frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 30 March 2023
DOI 10.3389/feduc.2023.1153647

OPEN ACCESS

EDITED BY
Patsie Polly,
University of New South Wales, Australia

REVIEWED BY
Mehmet Baris Horzum,
Sakarya University, Türkiye
Richard M. Ryan,
Australian Catholic University, Australia

*CORRESPONDENCE
Marius O. Johansen
✉ marius.johansen@uib.no

SPECIALTY SECTION
This article was submitted to STEM Education, a section of the journal Frontiers in Education

RECEIVED 29 January 2023
ACCEPTED 13 March 2023
PUBLISHED 30 March 2023

CITATION
Johansen MO, Eliassen S and Jeno LM (2023) The bright and dark side of autonomy: How autonomy support and thwarting relate to student motivation and academic functioning.
Front. Educ. 8:1153647.
doi: 10.3389/feduc.2023.1153647

The bright and dark side of autonomy: How autonomy support and thwarting relate to student motivation and academic functioning

Marius O. Johansen[1]*, Sigrunn Eliassen[1] and Lucas M. Jeno[2]

[1]Department of Biology, bioCEED–Centre of Excellence in Biology Education, University of Bergen, Bergen, Norway, [2]Department of Education, University of Bergen, Bergen, Norway

According to Self-Determination Theory, autonomy support is essential in fostering optimal learning, growth, and functioning in students across all levels. In contrast, autonomy thwarting is associated with student malfunctioning. The purpose of the current study was to investigate the relationship between perceptions of autonomy support and thwarting, students' autonomous and controlled motivations, and aspects of student functioning in a higher education setting. The sample consisted of 414 Norwegian university students recruited from introductory calculus courses. Structural equation modeling indicated that perceived autonomy support predicts autonomous motivation and is negatively linked to controlled motivation. Autonomy thwarting is negatively linked to autonomous motivation and positively predicts controlled motivation. We found that autonomous motivation predicts engagement, effort, and learning. Controlled motivation is negatively linked to vitality and engagement, and positively predicts effort. The results are in line with the tenets of Self-Determination Theory, and the present study highlights the importance of providing an autonomy supportive environment during higher education lectures.

KEYWORDS

self-determination theory (SDT), autonomous motivation, controlled motivation, autonomy support, autonomy thwarting, higher education

Introduction

Creating conditions for optimal student functioning in higher education contexts is an important task for instructors. Facilitating students to engage in learning activities and still possess a surplus of mental energy at the end of the day can be difficult, but nonetheless it is important for optimal growth, development, and psychological wellbeing (Strauss and Volkwein, 2002). Optimal student functioning is imperative as it relates to time management, learning awareness, academic achievements, and the ability to manage negative coping skills (Disch et al., 2000). Teacher autonomy support has been shown to be both a direct and indirect contributor to such student functioning (Kaplan, 2018). Although there exist a plethora of studies indicating that autonomy support is positively related to a myriad of academic outcomes (see e.g., Milyavskaya and Koestner, 2011; Núñez and León, 2016; Ryan and Deci, 2017; Cheon et al., 2018), less is known about how teacher autonomy thwarting

affects student functioning. That is, does teacher control reduce autonomous motivation and increase controlled motivation, and does this impact student functioning in the same way that autonomous motivation does? The aim of this study is to examine the correlates of how perceived autonomy support and thwarting can impact student motivation and in turn effort, engagement, vitality, and learning. By doing this, we investigate the «bright» and «dark» manifestations of student motivation which has received more attention recently, but not in higher education specifically (Haerens et al., 2015; Kubicek et al., 2017; Rodrigues et al., 2020). We investigate these relations using Self-Determination Theory (SDT; Ryan and Deci, 2017) among higher education STEM students in a calculus course.

Motivation and self-determination theory

Human motivation, which can be defined as the reason for behaving in a certain way, is an important constituent of a person's psychological experiences as it underpins human behavior and functioning (Pintrich et al., 1994). In educational settings, student motivation has been linked to academic achievements (Keller et al., 2016; Muenks et al., 2018), effort (Howard et al., 2021), drop-out intentions (Haivas et al., 2013; Rumberger and Rotermund, 2016), learning (Cerasoli et al., 2014; Manganelli et al., 2019), and psychological wellbeing (Howard et al., 2021). Hence, research on the underlying psychological aspects of student motivation and functioning remains an imperative task for educational institutions (Meens et al., 2018), especially since motivation generally declines as one progresses the educational ladder (Young et al., 2018).

Self-determination theory is a multi-dimensional meta-theory encompassing human motivation, development, and growth (Deci and Ryan, 2008; Ryan and Deci, 2017) in which different types of motivation can be distinguished depending on their level of self-determination (Ryan and Deci, 2000a; Vansteenkiste et al., 2018). According to SDT, volitional, or autonomous, forms of motivation refer to actions driven by a personal interest, whereas external, or controlling, motivation refers to behaviors driven by pressure (Núñez and León, 2016). As the sources of motivation differ, so can the impact of the various types of motivations. Not only can they differ in strength and maintainability, but they also differ in the behavioral outcomes of the activity that energizes the different motivations. Hence, it is important to differentiate motivation as a construct to account for the effects of the different types of motivations (Vansteenkiste et al., 2010; Martela et al., 2016; Howard et al., 2021).

Autonomous motivation is the most self-determined class and refers to a sense of volition or willingness to perform tasks (Ryan et al., 2006), and consists of intrinsic motivation (enacting out of the inherent pleasure and joy of the activity itself), integrated regulation (when the reason for doing an activity is not only because it is personally meaningful, but the activity is more deeply aligned with personal values and interests), and identified regulation (when someone recognizes personal relevance or utility of the learning content; Vansteenkiste et al., 2018). Research shows that autonomous motivation plays a vital role in facilitating learning and growth as it has been linked to increased academic achievements and psychological wellbeing (Taylor et al., 2014). When students are autonomously motivated, they self-endorse their reason to study and experience a sense of psychological freedom which has been linked to increased feelings of vitality, creativity, time management, and effort (Vansteenkiste et al., 2006; Yeager et al., 2014).

In contrast, when learning activities fail to resonate with a student's innate curiosity or they are unable to recognize any meaningful merit behind the learning content, the learning activity becomes an instrument to achieve outcomes that are detached from the learning activity, and motivation becomes pressured or controlled (Cerasoli et al., 2014; Cheon et al., 2020). Controlled motivation can be separated into two categories; external regulation (acting out of external contingencies such as studying to avoid punishment) and introjected regulation (the controlling pressure originating from within, such as acting out of shame, guilt, or pride; Pelletier et al., 2002; Reeve et al., 2002; Cerasoli et al., 2014). Consequently, externally regulated students will feel forced to commit to activities and experience less freedom and self-endorsement, creating an external locus of causality (Ryan and Deci, 2000b). Studies show that students experiencing controlled motivation are often linked to undesirable outcomes such as less engagement, increased anxiety, superficial processing of the learning material, increased drop out intentions, and reduced psychological wellbeing (Vansteenkiste et al., 2006). A recent meta-analysis by Howard et al. (2021) found that autonomous motivation positively relates to effort, engagement, academic performance, and vitality, while controlling forms of motivation relate to anxiety, avoidance, and reduced experiences of vitality and physical wellbeing.

Autonomy support and thwarting

In any learning activity, interpersonal contexts can either support or thwart student autonomy and thus affect to what extent a student's motivation is autonomous or controlled (Black and Deci, 2000). In a classroom setting, autonomy support can be facilitated through instructor behaviors that nurture and develop students' inner motivational resources (Reeve, 2009). When studying factors that facilitate motivation among higher education students, Kember et al. (2008) found that applying more relevant elements to abstract topics could increase student motivation. Providing a rationale in educational learning activities can both resonate with students' interests as well as help them recognize the importance of the learning content. This is supported by a plethora of research across educational levels (see e.g., Kember et al., 2008; Reeve, 2009; Terrón-López et al., 2017). More recently, based on a synthesis of 51 experiments, Reeve and Cheon (2021) concluded that teachers who provided rationales, avoided the use of controlling language, and provided students with time to think and ask questions fostered an autonomy supportive learning context (Reeve and Cheon, 2021). Further, Reeve (2009) reported that instructors that welcomed and acknowledged any negative emotions or connotations students experienced could also foster a more autonomy supportive learning climate. Research shows that students who experience autonomy support in the classroom achieve better grades (Okada, 2021), are more creative (Núñez and León, 2015), engage more with the learning content (Jiang and Tanaka, 2022), experience more

positive emotions (Oriol-Granado et al., 2017), and experience increased psychological wellbeing (Moller et al., 2006).

Moreover, in a study among adolescent students, Shen et al. (2009) found that students who experienced the learning context as autonomy supportive reported higher levels of autonomous motivation. Similar results were reported by Bronson (2016) where autonomy support also predicted autonomous motivation among nursing students, a finding that is also supported by a study among medical students by Feri et al. (2016). A more recent study by Ganotice et al. (2020) further corroborates this where autonomy support was found to be a positive predictor of autonomous motivation in Chinese university students.

In contrast to autonomy support, autonomy thwarting is instructor behavior that directs students to think or behave in a specific way (Assor et al., 2005). In a classroom setting, a teacher is autonomy thwarting by for instance overriding the students' perspectives on subjects and replaces them with the teacher's own. It should be noted that a teacher presenting their own perspective during a learning activity is not in itself thwarting, but it becomes controlling when the instructor pressures their own perspective *onto* the students (Assor et al., 2005). In other words, the instructor's behavior becomes autonomy thwarting when the learning activity pressures students into changing their behaviors. When this happens, the student's locus of causality changes from internal (doing something autonomously) to external (doing something for a controlled reason; Reeve, 2009). Instructors can be autonomy thwarting by intrusively interrupt activities and being dismissive. Autonomy thwarting instructors tend to be impatient with students by for instance not giving them enough time to provide answers in class (Reeve, 2009). When students experience autonomy thwarting, their positive functioning is weakened as it induces a sense of external pressure, and they experience a feeling of duty to either some external contingency, to others, or to one's negative emotion (Reeve et al., 2003). Research shows that students experiencing autonomy thwarting are more prone to anxiety (Patall et al., 2018), have lower psychological wellbeing (Ryan and Deci, 2017), engage less with the learning content (Reeve et al., 2004), and achieve lower grades than autonomy supported students (Vansteenkiste et al., 2004). Patall et al. (2018) conducted a diary study on high school students and found that thwarting practices in educational contexts promote experiences of controlled motivation and undermined autonomous motivation. When students are subject to autonomy thwarting experiences, their positive functioning is weakened as it induces a sense of external pressure (Reeve et al., 2003). In a similar longitudinal study, Cece et al. (2018) reported similar results where autonomy thwarting was positively related to controlled forms of motivation. A more recent study by Burgueño et al. (2022) further support this claim where they also reported that autonomy thwarting was positively linked to controlled motivation among physical education students.

Correlates of motivation and student functioning

When students are autonomously motivated, they reflect, evaluate, and integrate the learning content in line with their own personal interests and goals, and studies have shown that autonomously motivated students exert more effort into learning activities (Reeve et al., 2002; Joussemet et al., 2004; Howard et al., 2021) and are more resilient when facing challenging assignments (Xu et al., 2018, 2021; Lin et al., 2022). Effort has been shown to correlate with both academic achievements, increased recollection, and perceived competence, hence it constitutes a wide aspect of student functioning (Schmid and Bogner, 2015; Xu et al., 2018). Contrary, when students are experiencing controlled motivation, research shows that they are exerting less effort into learning activities (Ntoumanis, 2001; Howard et al., 2021). A review study by Ntoumanis and Standage (2009) corroborates this claim, where results indicate that autonomous forms of motivation positively predict exerted effort in physical education students. A meta-analysis spanning 36 studies from Vasquez et al. (2016) provides further support for these relations, where it was reported that experiences of autonomy positively predicted children's efforts and academic achievements. Similarly, a more recent study in China by Xu et al. (2021) reported that perceived autonomy support positively predicted effort among adolescent students. However, a study by Hagger et al. (2015) in Pakistan found no significant relationship between autonomous motivation in school and effort in high school students, but reported that out-of-school contexts, such as homework, were positively related to autonomy. Contrary to the SDT tenets, a study by Goodman et al. (2011) indicated that controlled motivation positively predicted effort as well among university students.

Autonomously motivated students engage more actively in their learning activities and show higher interest in topics since they endorse their own actions by integrating the learning outcomes with their own personal values and goals (Ryan et al., 2010). Engagement can be considered a manifestation of motivation, i.e., the student's engagement in the learning activity (Alley, 2019). *Emotional* engagement refers to the positive and negative affects students experience when interacting with the educational context (i.e., the instructors, their peers, and the learning material; Reschly and Christenson, 2016). According to SDT, it lies in human nature to be proactive and internalize new knowledge, and when autonomously motivated, students are more likely to engage with the educational context (Skinner and Pitzer, 2016). Studies show that autonomous motivation is positively linked to engagement among higher education students (Azila-Gbettor et al., 2021), and engagement has been shown to increase learning effectiveness among higher education students (Hu and Hui, 2012; Datu et al., 2016). Further, when autonomously motivated, students are more persisting in their tasks and assignments, and more likely to interact with the learning content since they can connect the material to their own personal values and interests. This claim is backed by a recent study by Azila-Gbettor et al. (2021), where it was found that autonomous motivation predicted engagement in higher education students. In contrast, when students experience a controlling educational context, individuals are more prone to disaffection and more likely to withdraw from their peers and interact less with the learning context (Skinner and Pitzer, 2016), and research indicates that controlled motivation is negatively related to engagement (Haivas et al., 2013; Li et al., 2015).

Autonomous and self-endorsed students act out of their own volition and are more likely to behave true to themselves. Consequentially, students can experience a psychological freedom

in the classroom which is often associated with feelings of vigor and rejuvenation. Studies have shown that autonomously motivated students also show an enhanced interest in their learning content (Kaur et al., 2014). When students are interested in topics it can yield deeper understanding as research has shown that interest is related to higher academic performance (Hidi et al., 2004). A study by Black and Deci (2000) found that autonomously motivated students achieved higher learning outcomes relative to controlled motivated students. These findings were similar to the findings by Roth et al. (2007) and Guay et al. (2016). Not only do autonomously motivated students achieve better academically relative to controlled students, but they are also associated with experiences of higher vitality and vigor (Bye et al., 2007; Núñez and León, 2016; Cheon et al., 2018). Subjective vitality can be defined as one's attentiveness to experiencing energy and aliveness (Ryan and Frederick, 1997), and has been linked to psychological wellbeing in students as it often is associated with feelings of better self-esteem, being spirited, enthusiastic and spontaneous, and negatively related to feelings of anxiety and stress. In a study among adolescent students in physical education, Mouratidis et al. (2011) reported that autonomously motivated students experienced higher levels of vitality. This result is supported in a study by Taylor and Lonsdale (2010), among British and Chinese students, and similar results were reported in a more recent study by Nishimura and Suzuki (2016) among undergraduate students in Japan. In contrast, controlled motivation is associated with pressure where students are experiencing less positive emotions (Nix et al., 1999), and a recent study by Tsoi et al. (2018) found that controlled motivation is negatively related to vitality.

Present study

The main aim of this study is to propose a comprehensive dual process model based on SDT tenets where we investigate the dual process of autonomy support and thwarting, and how it relates to aspects of student functioning (i.e., effort, engagement, vitality, and learning) mediated through autonomous and controlled motivation. In light of SDT's conceptualization and previous research, we hypothesize that (1) autonomy support positively predicts autonomous motivation which in turn positively predicts effort, engagement, vitality, and learning, (2) that autonomy thwarting positively predicts controlled motivation which in turn negatively predicts effort, engagement, vitality, and learning, and finally, and (3) we expect autonomy support to negatively predict controlled motivation and autonomy thwarting to negatively predict autonomous motivation. Although research has previously investigated autonomy satisfaction and frustration in relation to student functioning in higher education, few have investigated a dual process model focusing on autonomy (i.e., autonomy support vs. thwarting). Thus, we expand the current literature. First, as opposed to other studies (e.g., Núñez et al., 2014; Núñez and León, 2016; Neufeld and Malin, 2020; Lozano-Jiménez et al., 2021; Jiang and Tanaka, 2022), we investigate a dual process model where student functioning is related to autonomy support vs. thwarting. This is imperative in understanding the dual process behind autonomy underpinning student functioning. Further, in contrast to Patall et al. (2018), Neufeld and Malin (2020), and Vergara-Torres et al. (2020), we investigate a more comprehensive model by including effort, engagement, and learning as student functioning outcome variables alongside vitality. Although vitality is an important constituent of student functioning, these phenomena constitute a broadened proxy for student functioning as they have been shown to be associated with school resilience (Brooks et al., 2016), drop out intentions (Rumberger and Rotermund, 2016), anxiety (Quintero et al., 2022), and academic achievements (Christenson et al., 2012). Hence this is an important contribution to the current literature as it enables us to simultaneously investigate the effects of autonomy support and thwarting on academic functioning in higher education.

Materials and methods

Participants

The participants consisted of 414 (51% males) STEM students from introductory calculus courses at a Norwegian university. To protect participants' anonymity, age was asked in intervals (58.70% were 18–19, 36.96% were 20–21 years, and 4.34% were >21 years).

Procedure

Students were asked to participate in the study before the lectures started. Students that agreed to participate were given permission to complete the surveys 15 min before the end of the lecture session. We conducted the survey mid-term to ensure that the students were familiar with both the scope and content of the courses as well as the lecturers. Students participating in this study did not miss lecture content. During the study, the lecture was halted in agreement with the lecturer, and students who did not participate in the study were given an extra break. No reward was offered for participation.

Several ethical considerations were taken in the current study. First, the study obtained formal approval from the Norwegian Centre for Research Data (NSD). Next, the students received written information about the project, and were informed that they could withdraw from the study at any given time. The study was anonymous, and the data were treated confidentially.

Measures

Perceived autonomy support

We used the 6-item version of the Learning Climate Questionnaire (LCQ) to measure students' perceived autonomy support (Black and Deci, 2000). Students responded on a seven-point Likert scale, ranging from 1 (not true at all) to 7 (very true). An item example is "My instructor encouraged me to ask questions." In earlier studies, this scale has been shown to be both valid and reliable among higher education students (Williams and Deci, 1996). The Cronbach's alpha for the current study was $\alpha = 0.86$.

Perceived autonomy thwarting

Autonomy thwarting was measured using the 4-item autonomy thwarting subscale within the Interpersonal Behaviors Questionnaire (IBQ; Rocchi et al., 2017). Autonomy thwarting was measured on a seven-point Likert scale ranging from 1 (not true at all) to 7 (very true), and previous studies have found reliable results for this scale among higher education students (Rocchi et al., 2017). An item example is "My lecturer pressures me to do things their way." The Cronbach's alpha was found to be $\alpha = 0.70$.

Autonomous and controlled motivation

We employed the 12-item The Self-Regulation Questionnaire (SRQ-L) to measure autonomous and controlled motivation (Ryan and Connell, 1989). The students were presented with three statements (e.g., "I will likely follow my instructor's suggestions for studying mathematics") followed by either autonomous ("Because he/she seems to have insight about how best to learn the material") or controlled ("Because I would get a bad grade if I didn't do what he/she suggests") reasons for doing that specific behavior. Students answered on a seven-point Likert scale ranging from 1 (not true at all) to 7 (very true). The scale has been found to be reliable among higher education students (Williams and Deci, 1996), and the Cronbach's alpha for this scale was found to be $\alpha = 0.90$ for autonomous motivation and $\alpha = 0.60$ for controlled motivation.

Subjective vitality

We employed the seven-item Subjective Vitality Scales to measure the students' vitality (Ryan and Frederick, 1997). The vitality construct was measured on a seven-point Likert scale ranging from 1 (not true at all) to 7 (very true). The Subjective Vitality Scales has been found to be reliable in higher education (Bostic et al., 2000). An item example is "I have energy and spirit." The Cronbach's alpha for the current study was found to be $\alpha = 0.89$.

Effort

We used the five-item Effort Scale from the Intrinsic Motivation Inventory (Ryan et al., 1983) to measure the students' efforts. An item example is "I put a lot of effort into this." The students responded on a seven-point Likert scale ranging from 1 (not true at all) to 7 (very true). Previous research has found this scale to be reliable (Ostrow and Heffernan, 2018), and the Cronbach's alpha for our study was found to be $\alpha = 0.81$.

Emotional engagement

To measure emotional engagement, we employed the sub-scale Emotional engagement from the Four aspects of Engagement scale (Reeve and Tseng, 2011). This sub-scale consists of four items and the students were asked to answer on a seven-point Likert scale ranging from 1 (not true at all) to 7 (very true). An item example is "I enjoy learning new things in class." The scale has been shown to be reliable in educational settings (Reeve and Tseng, 2011). The Cronbach's alpha for this scale was $\alpha = 0.96$.

Learning

A four-item questionnaire was used to measure students' self-reported learning during the last 2 weeks. The questionnaire was adapted from Jeno et al. (2017). The students were asked to answer on a seven-point Likert scale ranging from 1 (not true at all) to 7 (very true). An item example is "I've learned a lot during the last 2 weeks." The Cronbach's alpha for this scale was $\alpha = 0.78$.

Analytical strategy

All statistical analyses were performed using R (RStudio, 2020). We used the "lavaan" package (Rosseel, 2012) to analyze our measurement model, structural equation model, and to test our study hypotheses. A confirmatory factor analysis was performed to establish the structure of the measurements. We utilized the conventional model fit indices Standardized Root Mean Squared Residual (SRMR), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA) and χ^2 to determine goodness-of-fit for our SEM model, where a good model fit is indicated by SRMR < 0.08 (perfect fit: 0.00), CFI > 0.90 (perfect fit: 1.00), TLI > 0.95 (perfect fit: 1.00), and RMSEA < 0.08 (perfect fit: 0.00), and finally χ^2 $p > 0.05$ is considered an indication of a good fit (Shi et al., 2018). For inadequate model fits, we employed modification indices (Jorgensen, 2017) to re-specify the model using proposed changes with modification index values >10 assuming the model changes were in line with SDT tenets.

Results

Descriptive analysis

Of the 414 students that participated in the study, 25 students (6%) did not complete the whole questionnaire. Little's missing completely at random (MCAR: Li, 2013) test indicated that the missing data were missing completely at random ($p > 0.05$). The missing data were therefore imputed (Schafer and Graham, 2002) using the MICE (Multivariate Imputation *via* Chained Equations) package for R (RStudio, 2020). Across all study variables, we found no gender differences (p's > 0.05), hence we collapsed gender across all variables.

The study variables are all within a normal distribution (**Table 1**). Correlational analyses show that autonomy support positively correlates with autonomous motivation, learning, effort, engagement, and vitality, and negatively with autonomy thwarting (**Table 2**). Autonomy thwarting correlates positively with controlled motivation, and negatively with learning, engagement, and vitality.

The relationship between autonomy support and thwarting, autonomous and controlled motivation, and effort, engagement, learning, and vitality

To test our main hypotheses (i.e., autonomy support positively predicts autonomous motivation which in turn predicts engagement, effort, learning, and vitality; autonomy thwarting

TABLE 1 Descriptive statistics for main variables.

	M	Range	SD	Skw.	Kurt.	α	Number of items
Autonomy support	4.23	1–7	0.82	−0.89	0.70	0.86	6
Autonomy thwarting	3.09	1–7	0.56	−0.29	0.16	0.70	4
Autonomous motivation	5.03	1–7	0.84	0.22	−0.85	0.90	5
Controlled motivation	4.11	1–7	0.43	0.84	0.85	0.60	7
Learning	3.73	1–7	0.23	0.01	−0.62	0.78	4
Effort	5.07	1–7	0.58	−0.73	1.48	0.81	5
Engagement	4.33	1–7	1.01	−0.06	−0.59	0.96	4
Vitality	3.87	1–7	0.80	−0.17	0.14	0.89	7

TABLE 2 Correlations of the main variables.

	1	2	3	4	5	6	7	8
1. Autonomy support	–							
2. Autonomy thwarting	−0.38**	–						
3. Autonomous motivation	0.47**	−0.37**	–					
4. Controlled motivation	−0.48**	0.50**	−0.30**	–				
5. Learning	0.30**	−0.21**	0.37**	−0.10*	–			
6. Effort	0.22**	0.01	0.28**	−0.04	0.25**	–		
7. Emotional engagement	0.67**	−0.38**	0.81**	−0.51**	0.42**	0.33**	–	
8. Vitality	0.47**	−0.36**	0.46**	−0.44**	0.38**	0.36**	0.60**	–

*$p < 0.05$, **$p < 0.01$.

positively predicts controlled motivation which in turn negatively predicts engagement, effort, learning, and vitality; autonomy support negatively predicts controlled motivation and autonomy thwarting negatively predicts autonomous motivation), we used structural equation modeling (SEM) to investigate the relationships between our study variables. It should be noted that the causal delineations of the SEM model pathways are based on theoretical assumptions anchored in SDT tenets and prior studies and cannot be proven in this study as it encompasses cross-sectional data.

First, we investigated a measurement model to verify the relationship between the variables and their corresponding item measures. The measurement model indicated acceptable fits, with CFI = 0.95, TLI = 0.92, RMSEA = 0.12 (CI = 0.11, 0.13), and SRMR = 0.03. Our initial proposed model (**Figure 1**) indicated poor model fit, with CFI = 0.76, TLI = 0.74, RMSEA = 0.13 (CI:0.11, 0.13), and SRMR = 0.076. Employing modification index algorithm (Jorgensen, 2017) to our baseline model indicated that autonomous motivation should covary with controlled motivation, and that some items should covary [only items measuring the same construct were included in the modifications; item 2 and 3 from LCQ (autonomy support); item 1 and 3 from IBQ (autonomy thwarting)]. The re-specified model (**Figure 2**) indicated acceptable model fit, with CFI = 0.91, TLI = 0.85, RMSEA = 0.12 (CI = 0.111, 0.135), and SRMR = 0.058. To check if the re-specified model was better compared to the baseline model, we utilized a chi-square difference test. We found a significant difference between the two models ($p < 0.01$), where the re-specified model ($\chi^2 = 3531$, df = 531) had a lower AIC (8004) and BIC (8169) relative to the base model ($\chi^2 = 4{,}586$; df = 534; AIC: 28,446; BIC: 28,816), indicating that the re-specified model better fits the data.

Our final model indicates that autonomy support positively predicts autonomous motivation and negatively predicts controlled motivation, whereas autonomy thwarting negatively predicts autonomous motivation and positively predicts controlled motivation, in line with our hypothesis. Autonomous motivation positively predicts engagement, learning, and effort, but we found no significant relationship between autonomous motivation and vitality in our model. Controlled motivation negatively predicts engagement and vitality, but positively predicts effort. We found no significant relationship between controlled motivation and learning. Finally, autonomous motivation and controlled motivation negatively covary. Due to the high correlation between autonomous and controlled motivation ($r = -0.71$), the potential presence of collinearity must be addressed. However, testing for collinearity for all variables using variance inflation factor revealed no issues (VIF < 10 for all variables; Hair et al., 1995).

Indirect effects

An analysis of the indirect effects for our process model (**Table 3**) indicates that autonomy support predicts engagement through autonomous and controlled motivation. Autonomy support predicts learning and effort through autonomous motivation and negatively predicts effort through controlled motivation. Autonomy thwarting negatively predicts engagement through autonomous motivation, and negatively through controlled motivation. Further, autonomy thwarting negatively predicts vitality through controlled motivation.

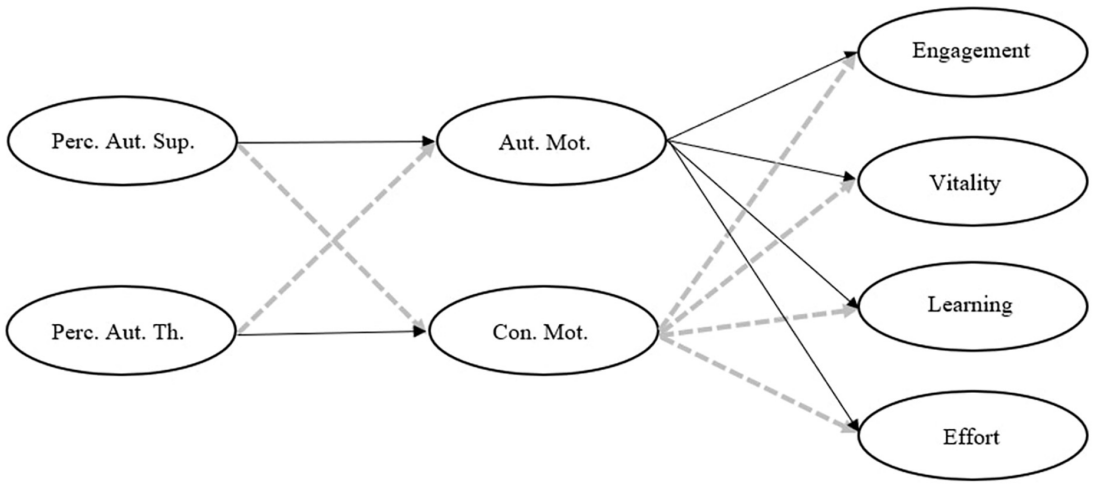

FIGURE 1
A process model of the hypothesized linkage between our study variables. Solid lines indicate positive relationship, dotted lines indicate negative relationship. Perc. Aut. Sup., Perceived autonomy support; Perc. Aut. Th., Perceived autonomy thwarting; Aut. Mot., Autonomous motivation; Con. Mot., controlled motivation.

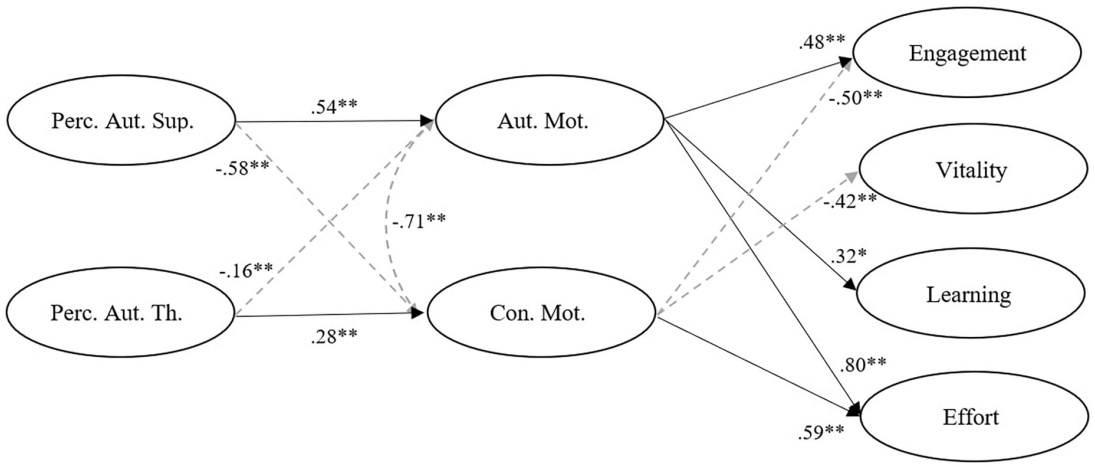

FIGURE 2
Modified path diagram with standardized regression coefficients. Solid lines indicate positive relationships, dotted lines indicate negative relationships. *$p < 0.05$, **$p < 0.01$. Perc. Aut. Sup., perceived autonomy support; Perc. Aut. Th., perceived autonomy thwarting; Aut. Mot., autonomous motivation; Con. Mot., controlled motivation. For clarity, non-significant paths have been removed from the model.

Discussion

The main aim of this study was to propose and investigate a comprehensive dual process model in which student functioning is related to autonomy support and thwarting mediated through autonomous and controlled motivation. Generally, the results supported our initial hypotheses, although there were some discrepancies. In line with our predictions, autonomy support positively predicts autonomous motivation, and negatively predicts controlled motivation. Autonomy thwarting negatively predicts autonomous motivation, and positively predicts controlled motivation. Further, autonomous motivation positively predicts engagement, effort, and learning, in line with our prediction. In our study, however, we did not find any (significant) relationship between autonomous motivation and vitality, but rather we found that controlled motivation negatively predicts vitality. These results are similar in magnitude to a study by Tsoi et al. (2018) conducted on pharmacy students. It is important to recognize that our measurement of controlled motivation had low reliability (alpha = 0.60). Since internal consistency entails to what extent the items measure the same construct, this low alpha could reflect a matter of dimensionality in our variable. This can be explained by the fact that controlled motivation consists of two very different types of motivations, namely, external regulation and introjected regulation (Cerasoli et al., 2014; Howard et al., 2021). SDT postulates that motivation is a multidimensional construct represented by a continuum of distinct types of motivations (i.e., the extrinsic regulations and intrinsic motivation). This conceptualization can lead to very complicated models when motivation is comprised of distinct

TABLE 3 Indirect effects of the relationships of the re-specified model.

Independent variable	Mediator	Dependent variable	Z	Indirect effect (standardized β)
Autonomy support	Autonomous motivation	Engagement	6.21***	0.26
Autonomy support	Autonomous motivation	Vitality	1.81	0.10
Autonomy support	Autonomous motivation	Learning	3.07***	0.17
Autonomy support	Autonomous motivation	Effort	5.89***	0.43
Autonomy support	Controlled motivation	Engagement	6.71***	0.29
Autonomy support	Controlled motivation	Vitality	3.86***	0.24
Autonomy support	Controlled motivation	Learning	1.02	0.06
Autonomy support	Controlled motivation	Effort	−4.49***	−0.34
Autonomy thwarting	Autonomous motivation	Engagement	−3.28**	−0.07
Autonomy thwarting	Autonomous motivation	Vitality	−1.64	−0.03
Autonomy thwarting	Autonomous motivation	Learning	−2.41*	−0.05
Autonomy thwarting	Autonomous motivation	Effort	−3.26*	−0.13
Autonomy thwarting	Controlled motivation	Engagement	−5.44***	−0.14
Autonomy thwarting	Controlled motivation	Vitality	−3.55***	−0.12
Autonomy thwarting	Controlled motivation	Learning	−1.01	−0.03
Autonomy thwarting	Controlled motivation	Effort	4.01***	0.16

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

constructs (external regulation, introjected regulation, identified regulation, and integrated regulation). There has, however, been interest in the empirical differences between the varied strategies of aggregation of this construct (Howard et al., 2020). On one hand, The Relative Autonomy Index (RAI; Grolnick and Ryan, 1989) represents the degree of relative autonomy as a single score. This reasoning is based on the autonomy continuum where each motivational construct is ordered, where identified and intrinsic motives increase the level of relative autonomy whereas external and introjected regulations decrease the score. This scoring system is highly aligned with the continuum of self-determined motivation, but it fails to address the role of each motivational construct in a model. Conversely, one could treat each motivational construct individually (Howard et al., 2020). The strength of this approach is rooted in its comprehensiveness where all motivational constructs can be modeled based on regulations. However, this approach downplays the continuum of self-determined motivation and no longer treats the autonomy continuum as a distinct factor. This can result in enhanced inter-regulation correlations as the effects of each motivational construct are amalgamated, resulting in potential erroneous effect sizes and even problems with effect directionality (Howard et al., 2020). Another approach is using higher-order models, where intrinsic and identified regulations are combined into autonomous motivation and introjected and external regulation are combined into controlled motivation. Although similar to the RAI approach in terms of not accounting for all the different motivational constructs, it does, however, present a dichotomous outlook of self-determination by investigating the effects of experiencing self-determination vs. experiencing a lack of self-determination (Howard et al., 2020). Alongside allowing the examination of indirect effects (Phillips and Johnson, 2018), higher order-models will often have easily interpretable results as an emblematic utilization of this approach may indicate a positive relation between autonomous motivation and, e.g., effort, whereas controlled motivation may negatively relate to the same variable (Howard et al., 2020).

Autonomously motivated students have often been associated with higher productiveness and willingness to put more effort into their assignments and learning activities (Ryan and Frederick, 1997). This claim is supported by our results, where we found that autonomous motivation positively predicts effort. Whenever learning activities are self-endorsed and carried out due to the students' own volitions, they are more willingly putting effort into learning activities (Mouratidis et al., 2011; Vansteenkiste et al., 2018). A similar result was also found by Feng et al. (2019), where they investigated homework effort in mathematics and found that autonomous motivation predicted effort with a very similar order of magnitude compared to our results. Further, we found that autonomy support has a positive indirect effect on effort mediated through autonomous motivation, and a negative indirect effect on effort mediated through controlled motivation. Students' ability to exert effort and persist is an important constituent in students' daily lives as effort has been shown to be a predictor of academic achievements (Komarraju and Nadler, 2013; Jiang et al., 2019). Yet, contrary to our initial hypothesis, our results indicate that controlled motivation positively predict effort as well. This could be explained by the fact that controlled motivation consists of two different types of motivations (external regulation and introjected regulation; Howard et al., 2021), hence our results must be interpreted in a more nuanced way. However, this finding is supported by a study by Goodman et al. (2011) on university students where they also found that controlled motivation positively predicts effort. Yet, the magnitude of the regression onto effort from autonomous motivation is considerably larger relative to controlled motivation according to our results. Interestingly, revisiting the indirect effect analysis (**Table 3**) we

can see that autonomy support strongly affects effort through both autonomous motivation and controlled motivation, while autonomy thwarting has a weaker effect on effort through both autonomous and controlled motivation.

Students who experience autonomy support and are self-endorsed during learning activities are more likely to value the learning material and associate the learning context with positive emotions (Assor et al., 2002). Hence, they are more likely to show emotional engagement, where they participate more actively in learning situations by showing involvement and enthusiasm. According to SDT, engagement can be considered an aspect of self-determined motivation (Skinner and Pitzer, 2016). It is human nature to be innately curious with a natural strive to learn and internalize, and fundamental to SDT is the core idea that when the basic need for autonomy is met by an educational autonomy supportive context, individuals will actively engage with the context (Skinner and Pitzer, 2016). This is mirrored in our results as well, where we observed a very high correlation between emotional engagement and autonomous motivation. Emotional engagement is an important constituent in higher education as previous research has shown that emotional engagement is linked to achievements and educational attainment (Elffers et al., 2012). In terms of our SEM model, we found that autonomous motivation positively predicts emotional engagement, a finding that is similar to a study by Froiland and Worrell (2016). Further, we found that controlling motivation negatively predicts engagement, a result that resemble those of Assor et al. (2005) and Jang et al. (2009). The results indicate that autonomy support positively predicts engagement mediated by both autonomous and controlled motivation with a very similar effect size, while autonomy thwarting negatively predicts engagement through both autonomous and controlled motivation. This is an interesting result as the direct effect of controlled motivation on engagement was negative, whereas the indirect effect (mediated through controlled motivation) from autonomy support on engagement was positive. This finding suggests that providing autonomy support in the classroom thus is pivotal in fostering engagement among students. In contrast, autonomy thwarting negatively predicts engagement mediated by both autonomous and controlled motivation.

In line with what we hypothesized, we found that autonomy support positively predicts autonomous motivation. When students are autonomy supported in a classroom setting, they are consequently more likely to endorse the course material in an autonomy supportive way, and hence will experience more autonomous forms of motivation (Reeve, 2009). Our findings support earlier similar research (Hagger et al., 2015) at a lower academic level, and hence we expand the theoretical implications to higher education numeracy courses. Further, as expected, autonomy support negatively predicts controlled motivation. When students are provided with an autonomy supportive learning climate, they are more likely to internalize the learning content in a less controlling way, thus one would expect autonomy support to negatively predict controlled motivation. However, our results contradict a study by Mouratidis et al. (2018) in which no significant relationship between autonomy support and controlled motivation was detected.

Although our analysis indicates that autonomous motivation does not predict vitality (neither directly nor indirectly), indirect effects analysis indicates that autonomy support positively predicts vitality mediated through controlled motivation. Further, controlled motivation directly negatively predicts vitality whereas autonomy thwarting negatively predicts vitality mediated through both controlled and autonomous motivation. And although similar findings have been reported before (Tsoi et al., 2018), some discussion regarding vitality as a variable is needed. Our results indicate that students pursuing the course in a controlled way experience less vitality. However, whereas the other outcome variables of our proposed model, i.e., engagement, learning, and effort, are subject relevant, vitality is a *general trait* which could be multidetermined beyond the context of the classroom (Ryan and Deci, 2017). Even though the feelings of being energized and vital are experiences students can report reliably (Ryan and Deci, 2017), experiences of vitality vary individually from person to person, and more noticeably, it varies within people. Adequate nutrient and liquid intake, sleep deprivation, exercise, and social interactions are examples of out-of-school contexts that directly affect vitality (Ryan and Frederick, 1997; Núñez and León, 2016; Cheon et al., 2018), hence the results surrounding vitality needs to be interpreted in a more nuanced way in our model.

Finally, in agreement with SDT tenets and our hypothesis, we found that autonomy thwarting negatively predicts autonomous motivation and positively predicts controlled motivation. Since autonomy thwarting is associated with a behavior or environment that pressures students to behave or act in a certain way (Assor et al., 2005), one would expect that students who experience autonomy thwarting will experience autonomous motivation to a lesser extent since the reason for the behavior has an external locus detached from the learning activity itself. Autonomy thwarting instructors tend to dismiss students' perspectives and use controlling practices and language; hence it can be difficult for students to fully accept the learning content and experience volition and self-endorsement. These findings have also been reported in a previous longitudinal diary study by Patall et al. (2018).

Limitations

There are several limitations worth mentioning when interpreting the results of our study. First, our study is cross-sectional in nature, hence we cannot infer causality. However, path directionality in our process model is based on strong theoretical propositions derived from SDT tenets and previous empirical research that supports our line of reasoning (e.g., Milyavskaya and Koestner, 2011; Yeager et al., 2014; Núñez and León, 2016; Cheon et al., 2018). Our strategy is thus appropriate for the purpose of our study (Bollen and Pearl, 2013). However, we recommend future studies to employ a longitudinal design throughout a semester to investigate how perceived autonomy support and thwarting impact changes in autonomous and controlled motivation to avoid any potential temporal issues.

Second, our study only focused on autonomy, as opposed to the remaining constituents in basic needs theory, namely, competence and relatedness. Future studies should include all three basic psychological needs to encompass the omitted aspects as studies show that both the need for competence and relatedness are important constituents for optimal learning outcomes (Niemec and Ryan, 2009; Beachboard et al., 2011).

Third, it is worth pointing out the construct validity of one of the study variables, *controlled motivation*. Calculation of Cronbach's alpha (0.60) implies there could be reason to question the internal consistency. Although the scale has shown good internal consistency in previous research (Williams and Deci, 1996; Black and Deci, 2000), a very similar Cronbach's alpha (0.55) was found in a more recent construct validity study (Iłendo-Milewska, 2019). It is, however, important to recognize that this variable is a construct consisting of two very different types of motives, i.e., external regulation and introjected regulation (Cerasoli et al., 2014). We therefore recommend future research to replicate our study using these motives independently instead of a compound approach. Further, it is worth noting that this implies that we are using a non-unidimensional construct as a single factor in our SEM model. However, according to item response theory there are a number of studies that have explored the robustness of variables used in models that violate unidimensionality assumptions, and generally the findings indicate that variables do not incur bias given that there is a strong general factor within the data (Drasgow and Parsons, 1983; Kirisci et al., 2001).

Finally, our study employed a self-report measure of learning. That is, we measured students' perceived learning, as opposed to an objective measure such as grades or test scores. Previous research has shown that perceived learning is a reliable measure of learning (Benton et al., 2013; Ratelle and Duchesne, 2014). However, caution is advised as self-reports are prone to memory bias (Pekrun, 2020) and have been shown to be less reliable among weaker students (Kuncel et al., 2005), hence future studies should include more objective measures of learning and other outcomes to investigate the relation between teacher support and thwarting, and student motivation.

Conclusion

To conclude, our study presented a comprehensive dual-process model delineating how autonomy support and autonomy thwarting underpin a proxy for student functioning. This study expands on previous research by exploring an investigative SDT model in a higher education calculus course to study how perceived autonomy support and thwarting affect student motivation and in turn, important aspects related to a good learning climate in an authentic classroom setting. The present study is the first study to investigate the dual process behind how perceived autonomy support and thwarting affect engagement, effort, vitality, and learning, indirectly through autonomous and controlled motivation simultaneously in a higher education setting. Students function better in a learning environment when they experience autonomy support, thus it is imperative for researchers to highlight the importance of an autonomy supportive learning environment.

We encourage future researchers to replicate and expand our study by implementing similar models in other disciplines in higher education.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Norwegian Social Science Data Services. The patients/participants provided their written informed consent to participate in this study.

Author contributions

MJ: conceptualization, methodology, formal analysis, software, writing—original draft, and investigation. LJ: conceptualization, methodology, writing—review and editing, and supervision. SE: conceptualization, writing—review and editing, and supervision. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Alley, K. M. (2019). Fostering middle school students' autonomy to support motivation and engagement. *Middle Sch. J.* 50, 5–14. doi: 10.1080/00940771.2019.1603801

Assor, A., Kaplan, H., Kanat-Maymon, Y., and Roth, G. (2005). Directly controlling teacher behaviors as predictors of poor motivation and engagement in girls and boys: The role of anger and anxiety. *Learn. Instr.* 15, 397–413. doi: 10.1016/j.learninstruc.2005.07.008

Assor, A., Kaplan, H., and Roth, G. (2002). Choice is good, but relevance is excellent: Autonomy-enhancing and suppressing teacher behaviours predicting students' engagement in schoolwork. *Br. J. Educ. Psychol.* 72, 261–278.

Azila-Gbettor, E. M., Mensah, C., Abiemo, M. K., and Bokor, M. (2021). Predicting student engagement from self-efficacy and autonomous motivation: A cross-sectional study. *Cogent Educ.* 8:1. doi: 10.1080/2331186X.2021.1942638

Beachboard, M. R., Beachboard, J. C., Li, W., and Adkinson, S. R. (2011). Cohorts and relatedness: Self-determination theory as an explanation of how learning communities affect educational outcomes. *Res. High. Educ.* 52, 853–874.

Benton, S. L., Duchon, D., and Pallett, W. H. (2013). Validity of student self-reported ratings of learning. *Assess. Eval. High. Educ.* 38, 377–388. doi: 10.1080/02602938.2011.636799

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

Bollen, K. A., and Pearl, J. (2013). *Eight myths about causality and structural equation models. Handbook of causal analysis for social research*. Berlin: Springer.

Bostic, T. J., Rubio, D. M., and Hood, M. (2000). A validation of the subjective vitality scale using structural equation modeling. *Soc. Indic. Res.* 52, 313–324. doi: 10.1023/A:1007136110218

Bronson, S. (2016). Autonomy support environment and autonomous motivation on nursing student academic performance: An exploratory analysis. *Nurse Educ. Today* 44, 103–108. doi: 10.1016/j.nedt.2016.05.013

Brooks, R., Brooks, S., and Goldstein, S. (2016). "The power of mindsets: Nurturing engagement, motivation, and resilience in students," in *Handbook of research on student engagement*, eds S. L. Christenson (Berlin: Springer Science),

Burgueño, R., García-González, L., Abós, Á, and Sevil-Serrano, J. (2022). Students' motivational experiences across profiles of perceived need-supportive and need-thwarting teaching behaviors in physical education. *Phys. Educ. Sport Pedagogy* [Epub ahead of print]. doi: 10.1080/17408989.2022.2028757

Bye, D., Pushkar, D., and Conway, M. (2007). Motivation, interest, and positive affect in traditional and nontraditional undergraduate students. *Adult Educ. Q.* 57, 141–158. doi: 10.1177/0741713606294235

Cece, V., Lienhart, N., Nicaise, V., Guillet-Descas, E., and Martinent, G. (2018). Longitudinal sport motivation among young athletes in intensive training settings: The role of basic psychological needs satisfaction and thwarting in the profiles of motivation. *J. Sport Exerc. Psychol.* 40, 186–195. doi: 10.1123/jsep.2017-0195

Cerasoli, C. P., Nicklin, J. M., and Ford, M. T. (2014). Intrinsic motivation and extrinsic incentives jointly predict performance: A 40-year meta-analysis. *Psychol. Bull.* 140, 980–1008. doi: 10.1037/a0035661

Cheon, S. H., Reeve, J., Lee, Y., and Lee, J. (2018). Why autonomy-supportive interventions work: Explaining the professional development of teachers' motivating style. *Teach. Teach. Educ.* 69, 43–51. doi: 10.1016/j.tate.2017.09.022

Cheon, S. H., Reeve, J., and Vansteenkiste, M. (2020). When teachers learn how to provide classroom structure in an autonomy-supportive way: Benefits to teachers and their students. *Teach. Teach. Educ.* 90:103004. doi: 10.1016/j.tate.2019.103004

Christenson, S. L., Reschly, A. L., and Wylie, C. (2012). *Handbook of research on student engagement*. Berlin: Springer Science.

Datu, J. A. D., King, R. B., and Valdez, J. P. M. (2016). Psychological capital bolsters motivation, engagement, and achievement: Cross-sectional and longitudinal studies. *J. Posit. Psychol.* 13, 260–270. doi: 10.1080/17439760.2016.1257056

Deci, E. L., and Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Can. Psychol.* 49, 182–185. doi: 10.1037/a0012801

Disch, W. B., Harlow, L., Campbell, J. F., and Dougan, T. R. (2000). Student functioning, concerns, and socio-personal well-being. *Soc. Indic. Res.* 51, 41–74. doi: 10.1023/A:1007013820439

Drasgow, F., and Parsons, C. K. (1983). Application of unidimensional item response theory models to mutidimensional data. *Appl. Psychol. Meas.* 7, 189–199. doi: 10.1177/014662168300700207

Elffers, L., Oort, F. J., and Karsten, S. (2012). Making the connection: The role of social and academic school experiences in students' emotional engagement with school in post-secondary vocational education. *Learn. Individ. Dif.* 22, 242–250. doi: 10.1016/j.lindif.2011.08.005

Feng, X., Xie, K., Gong, S., Gao, L., and Cao, Y. (2019). Effects of parental autonomy support and teacher support on middle school students' homework effort: Homework autonomous motivation as mediator. *Front. Psychol.* 10:612. doi: 10.3389/fpsyg.2019.00612

Feri, R., Soemantri, D., and Jusuf, A. (2016). The relationship between autonomous motivation and autonomy support in medical students' academic achievement. *Int. J. Med. Educ.* 7, 417–423. doi: 10.5116/ijme.5843.1097

Froiland, J. M., and Worrell, F. C. (2016). Intrinsic motivation, learning goals, engagement, and achievement in a diverse high school. *Psychol. Sch.* 53, 321–336. doi: 10.1002/pits.21901

Ganotice, F. A., Chan, L., Chow, A., Khoo, U. S., Lam, M. P., Liu, R. K. W., et al. (2020). What characterize high and low achieving teams in Interprofessional education: A self-determination theory perspective. *Nurse Educ. Today* 55, 701–712. doi: 10.1111/medu.14423

Goodman, S., Keresztesi, M., Mokgatle, D., and Schlechter, A. F. (2011). An investigation of the relationship between students' motivation and academic performance as mediated by effort. *South Afr. J. Psychol.* 41, 373–385. doi: 10.1177/008124631104100311

Grolnick, W. S., and Ryan, R. M. (1989). Parent styles associated with children's self-regulation and competence in school. *J. Educ. Psychol.* 81, 143–154. doi: 10.1037/0022-0663.81.2.143

Guay, F., Lessard, V., and Dubois, P. (2016). "How can we create better learning contexts for children? Promoting students' autonomous motivation as a way to foster enhanced educational outcomes," in *Building autonomous learners*, eds W. Liu, J. Wang, and R. Ryan (Singapore: Springer), doi: 10.1007/978-981-287-630-0_5

Haerens, L., Aelterman, N., Vansteenkiste, M., Soenens, B., and Petegem, S. V. (2015). Do perceived autonomy-supportive and controlling teaching relate to physical education students' motivational experiences through unique pathways? Distinguishing between the bright and dark side of motivation. *Psychol. Sport Exerc.* 16, 26–36. doi: 10.1016/j.psychsport.2014.08.013

Hagger, M. S., Sultan, S., Hardcastle, S. J., and Chatzisarantis, N. L. D. (2015). Perceived autonomy support and autonomous motivation toward mathematics activities in educational and out-of-school contexts is related to mathematics homework behavior and attainment. *Contemp. Educ. Psychol.* 41, 111–123. doi: 10.1016/j.cedpsych.2014.12.002

Hair, J. F. Jr., Anderson, R. E., Tatham, R. L., and Black, W. C. (1995). *Multivariate data analysis*, 3rd Edn. New York, NY: Macmillan.

Haivas, S., Hofmans, J., and Pepermans, R. (2013). Volunteer engagement and intention to quit from a self-determination theory perspective. *J. Appl. Soc. Psychol.* 43, 1869–1880. doi: 10.1111/jasp.12149

Hidi, S., Renninger, K. A., and Krapp, A. (2004). "Interest, A Motivational Variable That Combines Affective And Cognitive Functioning," in *Motivation, emotion and cognition: integrative perspectives on intellectual functioning and development*, eds D. Y. Dai and R. J. Sternberg (Mahwah, NJ: Lawrence Erlbaum), 89–115.

Howard, J. L., Bureau, J. S., Guay, F., Chong, J. X. Y., and Ryan, R. M. (2021). Student motivation and associated outcomes: A meta-analysis from self-determination theory. *Perspect. Psychol. Sci.* 16, 1300–1323. doi: 10.1177/1745691620966789

Howard, J. L., Gagné, M., Van den Broeck, A., Guay, F., Chatzisarantis, N., Ntoumanis, N., et al. (2020). A review and empirical comparison of motivation scoring methods: An application to self-determination theory. *Motiv. Emot.* 44, 534–548. doi: 10.1007/s11031-020-09831-9

Hu, P. J., and Hui, W. (2012). Examining the role of learning engagement in technology-mediated learning and its effects on learning effectiveness and satisfaction. *Decis. Support Syst.* 53, 782–792. doi: 10.1016/j.dss.2012.05.014

Iłendo-Milewska, A. (2019). The construct validity of the polish self-regulation questionnaire–learning (srq-l). *Int. J. Dev. Res.* 9:7.

Jang, H., Reeve, J., Ryan, R. M., and Kim, A. (2009). Can self-determination theory explain what underlies the productive, satisfying learning experiences of collectivistically oriented Korean students? *J. Educ. Psychol.* 101, 644–661. doi: 10.1037/a0014241

Jeno, L. M., Raaheim, A., Kristensen, S. M., Kristensen, K. D., Hole, T. N., Haugland, M. J., et al. (2017). The relative effect of team-based learning on motivation and learning: A self-determination theory perspective. *CBE Life Sci. Educ.* 16:ar59. doi: 10.1187/cbe.17-03-0055

Jiang, J., and Tanaka, A. (2022). Autonomy support from support staff in higher education and students' academic engagement and psychological well-being. *Int. J. Exp. Educ. Psychol.* 42, 42–63. doi: 10.1080/01443410.2021.1982866

Jiang, J., Vauras, M., Volet, S., Salo, A., and Kajamies, A. (2019). Autonomy-supportive and controlling teaching in the classroom: A video-based case study. *Educ. Sci.* 9, 1–19. doi: 10.3390/educsci9030229

Jorgensen, T. D. (2017). Applying permutation tests and multivariate modification indices to configurally invariant models that need respecification. *Front. Psychol.* 8:1455. doi: 10.3389/fpsyg.2017.01455

Joussemet, M., Koestner, R., Lekes, N., and Houlfort, N. (2004). Introducing uninteresting tasks to children: A comparison of the effects of rewards and autonomy support. *J. Pers.* 72, 139–166. doi: 10.1111/j.0022-3506.2004.00259.x

Kaplan, H. (2018). Teachers' autonomy support, autonomy suppression and conditional negative regard as predictors of optimal learning experience among high-achieving Bedouin students. *Soc. Psychol. Educ.* 21, 223–255. doi: 10.1007/s11218-017-9405-y

Kaur, A., Awang Hashim, R., and Noman, M. (2014). Teacher autonomy support: Does it hinder motivation among Thai students? *Malaysian J. Learn. Instr.* 11, 171–189.

Keller, M. M., Neumann, K., and Fischer, H. E. (2016). The impact of physics teachers' pedagogical content knowledge and motivation on students' achievement and interest. *J. Res. Sci. Teach.* 54, 586–614. doi: 10.1002/tea.21378

Kember, D., Ho, A., and Hong, C. (2008). The importance of establishing relevance in motivating student learning. *Active Learn. High. Educ.* 9, 249–263. doi: 10.1177/1469787408095849

Kirisci, L., Hsu, T.-C., and Yu, L. (2001). Robustness of item parameter estimation programs to assumptions of unidimensionality and normality. *Appl. Psychol. Meas.* 25, 146–162. doi: 10.1177/01466210122031975

Komarraju, M., and Nadler, D. (2013). Self-efficacy and academic achievement: Why do implicit beliefs, goals, and effort regulation matter? *Learn. Individ. Dif.* 25, 67–72. doi: 10.1016/j.lindif.2013.01.005

Kubicek, B., Paškvan, M., and Bunner, J. (2017). "The bright and dark sides of job autonomy," in *Job demands in a changing world of work*, eds C. Korunka and B. Kubicek (Cham: Springer), doi: 10.1007/978-3-319-54678-0_4

Kuncel, N., Crede, M., and Thomas, L. L. (2005). The validity of self-reported grade point averages, class ranks, and test scores: A meta-analysis and review of the literature. *Rev. Educ. Res.* 75, 63–82. doi: 10.3102/00346543075001063

Li, C. (2013). Little's test of missing completely at random. *Stata J.* 13, 795–809. doi: 10.1177/1536867X1301300407

Li, M., Wang, Z., You, X., and Gao, J. (2015). Value congruence and teachers' work engagement: The mediating role of autonomous and controlled motivation. *Pers. Individ. Differ.* 80, 113–118. doi: 10.1016/j.paid.2015.02.021

Lin, S., Mastrokoukou, S., Longobardi, C., Bozzato, P., Gastaldi, F. G. M., and Berchiatti, M. (2022). Students' transition into higher education: The role of self-efficacy, regulation strategies, and academic achievements. *High. Educ. Q.* 77, 121–137. doi: 10.1111/hequ.12374

Lozano-Jiménez, J. E., Huéscar, E., and Moreno-Murcia, J. A. (2021). From autonomy support and grit to satisfaction with life through self-determined motivation and group cohesion in higher education. *Front. Psychol.* 11:579492. doi: 10.3389/fpsyg.2020.579492

Manganelli, S., Cavicchiolo, E., Mallia, L., Biasi, V., Lucidi, F., and Alivernini, F. (2019). The interplay between self-determined motivation, self-regulated cognitive strategies, and prior achievement in predicting academic performance. *Educ. Psychol.* 39, 470–488. doi: 10.1080/01443410.2019.1572104

Martela, F., DeHaan, C. R., and Ryan, R. M. (2016). On enhancing and diminishing energy through psychological means: Research on vitality and depletion from self-determination theory. *Self-Regul. Ego Control* 2016, 67–85. doi: 10.1016/B978-0-12-801850-7.00004-4

Meens, E. E., Bakx, A. W. E. A., Klimstra, T. A., and Denissen, J. J. A. (2018). The association of identity and motivation with students' academic achievement in higher education. *Learn. Individ. Dif.* 64, 54–70. doi: 10.1016/j.lindif.2018.04.006

Milyavskaya, M., and Koestner, R. (2011). Psychological needs, motivation, and well-being: A test of self-determination theory across multiple domains. *Pers. Individ. Dif.* 50, 387–391. doi: 10.1016/j.paid.2010.10.029

Moller, A. C., Deci, E. L., and Ryan, R. M. (2006). Choice and egodepletion: The moderating role of autonomy. *Pers. Soc. Psychol. Bull.* 32, 1024–1036. doi: 10.1177/0146167206288008

Mouratidis, A., Michou, A., Aelterman, N., Haerens, L., and Vansteenkiste, M. (2018). Begin-of-school-year perceived autonomy-support and structure as predictors of end-of-schoolyear study efforts and procrastination: the mediating role of autonomous and controlled motivation. *Educ. Psychol.* 38, 435–450. doi: 10.1080/01443410.2017.1402863

Mouratidis, A., Vansteenkiste, M., Sideridis, G., and Lens, W. (2011). Vitality and interest-enjoyment as a function of class-to-class variation in need-supportive teaching and pupils' autonomous motivation. *J. Educ. Psychol.* 103, 353–366. doi: 10.1037/a0022773

Muenks, K., Yang, J. S., and Wigfield, A. (2018). Associations between grit, motivation, and achievement in high school students. *Motiv. Sci.* 4, 158–176. doi: 10.1037/mot0000076

Neufeld, A., and Malin, G. (2020). How medical students' perceptions of instructor autonomy-support mediate their motivation and psychological well-being. *Med. Teach.* 42, 650–656. doi: 10.1080/0142159X.2020.1726308

Niemec, C. P., and Ryan, R. M. (2009). Autonomy, competence, and relatedness in the classroom: Applying self-determination theory to educational practice. *Theory Res. Educ.* 7, 133–144. doi: 10.1177/1477878509104318

Nishimura, T., and Suzuki, T. (2016). Basic psychological need satisfaction and frustration in Japan: Controlling for the big five personality traits. *Jap. Psychol. Res.* 58, 320–331. doi: 10.1111/jpr.12131

Nix, G. A., Ryan, R. M., Manly, J. B., and Deci, E. L. (1999). Revitalization through self-regulation: The effects of autonomous and controlled motivation on happiness and vitality. *J. Exp. Soc. Psychol.* 35, 266–284. doi: 10.1006/jesp.1999.1382

Ntoumanis, N. (2001). A self-determination approach to the understanding of motivation in physical education. *Br. J. Educ. Psychol.* 71, 225–242. doi: 10.1348/000709901158497

Ntoumanis, N., and Standage, M. (2009). Motivation in physical education classes: A self-determination theory perspective. *Theory Res. Educ.* 7, 194–202. doi: 10.1177/1477878509104324

Núñez, J. L., Fernández, C., León, J., and Grijalvo, F. (2014). The relationship between teacher's autonomy support and students' autonomy and vitality. *Teach. Teach.* 21, 191–202. doi: 10.1080/13540602.2014.928127

Núñez, J. L., and León, J. (2015). Autonomy support in the classroom: A review of self-determination theory. *Eur. Psychol.* 20, 275–283. doi: 10.1027/1016-9040/a000234

Núñez, J. L., and León, J. (2016). The mediating effect of intrinsic motivation to learn on the relationship between student's autonomy support and vitality and deep learning. *Span. J. Psychol.* 19, 1–8. doi: 10.1017/sjp.2016.43

Okada, R. (2021). Effects of perceived autonomy support on academic achievement and motivation among higher education students: A meta-analysis. *Jap. Psychol. Res.* [Epub ahead of print]. doi: 10.1111/jpr.12380

Oriol-Granado, X., Mendoza-Lira, M., Covarrubias-Apablaza, C., and Molina-López, V. (2017). Positive emotions, autonomy support and academic performance of university students: The mediating role of academic engagement and self-efficacy. *Rev. Psicodidáctica* 22, 45–53. doi: 10.1387/RevPsicodidact.14280

Ostrow, K., and Heffernan, N. T. (2018). "Testing the validity and reliability of intrinsic motivation inventory subscales within ASSISTments," in *Proceedings of the Nineteenth International Conference on Artificial Intelligence in Education*, Cheltenham.

Patall, E. A., Steingut, R. R., Vasquez, A. C., Trimble, S. S., Pituch, K. A., and Freeman, J. L. (2018). Daily autonomy supporting or thwarting and students' motivation and engagement in the high school science classroom. *J. Educ. Psychol.* 110, 269–288. doi: 10.1037/edu0000214

Pekrun, R. (2020). Commentary: Self-report is indispensable to assess students' learning. *Frontline Learn. Res.* 8:185–193. doi: 10.14786/flr.v8i3.637

Pelletier, L. G., Fortier, M. S., Vallerand, R. J., and Briere, N. M. (2002). Associations among perceived autonomy support, forms of self-regulation and persistence: A prospective study. *Motiv. Emot.* 25, 279–306. doi: 10.1023/A:1014805132406

Phillips, L. A., and Johnson, M. A. (2018). Interdependent effects of autonomous and controlled regulation on exercise behavior. *Pers. Soc. Psychol. Bull.* 44, 49–62. doi: 10.1177/01461672177330

Pintrich, P. R., Brown, D. R., and Weinstein, C. E. (1994). *Student motivation, cognition, and learning*. London: Routledge.

Quintero, M., Hasty, L., Li, T., Song, S., and Wang, Z. (2022). A multidimensional examination of math anxiety and engagement on math achievement. *Br. J. Educ. Psychol.* 92, 955–973. doi: 10.1111/bjep.12482

Ratelle, C. F., and Duchesne, S. (2014). Trajectories of psychological need satisfaction from early to late adolescence as a predictor of adjustment in school. *Contemp. Educ. Psychol.* 39, 388–400. doi: 10.1016/j.cedpsych.2014.09.003

Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educ. Psychol.* 44, 159–175. doi: 10.1080/00461520903028990

Reeve, J., and Cheon, S. H. (2021). Autonomy-supportive teaching: Its malleability, benefits, and potential to improve educational practice. *Educ. Psychol.* 56, 54–77. doi: 10.1080/00461520.2020.1862657

Reeve, J., Jang, H., Carrell, D., Jeon, S., and Barch, J. (2004). Enhancing students' engagement by increasing teachers' autonomy support. *Motiv. Emot.* 28, 147–169. doi: 10.1023/B:MOEM.0000032312.95499.6f

Reeve, J., Jang, H., Hardre, P., and Omura, M. (2002). Providing a rationale in an autonomy-supportive way as a strategy to motivate others during an uninteresting activity. *Motiv. Emot.* 26, 183–207. doi: 10.1023/A:1021711629417

Reeve, J., Nix, G., and Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *J. Educ. Psychol.* 95, 375–392. doi: 10.1037/0022-0663.95.2.375

Reeve, J., and Tseng, C. (2011). Agency as a fourth aspect of students' engagement during learning activities. *Contemp. Educ. Psychol.* 36, 257–267. doi: 10.1016/j.cedpsych.2011.05.002

Reschly, A. L., and Christenson, S. L. (2016). "Jingle, jangle, and conceptual haziness: Evolution and future directions of the engagement construct," in *Handbook of research on student engagement*, ed. S. L. Christenson (Berlin: Springer Science),

Rocchi, M., Pelletier, L., Baxter, D., and Beaudry, S. (2017). Assessing need-supportive and need-thwarting interpersonal behaviours: The Interpersonal Behaviours Questionnaire (IBQ). *Pers. Individ. Dif.* 104, 423–433. doi: 10.1016/j.paid.2016.08.034

Rodrigues, F., Teixeira, D. S., Neiva, H. P., Cid, L., and Monteiro, D. (2020). The bright and dark sides of motivation as predictors of enjoyment, intention, and exercise persistence. *Scand. J. Med. Sci. Sports* 30, 787–800. doi: 10.1111/sms.13617

Rosseel, Y. (2012). lavaan: An R package for structural equation modelling. *J. Stat. Softw.* 48, 1–36. doi: 10.18637/jss.v048.i02

Roth, G., Assor, A., Kanat-Maymon, Y., and Kaplan, H. (2007). Autonomous motivation for teaching: How self-determined teaching may lead to self-determined learning. *J. Educ. Psychol.* 99, 761–774. doi: 10.1037/0022-0663.99.4.761

RStudio (2020). *Open source & professional software for data science teams*. Boston, MA: RStudio.

Rumberger, R. W., and Rotermund, S. (2016). "The relationship between engagement and high school dropout," in *Handbook of research on student engagement*, eds S. L. Christenson, A. Reschly, and C. Wylie (Berlin: Springer Science), doi: 10.1007/978-1-4614-2018-7_24

Ryan, R. M., Bernstein, J. H., and Brown, K. W. (2010). Weekends, work, and well-being: Psychological need satisfactions and day of the week effects on mood, vitality, and physical symptoms. *J. Soc. Clin. Psychol.* 29, 95–122. doi: 10.1521/jscp.2010.29.1.95

Ryan, R. M., and Connell, J. P. (1989). Perceived locus of causality and internalization: Examining reasons for acting in two domains. *J. Pers. Soc. Psychol.* 57, 749–761. doi: 10.1037/0022-3514.57.5.749

Ryan, R. M., and Deci, E. L. (2000a). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am. Psychol.* 55, 68–78. doi: 10.1037/0003-066X.55.1.68

Ryan, R. M., and Deci, E. L. (2000b). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemp. Educ. Psychol.* 25, 54–67. doi: 10.1006/ceps.1999.1020

Ryan, R. M., and Deci, E. L. (2017). *Self-determination theory – Basic psychological needs in motivation, development and wellness*. New York, NY: The Guilford Press.

Ryan, R. M., and Frederick, C. (1997). On energy, personality, and health: Subjective vitality as a dynamic reflection of well-being. *J. Pers.* 65, 529–565. doi: 10.1111/j.1467-6494.1997.tb00326.x

Ryan, R. M., Mims, V., and Koestner, R. (1983). Relation of reward contingency and interpersonal context to intrinsic motivation: A review and test using cognitive evaluation theory. *J. Pers. Soc. Psychol.* 45, 736–750. doi: 10.1037/0022-3514.45.4.736

Ryan, R. M., Rigby, C. S., and Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. *Motiv. Emot.* 30, 344–360. doi: 10.1007/s11031-006-9051-8

Schafer, J. L., and Graham, J. W. (2002). Missing Data: Our view of the state of the art. *Psychol. Methods* 7, 147–177. doi: 10.1037//1082-989X.7.2.147

Schmid, S., and Bogner, F. X. (2015). Effects of students' effort scores in a structured inquiry unit on long-term recall abilities of content knowledge. *Educ. Res. Int.* 2015:826734. doi: 10.1155/2015/826734

Shen, B., McCaughtry, N., Martin, J., and Fahlman, M. (2009). Effects of teacher autonomy support and students' autonomous motivation on learning in physical education. *Res. Q. Exerc. Sport* 80, 44–53. doi: 10.1080/02701367.2009.10599528

Shi, D., Lee, T., and Maydeu-Olivares, A. (2018). Understanding the model size effect on SEM fit indices. *Educ. Psychol. Meas.* 79, 310–334. doi: 10.1177/0013164418783530

Skinner, E. A., and Pitzer, J. R. (2016). "Developmental dynamics of student engagement, coping, and everyday resilience," in *Handbook of research on student engagement*, eds S. L. Christenson (Berlin: Springer Science),

Strauss, L. C., and Volkwein, J. F. (2002). Comparing student performance and growth in 2- and 4-year institutions. *Res. High. Educ.* 43, 133–161. doi: 10.1023/A:1014495823183

Taylor, G., Jungert, T., Mageau, G. A., Schattke, K., Dedic, H., Rosenfield, S., et al. (2014). A self-determination theory approach to predicting school achievement over time: The unique role of intrinsic motivation. *Contemp. Educ. Psychol.* 39, 342–358. doi: 10.1016/j.cedpsych.2014.08.002

Taylor, I. M., and Lonsdale, C. (2010). Cultural differences in the relationships among autonomy support, psychological need satisfaction, subjective vitality, and effort in British and Chinese physical education. *J. Sport Exerc. Psychol.* 32, 655–673. doi: 10.1123/jsep.32.5.655

Terrón-López, M., García-García, M., Velasco-Quintana, P., Ocampo, J., Montaño, M. V., and Gaya-López, M. (2017). Implementation of a project-based engineering school: increasing student motivation and relevant learning. *Eur. J. Eng. Educ.* 42, 618–631. doi: 10.1080/03043797.2016.1209462

Tsoi, S. L., de Boer, A., Croiset, G., Koster, A. S., van der Burgt, S., and Kusurkar, R. A. (2018). How basic psychological needs and motivation affect vitality and lifelong learning adaptability of pharmacists: A structural equation model. *Adv. Health Sci. Educ.* 23, 549–566. doi: 10.1007/s10459-018-9812-7

Vansteenkiste, M., Aelterman, N., Muynck, G. D., Haerens, L., Patall, E., and Reeve, J. (2018). Fostering personal meaning and self-relevance: A self-determination theory perspective on internalization. *J. Exp. Educ.* 86, 30–49. doi: 10.1080/00220973.2017.1381067

Vansteenkiste, M., Lens, W., and Deci, E. L. (2006). Intrinsic versus extrinsic goal contents in self-determination theory: Another look at the quality of academic motivation. *Educ. Psychol.* 41, 19–31. doi: 10.1207/s15326985ep4101_4

Vansteenkiste, M., Niemiec, C. P., and Soenens, B. (2010). The development of the five mini-theories of self-determination theory: An historical overview, emerging trends, and future directions. *Adv. Motiv. Achiev.* 16A, 105–165. doi: 10.1108/S0749-74232010000016A007

Vansteenkiste, M., Simons, J., Lens, W., Sheldon, K. M., and Deci, E. L. (2004). Motivating learning, performance, and persistence: The synergistic role of intrinsic goals and autonomy support. *J. Pers. Soc. Psychol.* 87, 246–260. doi: 10.1037/0022-3514.87.2.246

Vasquez, A. C., Patall, E. A., Fong, C. J., Corrigan, A. S., and Pine, L. (2016). Parent autonomy support, academic achievement, and psychosocial functioning: A meta-analysis of research. *Educ. Psychol. Rev.* 28, 605–644. doi: 10.1007/s10648-015-9329-z

Vergara-Torres, A. P., Tristán, J., López-Walle, J. M., González-Gallegos, A., Pappous, A., and Tomás, I. (2020). Students' perceptions of teachers' corrective feedback, basic psychological needs and subjective vitality: A multilevel approach. *Front. Psychol.* 11:558954. doi: 10.3389/fpsyg.2020.558954

Williams, G. C., and Deci, E. L. (1996). Internalization of biopsychosocial values by medical students: A test of self-determination theory. *J. Pers. Soc. Psychol.* 70, 767–779. doi: 10.1037/0022-3514.70.4.767

Xu, J., Du, J., Cunha, J., and Rosário, P. (2021). Student perceptions of homework quality, autonomy support, effort, and math achievement: Testing models of reciprocal effects. *Teach. Teach. Educ.* 108:103508. doi: 10.1016/j.tate.2021.103508

Xu, J., Du, J., Wu, S., Ripple, H., and Cosgriff, A. (2018). Reciprocal effects among parental homework support, effort, and achievement? An empirical investigation. *Front. Psychol.* 9:2334. doi: 10.3389/fpsyg.2018.02334

Yeager, D. S., Henderson, M. D., Paunesku, D., Walton, G. M., D'Mello, S., Spitzer, B. J., et al. (2014). Boring but important: A self-transcendent purpose for learning fosters academic self-regulation. *J. Pers. Soc. Psychol.* 107, 559–580. doi: 10.1037/a0037637

Young, A. M., Wendel, P. J., Esson, J. M., and Plank, K. M. (2018). Motivational decline and recovery in higher education STEM courses. *Int. J. Sci. Educ.* 40, 1016–1033. doi: 10.1080/09500693.2018.1460773