares about me	0.83
	… I have a warm feeling towards the PE teacher	0.81
Teacher Relatedness Frustration	… I get the impression that my PE teacher doesn't like me	0.75
	… I feel that the PE teacher is cold and distant towards me	0.78
	… I feel that the relationship I have with my PE teacher is superficial	0.62
	… I feel excluded by my PE teacher	0.66
Peer Relatedness Satisfaction	… I feel closely connected to classmates who are important to me	0.39
	… I feel that the classmates I care about also care about me	0.76
	… I feel connected with the classmates who care about me and whom I care about	0.78
	… I have a warm feeling towards the classmates I spend time with	0.67
Peer Relatedness Frustration	… I feel excluded from the group I want to belong to	0.57
	… I get the impression that the classmates I spend time with don't like me	0.64
	… I feel that the relationships I have with classmates are superficial	0.53
	… I feel that classmates who are important for me are cold and distant towards me	0.72

The standardized factor loadings from the 4-factor CFA were all statistically significant ($p < 0.001$), indicating that the items loaded well on their respective factors (see Table 1).

As for the correlations among factors, teacher relatedness satisfaction was negatively correlated with teacher relatedness frustration ($r = -0.82$) and peer relatedness frustration ($r = -0.34$) but positively correlated with peer relatedness satisfaction ($r = 0.40$). Teacher relatedness frustration was negatively correlated with peer relatedness satisfaction ($r = -0.35$) but positively correlated with peer relatedness frustration ($r = 0.48$). Peer relatedness satisfaction and peer relatedness frustration were negatively correlated ($r = -0.81$).

3.2 Preliminary analyses

3.2.1 Descriptive statistics and correlations

Table 2 presents the means, standard deviations, and correlations among all study variables. These correlations differ from those reported above, as they represent the relationships between the study variables (mean of scale items) rather than the relationships between the factors (latent variables) derived from the factor analyses. Given the relatively high correlations observed between some predictors, we checked for multicollinearity by calculating the Variance Inflation Factors (VIF) for each predictor. The VIF values ranged from 1.03 to 1.70, all well below the commonly used thresholds of 5 or 10, indicating low multicollinearity.

3.2.2 Intraclass correlations

Table 3 presents the intraclass correlation coefficients (*ICC*s) for each outcome variable. The *ICC* values range from 0.03 to 0.14, indicating that between 3 and 14% of the total variance in the outcomes is due to differences between higher-level units (classes).

3.3 Main analyses: associations with student outcomes

3.3.1 Associations with motivation types

The results for the motivation outcomes are presented in Fig. 1. Teacher relatedness satisfaction was positively associated with intrinsic motivation ($\beta = 0.28$, $p_{adj} < .001$), identified regulation ($\beta = 0.32$, $p_{adj} < .001$), and introjected regulation ($\beta = 0.18$, $p_{adj} < .001$), and negatively with amotivation ($\beta = -0.22$, $p_{adj} < .001$). Teacher relatedness frustration was negatively associated with intrinsic motivation ($\beta = -0.13$, $p_{adj} < .001$), and positively related to introjected regulation ($\beta = 0.11$, $p_{adj} = .013$), external regulation ($\beta = 0.22$, $p_{adj} < .001$), and amotivation ($\beta = 0.20$, $p_{adj} < .001$).Peer relatedness satisfaction was positively associated with intrinsic motivation ($\beta = 0.13$, padj $< .001$) and identified regulation ($\beta = 0.13$, $p_{adj} < .001$), while peer relatedness frustration was negatively related to intrinsic motivation ($\beta = -0.09$,

Table 2 Descriptive statistics and correlations among study variables

N = 1043	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Age	15.48	1.65	1															
2. Gender (1 = female)	59%	NA	− 0.06*	1														
3. Edu. track (1 = gen.)	76%	NA	− 0.30**	0.13**	1													
4. Peer rel. sat.	3.94	0.70	− 0.06	0.04	0.12**	1												
5. Peer rel. frus.	1.90	0.68	0.01	0.07*	− 0.07*	− 0.58**	1											
6. Teacher rel. sat.	3.20	0.83	0.08*	− 0.05	0.06*	0.24**	− 0.16**	1										
7. Teacher rel. frus.	2.07	0.69	− 0.04	− 0.01	− 0.10**	− 0.22**	0.32**	− 0.61**	1									
8. Intrinsic mot.	3.69	0.96	− 0.01	− 0.20**	0.06*	0.30**	− 0.30**	0.45**	− 0.38**	1								
9. Identified reg.	3.44	0.94	0.04	− 0.12**	0.06	0.26**	− 0.23**	0.40**	− 0.30**	0.78**	1							
10. Introjected reg.	2.46	0.82	− 0.04	− 0.00	0.00	− 0.14**	0.30**	0.07*	0.09**	0.06*	0.21**	1						
11. External reg.	2.02	0.76	− 0.01	0.02	− 0.09**	− 0.32**	0.51**	− 0.16**	0.33**	− 0.35**	− 0.24**	0.54**	1					
12. Amotivation	2.02	0.89	0.01	0.06*	− 0.09**	− 0.26**	0.30**	− 0.39**	0.41**	− 0.73**	− 0.70**	0.02	0.43**	1				
13. Behavioral eng.	3.74	0.67	− 0.05	− 0.05	0.06*	0.29**	− 0.24**	0.42**	− 0.31**	0.56**	0.58**	0.13**	− 0.21**	− 0.50**	1			
14. Emotional eng.	3.73	0.80	− 0.03	− 0.18**	0.09**	0.37**	− 0.35**	0.45**	− 0.38**	0.85**	0.76**	0.05	− 0.37**	− 0.71**	0.68**	1		
15. Cognitive eng.	3.20	0.78	− 0.09**	− 0.19**	0.01	0.21**	− 0.16**	0.26**	− 0.16**	0.49**	0.54**	0.17**	− 0.13**	− 0.42**	0.51**	0.54**	1	

edu. Educational, *gen.* general (vs. technical) education, *sat.* satisfaction, *frus.* Frustration, *mot.* Motivation, *reg.* regulation, *eng.* engagement; *$p < 0.05$; **$p < 0.01$

Table 3 Intraclass correlation coefficients (*ICC*s) for outcome variables

Outcome variable	*ICC*
Intrinsic Motivation	0.14
Identified Regulation	0.14
Introjected Regulation	0.03
External Regulation	0.07
Amotivation	0.07
Behavioral Engagement	0.09
Emotional Engagement	0.12
Cognitive Engagement	0.09
Agentic Engagement	0.09

padj = .011), and positively related to introjected regulation (β = 0.29, $p_{adj} < .001$), external regulation ($\beta = 0.42$, $p_{adj} < .001$), and amotivation ($\beta = 0.15$, $p_{adj} < .001$).

Peer relatedness satisfaction was positively associated with intrinsic motivation ($\beta = 0.18$, $p_{adj} < 0.001$) and identified regulation ($\beta = 0.18$, $p_{adj} < 0.001$), while peer relatedness frustration was negatively related to intrinsic motivation ($\beta = -0.13$, $p_{adj} = 0.009$), and positively related to introjected regulation ($\beta = 0.35$, $p_{adj} < 0.001$), external regulation ($\beta = 0.46$, $p_{adj} < 0.001$), and amotivation ($\beta = 0.19$, $p_{adj} < 0.001$).

Comparisons between the regression coefficients (see Table 4) revealed that teacher relatedness satisfaction had significantly stronger positive associations with intrinsic motivation, identified regulation, and introjected regulation compared to peer relatedness satisfaction. Additionally, teacher relatedness satisfaction showed a significantly stronger negative association with amotivation. In contrast, peer relatedness frustration was more strongly linked to introjected and external regulation compared with teacher relatedness frustration.

3.3.2 Associations with engagement types

The results for the engagement outcomes are shown in Fig. 2. Teacher relatedness satisfaction was positively associated with all four engagement dimensions: behavioral ($\beta = 0.34$, $p_{adj} < .001$), emotional ($\beta = 0.30$, $p_{adj} < .001$), cognitive ($\beta = 0.23$, $p_{adj} < .001$), and agentic ($\beta = 0.36$, $p_{adj} < .001$). Teacher relatedness frustration was negatively associated with emotional engagement ($\beta = -0.10$, $p_{adj} = .007$).Peer relatedness satisfaction was positively associated with all engagement dimensions (behavioral: $\beta = 0.15$, padj < .001; emotional: $\beta = 0.17$, $p_{adj} < .001$; cognitive: $\beta = 0.15$, $p_{adj} < .001$; agentic: $\beta = 0.18$, $p_{adj} < .001$), whereas peer relatedness frustration was negatively related to behavioral ($\beta = -0.08$, $p_{adj} = .036$), emotional ($\beta = -0.14$, $p_{adj} < .001$), and agentic engagement ($\beta = -0.09$, $p_{adj} = .018$).

Peer relatedness satisfaction was positively associated with all engagement dimensions (behavioral: $\beta = 0.14$, $p_{adj} < 0.001$; emotional: $\beta = 0.19$, $p_{adj} < 0.001$; cognitive: $\beta = 0.16$, $p_{adj} < 0.001$; agentic: $\beta = 0.20$, $p_{adj} < 0.001$), whereas peer relatedness frustration was negatively related to behavioral ($\beta = -0.08$, $p_{adj} = 0.032$),

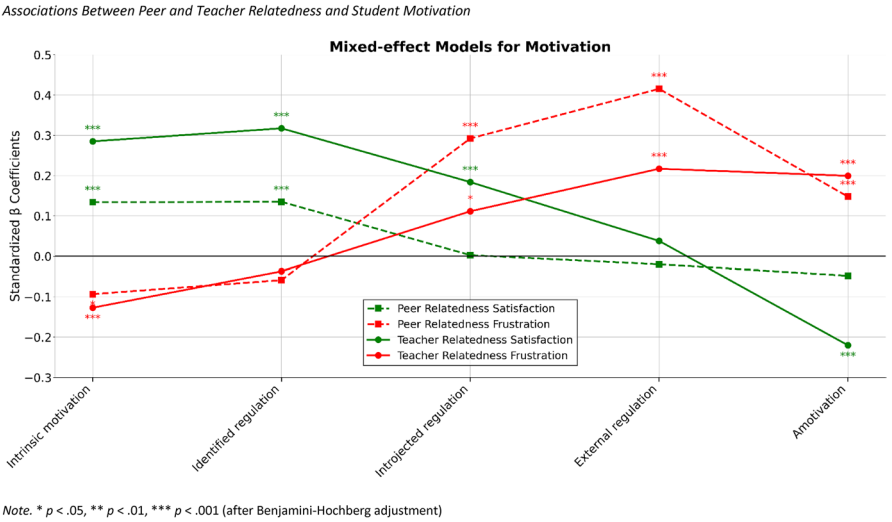

Fig. 1 Associations Between Peer and Teacher Relatedness and Student Motivation. *Note*. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ (after Benjamini–Hochberg adjustment)

Table 4 Comparisons between peer and teacher relatedness satisfaction and frustration

Model	Comparison	Estimate difference (peer–teacher)	*z*-value	*p*-value	*p*-value (adjusted)
Intrinsic motivation	Satisfaction	− 0.15	− 2.92	**0.004**	**0.006**
	Frustration	0.03	0.64	0.522	0.580
Identified regulation	Satisfaction	− 0.18	− 3.30	**0.001**	**0.005**
	Frustration	− 0.02	− 0.39	0.699	0.699
Introjected regulation	Satisfaction	− 0.18	− 3.01	**0.003**	**0.006**
	Frustration	0.18	2.90	**0.004**	**0.006**
External regulation	Satisfaction	− 0.06	− 1.08	0.280	0.400
	Frustration	0.20	3.61	**0.000**	**0.003**
Amotivation	Satisfaction	0.17	3.10	**0.002**	**0.006**
	Frustration	− 0.05	− 0.91	0.363	0.454
Behavioral engagement	Satisfaction	− 0.19	− 3.44	**0.001**	**0.003**
	Frustration	− 0.06	− 1.02	0.309	0.372
Emotional engagement	Satisfaction	− 0.13	− 2.49	**0.013**	**0.032**
	Frustration	− 0.05	− 0.89	0.373	0.373
Cognitive engagement	Satisfaction	− 0.09	− 1.50	0.134	0.215
	Frustration	− 0.06	− 0.98	0.325	0.372
Agentic engagement	Satisfaction	− 0.19	− 3.36	**0.001**	**0.003**
	Frustration	− 0.14	− 2.41	**0.016**	**0.032**

The bold *p*-values are all significant at the $p < 0.05$ level

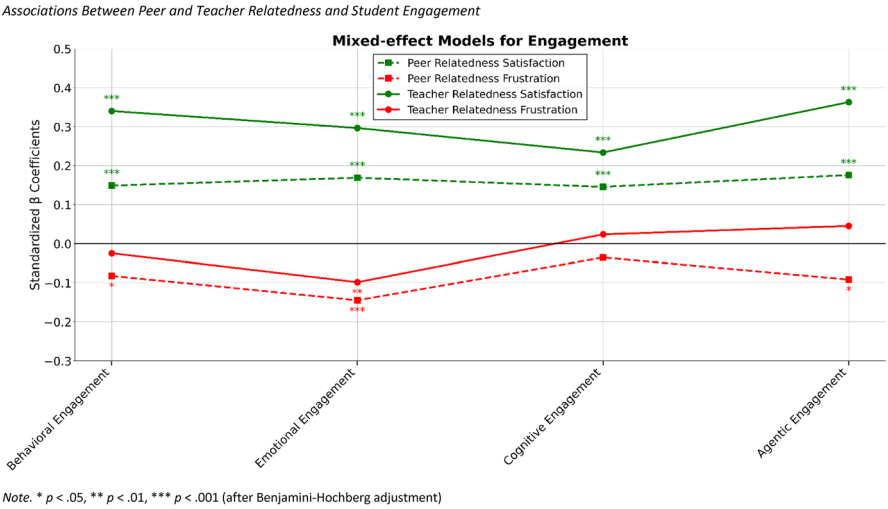

Fig. 2 Associations Between Peer and Teacher Relatedness and Student Engagement. *Note*. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ (after Benjamini–Hochberg adjustment)

emotional ($\beta = -0.17$, $p_{adj} < 0.001$), and agentic engagement ($\beta = -0.11$, $p_{adj} = 0.016$).

Comparisons (see Table 4) indicated that teacher relatedness satisfaction had significantly stronger positive associations with behavioral, emotional, and agentic engagement compared to peer relatedness satisfaction. In contrast, peer relatedness frustration was more strongly negatively associated with agentic engagement compared with teacher relatedness frustration.

4 Discussion

The present study aimed to address key gaps in the literature on relatedness in secondary education by adapting the BPNSFS to distinguish between student-reported peer and teacher relatedness satisfaction and frustration, and by examining their associations with a broad range of motivational and engagement outcomes. Our findings provide strong support for the distinctiveness of peer and teacher relatedness satisfaction and frustration, as well as for their differential relationships with student motivation and engagement in secondary PE.

4.1 Differentiating between peer and teacher relatedness by adapting the BPNSFS

The first aim of this study was to address the methodological limitations of existing measures by adapting the BPNSFS (Chen et al., 2015) to distinguish between peer and teacher relatedness in secondary education. We created additional items

to assess teacher relatedness satisfaction and frustration, as teacher relatedness was not captured in the original scale for PE. Our factor analyses supported the distinctiveness of peer and teacher relatedness satisfaction and frustration, with a 4-factor model providing the best fit to the data.

These findings align with and extend previous research emphasizing the importance of considering both peer and teacher relatedness in secondary education (Cox & Ullrich-French, 2010; Cox et al., 2009; Gairns et al., 2015). Moreover, the findings build upon the work of Fedesco et al. (2019), who modified the BPNSFS in higher education by adding teacher relatedness items. However, that study used a composite score for relatedness satisfaction and frustration. The current results highlight the importance of explicitly separating the two constructs. This aligns with previous general SDT-based research that suggests that need satisfaction and frustration are distinct constructs with unique antecedents and consequences (Bartholomew et al., 2011; Haerens et al., 2015; Vansteenkiste & Ryan, 2013). Thus, by independently assessing satisfaction and frustration for peer and teacher relatedness, our adapted scale enables a more comprehensive understanding of students' sense of relatedness in the classroom.

4.2 Peer and teacher relatedness: associations with student motivation and engagement

The second aim of this study was to investigate the relationships between peer and teacher relatedness satisfaction and frustration and various types of motivation and engagement. Our findings confirmed that both peer and teacher relatedness have significant and distinct relationships with student outcomes in secondary education, aligning with previous research on relatedness satisfaction (Cox & Ullrich-French, 2010; Cox et al., 2009; Gairns et al., 2015; King, 2015; Shen et al., 2012; Xiang et al., 2017). The results build upon existing literature by examining a wider range of motivation (five types) and engagement (four types) and by also assessing how relatedness frustration is linked to these outcomes. These methodological improvements allowed us to uncover the unique roles of teacher and peer relatedness.

4.2.1 Relatedness satisfaction and the "bright" pathway

Teacher and peer relatedness satisfaction related positively to autonomous forms of motivation and to engagement. These findings can be understood through the lens of the "bright" pathway in SDT (Haerens et al., 2015; Vansteenkiste & Ryan, 2013), which suggests that need-supportive contexts and experiences of need satisfaction are more strongly linked to adaptive outcomes compared to need-thwarting contexts and experiences of need frustration.

When comparing the strength of associations, teacher relatedness satisfaction exhibited stronger associations with adaptive outcomes, particularly autonomous motivation (intrinsic motivation and identified regulation), behavioral engagement, emotional engagement, and agentic engagement, relative to peer relatedness satisfaction. This aligns with previous research showing stronger relationships between

teacher relatedness satisfaction and identified regulation in Canada (Guay et al., 2017), and school motivation (Ryan et al., 1994) and behavioral and emotional engagement in the USA (Shen et al., 2012), compared with peer relatedness satisfaction. However, Xiang et al. (2017) found peer relatedness satisfaction to be more important for emotional and cognitive engagement in Turkish students. These discrepancies may potentially be explained by cultural differences. It is possible that in more collectivistic cultures like Turkey, peer relationships are more salient for predicting engagement, while in more individualistic cultures like the USA, Canada, and Belgium (the current sample), teacher-student relationships are more influential (Hofstede et al., 2010).

Moreover, teacher relatedness satisfaction also demonstrated a stronger negative association with amotivation compared to peer relatedness satisfaction. This finding suggests that positive teacher-student relationships not only foster autonomous motivation and engagement but also play a crucial role in buffering against amotivation, a finding in line with previous research in secondary PE (Shen et al., 2010).

The more prominent role of teacher relatedness satisfaction in promoting adaptive outcomes and reducing amotivation compared to peer relatedness satisfaction may be due to teachers' unique position as authority figures, experts, and mentors in secondary education (Macleod et al., 2012; Pianta et al., 2012). Positive teacher-student relationships, marked by warmth, trust, and support, could be particularly effective in activating the "bright" pathway, as teachers have the power to create a structured, nurturing, and intellectually stimulating learning environment that supports students' basic psychological needs (Pianta et al., 2012; Ruzek et al., 2016; Vasconcellos et al., 2020). This effect may be especially salient in PE, where physical challenges, cooperation, and competition are common, and students often rely on their teachers for guidance, encouragement, and support in navigating these demands (Opstoel et al., 2020; Sparks et al., 2015).

4.2.2 Relatedness frustration and the "dark" pathway

In contrast, teacher and peer relatedness frustration were associated with maladaptive outcomes, such as controlled motivation (introjected and external regulation) and amotivation. These findings can be interpreted through the lens of the "dark" pathway in SDT, which suggests that need-thwarting contexts and experiences of need frustration are more strongly linked to maladaptive outcomes compared to need-supportive contexts and experiences of need satisfaction (Haerens et al., 2015; Vansteenkiste & Ryan, 2013).

When comparing the strength of associations, peer relatedness frustration showed stronger associations with maladaptive outcomes, such as controlled motivation (introjected and external regulation) and a more negative association with agentic engagement compared to teacher relatedness frustration. These findings are consistent with previous research that has linked peer relatedness frustration to controlled forms of motivation in (mostly) secondary school students (Leo et al., 2023). When students feel excluded or rejected by their classmates, they may be more likely to participate in PE classes to avoid negative emotions like guilt or shame (introjected

regulation) or to gain approval or rewards from others (external regulation). Furthermore, the stronger negative association between peer relatedness frustration and agentic engagement suggests that negative peer experiences may be particularly detrimental to students' proactive contribution and involvement in class. This finding aligns with research indicating that peer rejection and exclusion can undermine students' sense of agency and willingness to actively participate in classroom activities (Buhs et al., 2006).

The stronger link between peer relatedness frustration and maladaptive outcomes can be understood in light of the central role peers play in shaping adolescents' self-concepts, social identities, and motivational experiences (Brown & Larson, 2009; Ryan, 2000). Adolescents rely heavily on peers for social validation, emotional support, and a sense of belonging (Brechwald & Prinstein, 2011; Rubin et al., 2006). Negative peer experiences, such as exclusion or rejection, could powerfully activate the "dark" pathway (Ladd et al., 2017; Ruggieri et al., 2013). When students feel judged or rejected by peers in PE, they seem to focus more on avoiding negative social outcomes and preserving self-worth than on engaging in learning activities for their inherent value and enjoyment. This effect may be particularly pronounced in PE, where social comparisons, physical competence, and peer status are often on public display, creating a high-stakes environment for social evaluation (Portman, 1995; Smith & St Pierre, 2009).

While these findings highlight the particular importance of teacher relatedness satisfaction and peer relatedness frustration, it is important to recognize that peer relatedness satisfaction and teacher relatedness frustration also played significant roles. While these relationships were relatively less pronounced, peer relatedness satisfaction was still positively linked to adaptive outcomes and teacher relatedness frustration was still associated with maladaptive outcomes. These findings emphasize the necessity of examining both relatedness satisfaction and frustration for both actors (peers and teachers) to gain a comprehensive understanding of the social influences on student motivation and engagement.

4.3 Methodological implications for measuring relatedness

The distinct associations between peer and teacher relatedness satisfaction and frustration and various outcomes highlight the need for more nuanced measurement of relatedness in future educational research. In general education, relatedness is often assessed as a single, global construct that combines aspects of both peer and teacher relationships (Chen et al., 2015; Tian et al., 2014). This approach may obscure important differences in how peer and teacher relatedness uniquely contribute to students' motivational experiences. For example, Jang et al. (2009) found that high school students' relatedness (measured as a general construct) was less predictive of student outcomes such as intrinsic motivation and behavioral engagement compared to students' autonomy and competence. The present study suggests that, had the researchers measured peer and teacher relatedness separately, this approach

might have yielded different results, with teacher relatedness potentially emerging as a stronger predictor of these adaptive outcomes.

Similarly, PE research often assesses only peer relatedness, overlooking the role of teacher relatedness (e.g., Behzadnia et al., 2018; Haerens et al., 2015). The widely used BPNSFS in PE typically focuses on peer relatedness, potentially providing an incomplete picture of relatedness in this context. This limitation may have contributed to the relatively small associations between relatedness and autonomous motivation found in Vasconcellos and colleagues' (2020) meta-analysis of SDT in PE. Considering the current study's results, had teacher relatedness been measured more consistently across the studies included in the meta-analysis, the overall association between relatedness and autonomous motivation might have been stronger.

Moreover, even when research in both general education and PE contexts distinguishes between peer and teacher relatedness, it often does not separately measure relatedness frustration (Cox & Ullrich-French, 2010; Cox et al., 2009; Gairns et al., 2015; Guay et al., 2017; King, 2015; Ryan et al., 1994; Shen et al., 2012). Neglecting to assess relatedness frustration independently may underestimate its relationship with negative outcomes. The current study's findings suggest peer relatedness frustration could be a crucial factor in the development of controlled motivation, such as introjected and external regulation. These results highlight the need for more nuanced measurement approaches in future studies investigating relatedness in educational settings.

4.4 Practical implications

Our results suggest that teachers should prioritize building strong, supportive relationships with their students while also being attentive to peer dynamics. Specific teacher behaviors that support teacher relatedness include individualized conversations, task-related support, promoting cooperation, displaying enthusiasm, being aware of individual needs, demonstrating care, and maintaining friendly communication (Sparks et al., 2016). Creating a classroom climate that promotes mutual respect, inclusion, and open communication can further strengthen teacher-student relationships (Sparks et al., 2015). Incorporating these behaviors into teacher training programs can be an effective way to enhance relatedness support and student outcomes in PE (Sparks et al., 2017). However, while relatedness support interventions show promise, targeting all three basic psychological needs (autonomy, competence, and relatedness) may be necessary for achieving broader motivational improvements in PE (Sparks et al., 2017).

To mitigate the detrimental effects of negative peer dynamics, which might be exacerbated by teachers' relatedness thwarting behaviors (Leo et al., 2023), PE teachers can implement strategies that promote positive interactions and cooperation among students. Cooperative learning activities, such as group projects, team challenges, or peer teaching, can encourage students to work together, share responsibilities, and support each other's learning (Dyson & Casey, 2012). Peer mentoring programs, where older or more skilled students are paired with younger or less experienced ones, can also foster a sense of connection and belonging among students

(Jenkinson et al., 2013). Additionally, teachers can cultivate a classroom culture that values inclusivity, respect, and sportsmanship by modeling these behaviors, setting clear expectations, and providing opportunities for students to reflect on their interactions with peers (Gairns et al., 2015; Pennington, 2017).

4.5 Limitations

While this study offers valuable insights into the roles of peer and teacher relatedness in PE, it is important to acknowledge its limitations. First, the cross-sectional design precludes us from drawing causal inferences about the relationships between relatedness, motivation, and engagement. The observed associations between variables may be subject to reverse causality or the influence of unmeasured confounding variables.

Second, the reliance on self-report measures may have introduced response biases, such as social desirability bias (Van de Mortel, 2008), where participants respond in a manner that presents them favorably. This could have led to underreporting of negative experiences (e.g., relatedness frustration) or overreporting of positive experiences (e.g., relatedness satisfaction). Additionally, acquiescence bias, the tendency to agree with items regardless of content (Weijters et al., 2010), may have inflated associations between variables.

Third, data were collected over two academic years, involving two student cohorts. While this approach may enhance the generalizability of the findings by capturing a more diverse sample across different academic years, it also introduces the potential for cohort effects. If there are systematic differences between the two cohorts that are not accounted for in the analyses, this could have biased the results. However, the use of random class selection and multilevel modeling helped mitigate these concerns.

Fourth, the use of a convenience sample from secondary schools in Belgium may limit the generalizability of the findings to other educational contexts and cultural settings. While SDT's principles suggest that the basic psychological needs are universal across contexts, the relative influence of peer and teacher relatedness may differ in subjects that involve less physical interaction and competition. Additionally, cultural factors may play a role in shaping the relative importance of peer and teacher relatedness. For example, in high power distance (i.e., more hierarchical) cultures, teacher relatedness might be more influential due to the greater respect for authority figures, while in low power distance cultures, peer relatedness might be more important due to the more egalitarian nature of relationships (Hofstede et al., 2010).

Finally, while the current study focused on the basic psychological need of relatedness, it did not include measures of autonomy and competence, which are also central to SDT (Ryan & Deci, 2017). Previous research has demonstrated that all three needs contribute to shaping students' motivation and engagement (Jang et al., 2010, 2016; Vasconcellos et al., 2020). By not assessing autonomy and competence alongside relatedness, the current study may provide an incomplete understanding of the motivational processes in PE.

4.6 Future directions

First, to address the limitations of the cross-sectional design, future studies should employ longitudinal designs to establish temporal precedence and better understand the causal dynamics between relatedness, motivation, and engagement.

Second, to mitigate potential response biases associated with student self-report measures, future research could triangulate findings by incorporating observational measures and reports from multiple informants (e.g., teachers, peers) alongside students' self-report questionnaires. These multi-method approaches could provide a more comprehensive and accurate picture of the motivational dynamics in the classroom.

Third, to enhance the generalizability of the findings, future studies should aim to replicate the current results with more diverse and representative samples across various academic contexts and cultural settings. This could involve examining the role of relatedness in different subject areas (e.g., mathematics, languages, arts), educational levels (e.g., primary, higher education), and cultures with varying power distance orientations and social norms (Hofstede et al., 2010). Such research can help determine the boundary conditions of the current findings and identify potential moderators of the relationship between relatedness and student outcomes.

Fourth, to gain a more complete understanding of students' motivation and engagement in secondary education, future research could explore the interplay between autonomy, competence, and relatedness in shaping student motivation and engagement. Additionally, studies could investigate whether the relationships of autonomy and competence with motivational outcomes also differ depending on the social agent. However, Vasconcellos et al. (2020) found that teachers and peers had a similar impact on students' overall relatedness, but teachers had a stronger influence on autonomy and competence, suggesting that differentiating these needs based on the source may be less crucial compared to relatedness. This might be because it is primarily teachers, as authority figures, who are responsible for structuring learning activities and providing guidance and feedback, which are key factors in supporting students' autonomy and competence (Vasconcellos et al., 2020). Nevertheless, investigating the impact of different social agents on the outcomes of all three psychological needs could provide valuable insights, particularly in collaborative learning contexts where students may play a more significant role in shaping each other's autonomy and competence.

Fifth, while our study used linear mixed-effects models to examine the unique associations between relatedness and student outcomes, future research could consider using Structural Equation Modeling (SEM). SEM offers several advantages, such as the ability to simultaneously model relationships at both the student and class levels, and to account for measurement error by modeling latent variables. However, this approach might require larger sample sizes at the teacher level to ensure the robustness and validity of the results (Hox et al., 2010).

Sixth, although our study examined peer relatedness in relation to all classmates as a whole, students' sense of connection may heavily depend on relationships with specific peers. Future research could examine the effects of more complex relatedness patterns, such as whether positive bonds with a few classmates buffer against

negative relationships with other peers, or how relationships with individual peers are affected by the general class climate. Furthermore, investigating dyadic relationships and students' positions in the peer network using social network analysis could provide a more nuanced understanding of the impact of peers on motivation and engagement (DeLay et al., 2021; Marin & Wellman, 2011; Reitz et al., 2014).

Finally, future studies could explore the potential interaction effects between peer and teacher relatedness on student motivation and engagement. Research on complex social ecologies (Skinner et al., 2022) identifies several key interaction types. For instance, *amplifying effects* occur when one social partner's positive influence enhances another partner's positive effects. An example of this is when high peer relatedness satisfaction amplifies the positive effects of high teacher relatedness satisfaction. On the other hand, *buffering effects* happen when support from one social partner protects against negative influences from another social context. For example, strong teacher relatedness satisfaction might buffer against the negative effects of peer relatedness frustration (León & Liew, 2017), while high peer relatedness satisfaction could potentially protect against low teacher relatedness satisfaction (Vollet et al., 2017). Additionally, *sequential effects* represent another important interaction pattern in which one relationship influences another at a later point in time, creating causal chains. For example, the quality of students' relationships with their teacher may subsequently affect the quality of their peer relationships (Kilday & Ryan, 2022). Examining these interaction and sequential effects can provide a more nuanced understanding of the social dynamics in the classroom.

5 Conclusion

This study highlights the distinct roles of peer and teacher relatedness in shaping student motivation and engagement in secondary PE. By adapting the relatedness subscale of the BPNSFS to differentiate between peer and teacher relatedness satisfaction and frustration, we found that both peer and teacher relatedness satisfaction were positively associated with adaptive outcomes. However, teacher relatedness satisfaction showed stronger associations with autonomous motivation and engagement than peer relatedness satisfaction. Conversely, while both peer and teacher relatedness frustration were related to maladaptive outcomes, peer relatedness frustration was more strongly linked to controlled motivation and lower agentic engagement than teacher relatedness frustration.

These findings suggest that both peer and teacher relatedness are important, but their relative influence differs depending on whether the outcomes are adaptive or maladaptive. Teacher-student relationships appear especially important for supporting positive forms of motivation and engagement, while peer relationships may have a greater potential to contribute to adverse student outcomes. The adapted BPNSFS provides researchers with a more nuanced tool for examining the distinct contributions of peer and teacher relatedness. For teachers, our results underscore the importance of fostering supportive relationships with students to promote autonomous motivation and engagement. Simultaneously, implementing strategies to mitigate

negative interactions between students may help reduce controlled forms of motivation while enhancing agentic engagement.

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Data availability The research data of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare no conflict of interest.

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