The Journal of Experimental Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/vjxe20

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To cite this article: Yeo-eun Kim , Shirley L. Yu , Alison C. Koenka , Hyewon Lee & Andrew F. Heckler (2021): Can Self-Efficacy and Task Values Buffer Perceived Costs? Exploring Introductory- and Upper-Level Physics Courses, The Journal of Experimental Education, DOI: 10.1080/00220973.2021.1878992

To link to this article: https://doi.org/10.1080/00220973.2021.1878992

THE JOURNAL OF EXPERIMENTAL EDUCATION
https://doi.org/10.1080/00220973.2021.1878992

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MOTIVATION AND SOCIAL PROCESSES

Can Self-Efficacy and Task Values Buffer Perceived Costs? Exploring Introductory- and Upper-Level Physics Courses

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ABSTRACT

Students' cost perceptions have been associated with lower retention and academic performance in science, technology, engineering, and mathematics (STEM). Guided by expectancy-value theory, we examined whether relations between perceived costs and physics outcomes (i.e., engagement and achievement) varied as a function of self-efficacy or task values among undergraduate physics students ($N = 1{,}124$). We also examined whether the interactive relations were further moderated by course level in the curricular sequence. Overall, findings from moderated moderation analyses indicated that perceived costs were negatively related to different components of engagement (i.e., effort, persistence, procrastination, and choice) and achievement (i.e., physics course grades). However, the magnitude of relations often depended on levels of self-efficacy or task value. Some of the interactive relations between these variables also differed between introductory- and upper-level physics courses. Taken together, results indicated that higher self-efficacy or task values do not compensate for the negative effects of perceiving high cost on engagement. Moreover, cost perceptions were in some cases more negatively related to engagement when students reported higher self-efficacy or task values. Finally, mitigating cost perceptions may be particularly important in introductory undergraduate physics courses. Implications and directions for future research are discussed.

KEYWORDS

College students; course level; expectancy-value theory; motivation; perceived costs

ALTHOUGH EDUCATORS EMPHASIZE the importance of overcoming challenges and pushing through barriers, college students often struggle to remain engaged and persist in academic tasks. Many theories of motivation have focused on explaining how students become motivated to engage in achievement-related activities (e.g., Eccles et al., 1983; Pintrich, 2000; Ryan & Deci, 2000; Weiner, 1985; Zimmerman, 2000). However, less attention has been devoted to explaining what motivational processes prevent students from engaging in such activities. A growing body of literature guided by one theory of motivation—expectancy-value theory (EVT; Eccles et al., 1983)—suggests that higher *cost* perceptions may predict maladaptive motivation, lower engagement, negative classroom affect, and lower achievement (Battle & Wigfield, 2003; Bergey et al., 2018; Jiang et al., 2018). That is, if students perceive a task to require (a) a lot of work, (b) a sacrifice of other attractive alternatives, or (c) stress, they are more likely to experience suboptimal academic outcomes (Gaspard et al., 2015; Perez et al., 2014).

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Supplemental data for this article can be accessed at https://doi.org/10.1080/00220973.2021.1878992.
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Considering the various challenges that students may experience and the perceived costs that are likely to accompany them, it is essential to understand the role of costs and their relation to various outcomes. Over the past several years, more researchers have focused on the complex role of cost perceptions in achievement settings (e.g., Bergey et al., 2018), especially in science, technology, engineering, and mathematics (STEM; Jiang et al., 2018; Perez et al., 2019a, 2019b). However, there is still little known about how cost perceptions interact with two other motivational processes—self-efficacy and task values—to predict academic outcomes. Investigating the interactions between these components is necessary, given that it allows us to understand the potential synergistic or antagonistic consequences of perceived costs. Therefore, in the current study, we explored whether the hypothesized negative relations between perceived costs and physics outcomes (i.e., engagement, achievement) are buffered by high competence beliefs or task values. Moreover, previous research on the interactive relations between competence beliefs and task values has been conducted primarily in introductory STEM courses (e.g., Perez et al., 2019a), leaving other postsecondary STEM contexts—namely upper-level courses—largely underexplored. Given that knowledge of students' experiences across levels within the curricular sequence is important for a more complete understanding of the postsecondary STEM pipeline, this gap in the literature is important to address. Thus, we focused on exploring whether the interactive relations between motivational beliefs (competence beliefs, task values, and costs) differed according to course level in the curricular sequence by comparing introductory- and upper-level STEM courses.

We specifically focused on physics because of multiple national concerns within this discipline. In particular, recent evaluations of this discipline point to (a) relatively stagnant numbers of physics majors in comparison to other STEM areas, (b) shortages in production of high school physics teachers, (c) insufficient development of critical professional skills among physics graduates, and (d) lower levels of learning within physics courses (American Physical Society, n.d.). Furthermore, physics is a unique discipline in STEM that is heavily dependent on math (Kapucu et al., 2016) and often perceived by students as a less favorable subject compared to other science subjects (Barmby & Defty, 2006). Given these characteristics, we investigated whether the potential interactions between competence beliefs, task values, and costs differed according to course level within physics (i.e., introductory- vs. upper-level physics courses).

Expectancy-value theory

EVT emphasizes that students' competence beliefs ("Can I do this?") and task values ("Why do I want to do this?") play essential roles in understanding motivation and academic success (Eccles et al., 1983; Eccles & Wigfield, 2002; Wigfield & Eccles, 2000). Findings generally suggest that competence beliefs are more strongly related to performance, whereas task values are more strongly related to choice, effort, and persistence (Eccles et al., 1984; Marsh et al., 2005; Meece et al., 1990).

Expectancies for success were initially conceptualized as students' beliefs about how well they will perform on upcoming tasks in the future (Eccles et al., 1983). Students' expectancies for success can be directly influenced by *academic self-concepts*, which refers to more stable and general beliefs about their own competency to perform academic tasks, as well as their estimate of *task difficulty*, which refers to the assessment of the perceived difficulty of a specific task (Eccles et al., 1983). Although these constructs can be theoretically distinguished, empirical studies suggest that they are indistinguishable due to the high correlation and conceptual overlap (Eccles & Wigfield, 1995; Santyasa et al., 2020; Wigfield & Eccles, 2000). Consequently, researchers often use a single construct to measure competence beliefs or closely related constructs (e.g., *self-efficacy*, which is considered to be conceptually very similar to task-specific expectancies for success, Santyasa et al., 2020; Wigfield & Eccles, 2000) to understand students' beliefs about their competence in completing their tasks (e.g., Jiang et al., 2018; Lauermann et al., 2017).

Eccles et al. (1983) further differentiate task values into four components: *utility value*, or the perceived usefulness of a task; *attainment value*, or the personal importance of succeeding in a task; *intrinsic value*, or enjoyment derived from a task; and *cost*, or negative appraisals of engaging in a task. However, cost has historically been understudied in EVT research. Work over the last several years has more closely considered cost perceptions (e.g., Flake et al., 2015; Jiang et al., 2018; Perez et al., 2014, 2019a), yet further studies are still needed to uncover its nuances.

Understanding the role of perceived costs

Eccles et al. (1983) acknowledged the importance of perceived costs by applying the concept of cost/benefit ratio to motivation. In particular, as students perceive both costs and benefits of completing an academic task, these factors may interact to determine the cost/benefit ratio and ultimately their academic outcomes (Eccles et al., 1983). Eccles et al. (1983) originally posited three dimensions of cost: *Effort cost* involves the amount of perceived effort needed to be successful at a given task; *loss of valued alternatives cost* involves giving up other attractive activities by engaging in a task; and *psychological cost of failure* involves mental stress coming from uncertainty or potential failure of the task. Wigfield and Eccles (2000) later used the term *emotional cost* to refer to this latter construct.

More recent studies examining the role of costs suggest that they are salient to students and have negative consequences for performance and persistence (Flake et al., 2015; Watkinson et al., 2005). For example, students' cost perceptions were frequently identified as reasons for disengagement or withdrawal (Watkinson et al., 2005). Also, cost perceptions were empirically distinct from competence beliefs or other task values (Bergey et al., 2018; Conley, 2012; Trautwein et al., 2012), which negatively and uniquely predicted achievement and choice-related behaviors in STEM (Jiang et al., 2018; Perez et al., 2014). Specifically, students' cost perceptions have been associated with maladaptive motivational beliefs, negative affect, lower retention in STEM, and lower academic performance (e.g., Bergey et al., 2018; Jiang et al., 2018; Perez et al., 2014; Trautwein et al., 2012). Moreover, Rosenzweig et al. (2020) have demonstrated that reducing college students' cost perceptions (i.e., cost reduction interventions) improves performance in introductory physics courses. Despite these contributions, critical questions remain underexplored, including the interactive relations between different components of EVT in different settings. The current study expands previous research by investigating (1) how each dimension of costs interacts with self-efficacy and task values to predict various indicators of academic engagement and achievement and (2) how variations in course level may influence these relations.

Multidimensionality of perceived costs

One of the major challenges in examining cost is the lack of consensus on how to operationalize and measure it (Flake et al., 2015). Although a growing body of research has attempted to investigate cost perceptions, different approaches to do so may be producing inconsistent conclusions. For example, Trautwein and his colleagues (2012) used two items to measure effort cost (e.g., "I'd have to invest a lot of time to get good grades in mathematics") and loss of valued alternatives (e.g., "I'd have to sacrifice a lot of free time to be good at mathematics"), respectively. Conley (2012) also used two items to measure cost, which both focused on loss of valued alternatives (e.g., "I have to give up a lot to do well in math", "Success in math requires that I give up other activities I enjoy"). Although both Trautwein et al. (2012) and Conley (2012) found initial evidence on the relation of cost to students' learning, using two-item measures of cost can be limited given that its multidimensional nature was not taken into account.

Researchers have recently addressed this issue by adopting a multidimensional perspective on cost (e.g., Flake et al., 2015; Perez et al., 2014). Rather than assessing cost as a single construct,

recent studies have contributed to the literature by capturing its theorized subdimensions. Perez et al. (2014, 2019a) maintained the three dimensions of cost (i.e., effort cost, opportunity cost, and psychology cost) identified by Eccles et al. (1983) and adapted items from a previous scale (Battle & Wigfield, 2003) to reflect this conceptualization. Further, Flake et al. (2015) provided empirical support for a fourth dimension: *outside effort cost*, which involves the perceived amount of effort needed for a task in other areas of their life (e.g., part-time job, family emergency). This was a unique contribution because it acknowledges that students may have multiple duties and responsibilities to manage outside in addition to within the learning context, which may inhibit their engagement for a given task (Flake et al., 2015). Based on Flake et al. (2015) empirical evidence, this perception is different from feelings of sacrificing other attractive opportunities (i.e., loss of valued alternatives). Thus, in the current study, we aimed to build on these finer-grained insights on the relations between various dimensions of cost and physics outcomes by adopting the four dimensions of cost identified by Flake et al. (2015).

The multiplicative function of expectancy-value theory

Although the expectancy-value product term was one of the core assumptions in Atkinson's (1957) original model, it has played a less prominent role in modern conceptualizations of EVT (Eccles et al., 1983; Wigfield & Eccles, 2000). Understanding the framework as interactive, rather than additive, provides unique implications when applying the model in practice (Meyer et al., 2019; Nagengast et al., 2011; Trautwein et al., 2012). With additive models, the focus is more on how each component uniquely predicts physics outcomes. However, because synergistic or antagonistic effects are assumed in interactive models, the combined effect would be different from the sum of individual effects (Nagengast et al., 2011). That is, competence beliefs and task values may interact with one another to ultimately determine physics outcomes. For example, stronger intrinsic value may amplify the effects of feeling capable, which suggests the importance of facilitating various aspects of motivation simultaneously or providing multicomponent interventions.

Recent methodological advances have enabled researchers to explore the multiplicative relations of competence beliefs and task values to achievement and educational aspirations (Guo et al., 2015, 2017; Nagengast et al., 2011; Trautwein et al., 2012). In one of the first known studies to do so (Nagengast et al., 2011), results suggested that expectancy for success and intrinsic value in science could not compensate one another in predicting engagement and career aspirations in science. That is, lack of expectancy or intrinsic value can undermine the benefit of the other. However, the findings were limited in that only one dimension (i.e., intrinsic value) of task values was examined. Trautwein and his colleagues (2012) corroborated this conclusion when they investigated interactions between expectancy and all four components of task values in both English and mathematics. In particular, German students at the end of their secondary education showed especially high achievement in these domains when expectancy and task value were both high. Moreover, when either expectancy or task value was low, results suggested that high levels of one construct could not compensate for low levels of the other. Building on this body of research, Guo and his colleagues (Guo et al., 2015, 2017) provided empirical support for the presence of interactive relationships between students' self-concept and task values in predicting math achievement and higher aspirations for science courses. Moreover, Lauermann and colleagues (2017) demonstrated that the multiplicative relation between adolescents' expectancy and task values in math can also predict long-term academic outcomes such as career attainment. Taken together, recent work has provided compelling evidence for the interactive relationship between expectancies and task values, and findings suggest that high levels of one component cannot compensate for low levels of the other in its relation with academic outcomes.

Despite the growing number of studies reporting multiplicative effects of expectancy and task value beliefs, research that has considered the moderating role of perceived costs are scant.

Limited evidence suggests that students perform better when competence beliefs are high and cost perceptions are low (Trautwein et al., 2012). However, the aforementioned work did not consider multidimensionality of cost, leaving critical aspects of the EVT model underexplored. For example, studies have often used an overall score or one dimension (e.g., effort cost) of cost perceptions when examining how they relate to academic outcomes (Bergey et al., 2018; Jiang et al., 2018; Meyer et al., 2019).

To our knowledge, only one study has considered the moderating roles of each cost dimension in predicting academic outcomes (Perez et al., 2019a). In this study, Perez and his colleagues (2019a) examined how each dimension of cost interacts with expectancy beliefs to predict achievement in a gateway biology course. Specifically, results indicated that the association between expectancy beliefs and achievement was stronger with lower effort cost perceptions. Other dimensions of cost (i.e., opportunity cost, psychological cost) did not interact with expectancy beliefs to predict achievement. These findings provided a more nuanced understanding of how distinct components of cost can interact with expectancy beliefs differently. Nonetheless, Perez et al. (2019a) highlighted the need for examining the interactions between cost and task values and referred to it as important but underexplored question. Relatedly, other studies have also highlighted the multidimensionality of task values and the importance of value X value interactions (Barron & Hulleman, 2015; Trautwein et al., 2013). The most recent conceptual iterations of EVT reflect the multidimensionality and interactional nature of values: Eccles and Wigfield (2020) situated expectancy-value theory, for example, emphasizes the situative nature of motivational processes and the hierarchical nature of expectancies and values. Therefore, it is critical to explore the meaningful interactive relations in different settings. As Eccles and Wigfield (2020) noted, "investigating the interplay of the different aspects of task in determining overall subjective task value" is an essential area for future research. Due to the multidimensionality and hierarchical nature of task values, it is still unclear how various components of EVT operate together to predict learning outcomes. Taken together, better understanding the interactive relation between values and costs is important, and we attempted to address this gap in the current study.

Contributing further to recent advances on the multidimensionality of cost and differential consequences, we thus aimed to explore the extent to which unique cost dimensions depend on not only self-efficacy but also task values in their relations with physics outcomes. Self-efficacy is known to have a strong association with achievement, while task values have strong associations with choice-related behaviors (Eccles et al., 1983; Wigfield & Eccles, 2000). Guided by prior research (Fredricks et al., 2004; Wolters, 2004), in the current study we focused on four indicators of engagement in physics (i.e., effort, persistence, procrastination, and choice) and physics performance (i.e., course grades) as outcomes. Engagement in the domain of science has received much attention due to its impact on learning outcomes (e.g., Sinatra et al., 2015). We explored engagement outcomes in the current study to capture not only adaptive but also maladaptive academic behaviors (i.e., procrastination). Doing so is important in order to gain insight into how motivational beliefs not only promote but also undermine learning outcomes. Procrastination has been conceptualized as a prevalent form of self-regulatory failure due to its negative impact on performance and mental health (Rozental & Carlbring, 2014; Steel, 2007). Relatedly, a recent study suggests that lower academic procrastination was associated with higher achievement in physics (Santyasa et al., 2020).

The importance of course levels

In order to understand students' experiences through the postsecondary STEM pipeline, it is necessary to consider multiple levels of courses within the curricular sequence. Recent work has examined the interactive relations between competence beliefs and task values in gateway STEM courses (e.g., Perez et al., 2019a), but students need to remain engaged beyond their

introductory-level courses in order to complete a STEM degree and ultimately pursue a career in STEM. Thus, we add to the existing literature by exploring the aforementioned relations in both postsecondary introductory- and upper-level courses. In particular, we do so by examining how the interactive relations between expectancies, task values, and costs may differ between introductory versus more advanced courses in physics.

Exploring these interactive relations in multiple levels of undergraduate physics is critical for at least three reasons. First, it is unclear how the interactions operate specifically in physics as a science discipline. Especially given that physics tends to be perceived as a less favorable subject compared to other science subjects (Barmby & Defty, 2006), it is important to examine whether the interactive relations observed from other disciplines (e.g., biology; Perez et al., 2019a) can be generalized to physics.

Second, further research is needed to examine the relations across different course levels because the tenets of EVT suggest that self-efficacy, task values, and cost perceptions may be heavily influenced by the cultural milieu of the course setting (Eccles et al., 1983). That is, students' motivational beliefs are shaped by socialization experiences that they have in the classroom as a result of teacher-student relationships, classroom norms/climate, or instructional practices (e.g., Eccles et al., 1994, 2009; Eccles & Wigfield, 2020). A large literature suggests, for example, that educators have lower expectations and provide less adaptive feedback to students they perceive as having "low ability" in a given domain (e.g., Andersen, 2018; Good, 1987), which has negative consequences for motivation. For students in upper-level physics courses, it is thus plausible that their instructors have more favorable perceptions of their physics abilities compared to their introductory student counterparts, which should foster more motivationally adaptive relationships. Moreover, students' perceptions about the nature of "weed-out" courses in and these courses' inherently competitive nature may also contribute to the differential motivational experiences (Canning et al., 2020). In particular, given the competitive grading practices that often accompany weed-out courses, they are likely to foster maladaptive motivational beliefs and trajectories (Ames, 1992; Meece et al., 2006).

Finally, examining different course levels may reveal distinct patterns and outcomes because students are in unique stages of their academic trajectories. In particular, students' commitment to the course may vary depending on their academic paths or career trajectories. The costs that students perceive within their course and the impact of these perceptions, for example, may vary depending on whether they have already declared their major in physics. Taken together, a nuanced understanding on whether and how the relations differ between introductory- and upper-level courses will provide timely implications to improve performance and ultimately retention in physics.

Present study

In the current study, we attempted to address the following three understudied issues in the literature: (1) the complex role of distinct cost dimensions, (2) the interactive relations between self-efficacy, task values, and costs, and (3) the moderating role of course level in an undergraduate physics environment. As a result, we examined how each dimension of costs interacts with self-efficacy (a variable closely related to expectancy for success; Wigfield & Eccles, 2000) and task values to predict various indicators of academic engagement and achievement in undergraduate physics. In particular, we expand previous research by investigating whether self-efficacy or task values can buffer the hypothesized negative relations between costs and physics outcomes (i.e., four indicators of engagement—effort, persistence, procrastination, and choice—and achievement) in introductory- versus upper-level physics courses. That is, we examined whether the hypothesized interactions differed across two different course levels. Figure 1 illustrates the

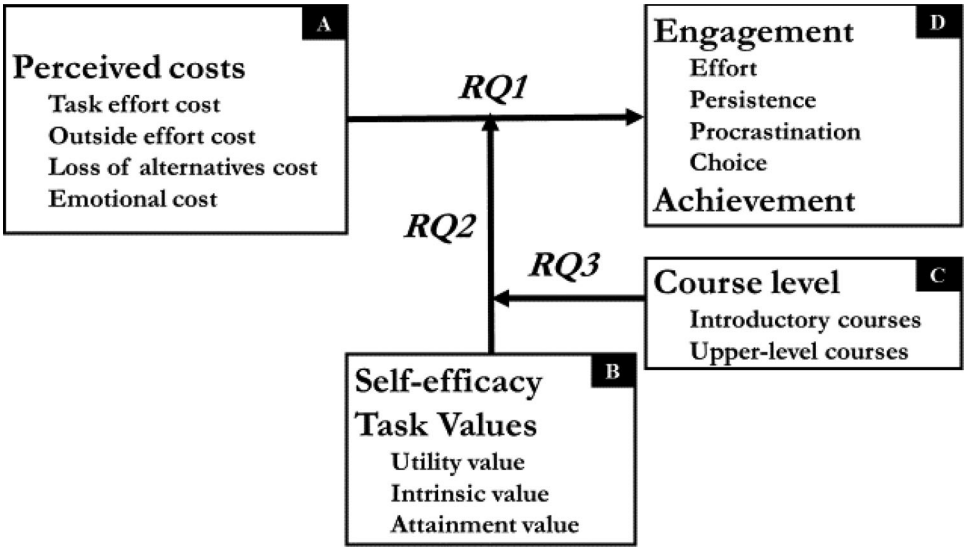

Figure 1. Graphical representation of research questions.

conceptual model that we tested, and our specific research questions and hypotheses are summarized below.

Research Question 1. Do different dimensions of cost (i.e., task effort cost, outside effort cost, loss of valued alternatives cost, and emotional cost) negatively predict undergraduate students' engagement and achievement in physics?

Hypothesis 1. Higher cost perceptions will predict lower engagement and achievement. Drawing from prior work (Perez et al., 2019a), we hypothesized that between the four costs, effort cost and opportunity cost will have stronger negative relations with engagement and achievement.

Research Question 2. Do cost perceptions interact with self-efficacy or task values to predict engagement and achievement?

Hypothesis 2. High perceptions of self-efficacy or task values in physics are expected to buffer the negative relations between costs to engagement and achievement. However, we did not have specific hypotheses for how each dimension of cost might interact with self-efficacy or task values due to lack of evidence.

Research Question 3. Do the hypothesized interactions between costs and both self-efficacy and task values vary as a function of course level (i.e., introductory-level versus upper-level physics courses)?

No specific hypothesis was proposed due to lack of previous research. To our knowledge, the current study is the first to investigate the interactive relations between self-efficacy, task values, and costs across different course levels. Thus, we aimed to conduct an exploratory investigation of how the interactive relations varied between introductory courses and upper-level courses.

Method

Participants

Undergraduate students ($N = 1{,}124$) enrolled in one of six physics courses at a large, Midwestern university in the United States participated in the current study. All undergraduate levels were represented in the sample (39.7% freshmen, 31.9% sophomores, 11.9% juniors, and 5.6% seniors; $M_{age} = 19.96$, $SD = 2.87$). Participants' gender (71.9% male) and race/ethnicity (67.8% White, 24.0% Asian, 2.6% Hispanic, 1.7% African American, and 3.9% identified with other races/

ethnicities) were representative of the demographics of the undergraduate physics population at the institution. All of the students received credit for completing an assignment in their course as compensation for their participation. Participation was voluntary and students had an option to complete an alternative assignment to receive credit. We obtained approval from the university's institutional review board (IRB) and the study was conducted in accordance with the human subjects guidelines.

Introductory- and upper-level physics courses

Students were enrolled in one of three introductory physics courses ($n = 974$; 70% male) or one of three upper-level physics courses ($n = 150$; 83.4% male). Introductory courses consisted of mostly freshmen and sophomores (together 86.1%) with a few physics majors (8.4%) and minors (0.8%). The majority of the students reported their ethnicity as White (68.2%) or Asian (24.1%). These courses provide a general understanding of classical physics (e.g., mechanics, fluids, thermodynamics, electromagnetism, waves) to students in physics, engineering, and other science majors. Students usually attend three lectures, one recitation, and one laboratory session every week. Upper-level courses consisted of mostly juniors and seniors (60.7%) and many of them were physics majors (89.3%) and minors (4.7%). Similar to the students from the introductory courses, the majority of the students reported their ethnicity as White (64.8%) or Asian (23.4%). These courses are much smaller in size and focus on intermediate and quantum mechanics, among other topics. Students usually meet four times a week with the instructor.

Procedures and measures

Students completed an online survey during the 14th week of a 16-week semester as part of a larger, longitudinal project focusing on retention of undergraduates in physics. As a result, students' self-efficacy, task values, and cost perceptions with respect to their physics course were all thought to be well-established at this stage of the semester. The survey was worded with respect to the physics course in which they were enrolled. After the semester ended, we retrieved each student's final grade in the physics course in which they were enrolled from the university's records. All of the items used in the study are presented in the online supplemental material (Appendix A).

Self-efficacy

Self-efficacy, or students' beliefs about their capability to perform successfully in their physics coursework (Bandura, 1986), was measured with five items adapted from the Patterns of Adaptive Learning Scales (PALS; Midgley et al., 2000). Students indicated their perceived capability to succeed in the course on a seven-point Likert scale (1= "Not at all true"; 7= "Very true"; $\alpha = .95$). A sample item was, "In this physics class, I'm certain I can master the skills taught this year."

Task values

Task values were assessed with seven items on a seven-point Likert scale with varying anchors, adapted from Eccles and Wigfield (1995). A sample item for utility value was, "How useful is learning the physics from this physics class for what you want to do in the future?" (2 items[1]; $\alpha = .75$); a sample item for intrinsic value was, "How much do you like doing the physics covered in this class? (2 items; $\alpha = .75$); a sample item for attainment value was, "How important is it to you to get good grades in this physics class? (3 items; $\alpha = .71$).

Costs

Perceived costs, or students' negative appraisals while engaging in their physics courses, was measured with nineteen items adapted from Flake et al. (2015). A sample item for task effort cost was, "This physics class requires too much effort" (5 items; $\alpha = .95$). A sample item for outside effort cost was, "I have so many other commitments that I can't put forth the effort needed for this physics class." (4 items; $\alpha = .93$). A sample item for loss of valued alternatives cost was, "Taking this physics class causes me to miss out on too many other things I care about." (4 items; $\alpha = .93$). A sample item for emotional cost was, "This physics class is too stressful." (6 items; $\alpha = .95$). A nine-point Likert scale was used (1= "Completely disagree"; 5= "Neither disagree nor agree"; 9= "Completely agree").

Engagement

We measured four components of students' engagement within their physics course with seventeen items adapted from Wolters (2004). *Effort* reflected students' beliefs about their hard work toward the tasks in the course; *persistence* referred to students' perseverance on course tasks under difficult and challenging situations; *procrastination* assessed students' tendency to put off their coursework; and *choice* reflected their attitude toward taking additional physics-related courses in the future. A sample item for effort was, "In this physics class, I always put a lot of effort into doing my work." (4 items; $\alpha = .72$). A sample item for persistence was, "Even if my physics work in this class is dull or boring, I keep at it until I am finished." (4 items; $\alpha = .74$). A sample item for procrastination was, "I postpone doing the work for this physics class until the last minute." (5 items; $\alpha = .90$). A sample item for choice was, "I look forward to taking more physics classes in the future." (4 items; $\alpha = .88$). A seven-point Likert scale was used (1= "Strongly disagree"; 7= "Strongly agree").

Physics course grades and prior achievement

Final letter grades in the physics were converted to a four-point scale in accordance with the university's Grade Point Average (GPA), where 4.0 represents an "A" and 0.0 represents an "E" or a failing grade. In line with prior literature (e.g., Robinson et al., 2019), to statistically control for prior achievement, standardized college entrance math scores (i.e., ACT math scores, SAT math scores) were retrieved from student record data and included as a covariate in all analyses.[2] For students who only had SAT math scores, the scores were converted into ACT scores based on the national percentile norms for the two tests (College Board, n.d.).

Data analytic approach

We conducted multiple moderated moderation (i.e., three-way interaction) analyses to examine whether the hypothesized interactions between costs, self-efficacy, and task values were further moderated by physics course level (introductory- vs. upper-level courses). We used the PROCESS macro in SPSS version 24, which is a computational tool suitable for regression-based mediation and moderation analysis (Hayes, 2017). A bootstrapping approach (with 10,000 re-samples) was used to derive robust estimates. Because bootstrapping approach is not restricted by the traditional assumptions (e.g., normality) of parametric tests (Russell & Dean, 2000), this approach allowed us to partially address the disproportionate number of students in introductory versus advanced courses. Especially with small samples, the bootstrapping approach provides tests with greater confidence as it involves repeated sampling from the data set (Preacher & Hayes, 2004). Prior to all analyses, all continuous variables were standardized to have a mean of 0 and standard deviation of 1 for practically relevant and straightforward interpretation (see Hayes, 2017).

Table 1. Means and standard deviations of variables.

	Full sample			Introductory courses			Upper-level courses		
Variable	*N*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Self-efficacy	1115	4.84	1.42	967	4.78	1.41	148	5.24	1.41
Utility value	1115	4.32	1.56	967	4.22	1.57	148	4.95	1.32
Intrinsic value	1115	4.12	1.56	967	3.97	1.54	148	5.09	1.36
Attainment value	1115	5.30	1.20	967	5.23	1.21	148	5.79	1.02
Task effort cost	1114	5.11	1.95	966	5.13	1.93	148	4.97	2.09
Outside effort cost	1114	4.91	1.96	966	4.93	1.94	148	4.80	2.05
Loss of valued alternatives cost	1114	4.81	1.96	966	4.82	1.96	148	4.73	1.99
Emotional cost	1114	5.40	2.05	966	5.43	2.04	148	5.18	2.13
Effort	1115	4.84	1.12	968	4.75	1.09	147	5.45	1.17
Persistence	1115	4.65	1.12	968	4.63	1.11	147	4.78	1.20
Procrastination	1124	3.65	1.41	974	3.64	1.40	150	3.76	1.48
Choice	1115	3.96	1.67	968	3.70	1.57	147	5.67	1.26
Achievement	1119	2.81	1.02	969	2.79	1.01	150	2.95	1.06
Prior achievement	1041	30.56	3.38	910	30.40	3.35	131	31.69	3.39

Note. Costs were measured on a 9-point Likert scale; all other variables were measured on a 7-point Likert scale.

As seen in Figure 1, we were interested in examining how each dimension of cost (Box A in Figure 1) interacts with self-efficacy or a specific dimension of task values (Box B) and whether this relation varies across different course levels (Box C) in predicting physics outcomes (Box D). Thus, either self-efficacy or one dimension of task values was entered as a first moderator in each analysis, and course level (i.e., introductory-level, upper-level) was entered as a second moderator for all analyses in order to investigate the interacting effect of course level in this moderating relationship. We focused on the unique interactions of specific dimensions of EVT constructs. Therefore, for each analysis, all of the product terms—both two-way interactions and three-way interactions—were included. To statistically control for initial achievement differences, prior achievement (i.e., ACT scores) was entered as a covariate. Moreover, self-efficacy and other dimensions of task values (i.e., utility value, attainment value, and intrinsic value) were entered as covariates when they were not serving as a moderator. Each of the aforementioned analyses was performed separately for each academic outcome (effort, persistence, procrastination, choice, and achievement).

Significant interactions were probed with the *pick-a-point approach* (Bauer & Curran, 2005), which is also known as analysis of simple slopes. To do so, we examined the conditional effects of the predictors at various points: when the moderator is high (i.e., one standard deviation above the mean), medium (i.e., at the mean), or low (i.e., one standard deviation below the mean; Hayes, 2017). We did not have any data points that were outside the range of the observed data. When there was no significant three-way interaction (i.e., when the interactive relation was not moderated by course level), two-way interactions between cost and self-efficacy (or one dimension of task values) were probed in the PROCESS macro.

Results

Descriptive statistics and preliminary analyses

Means, standard deviations, and sample sizes of variables for the full sample and separately for introductory- and upper-level students are presented in Table 1. Independent group *t*-tests revealed that students from upper-level courses reported significantly higher mean levels of self-efficacy, utility value, attainment value, and intrinsic value in physics compared to students from introductory courses (all $ps < .05$). Students from upper-level courses also reported significantly greater mean levels of effort and choice to continue pursuing physics (all $ps < .05$). There were no significant differences between introductory- and upper-level students in any of the cost

Table 2. Correlations between variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Self-efficacy	–												
2. Utility value	.48**	–											
3. Intrinsic value	.56**	.71**	–										
4. Attainment value	.56**	.61**	.60**	–									
5. Task effort cost	−.43**	−.27**	−.37**	−.25**	–								
6. Outside effort cost	−.34**	−.19**	−.26**	−.21**	.70**	–							
7. Loss of valued alternatives cost	−.38**	−.21**	−.28**	−.22**	.88**	.73**	–						
8. Emotional cost	−.44**	−.28**	−.39**	−.17**	.86**	.63**	.80**	–					
9. Effort	.31**	.26**	.36**	.50**	−.02	−.19**	−.03	.02	–				
10. Persistence	.34**	.19**	.25**	.35**	−.35**	−.39**	−.34**	−.34**	.46**	–			
11. Procrastination	−.22**	−.14**	−.24**	−.22**	.29**	.40**	.29**	.32**	−.38**	−.59**	–		
12. Choice	.46**	.60**	.69**	.44**	−.38**	−.27**	−.31**	−.40**	.29**	.25**	−.18**		
13. Achievement	.28**	.10**	.16**	.18**	−.25**	−.25**	−.23**	−.30**	.09**	.20**	−.17**	.18**	
14. Prior achievement	.130**	0.00	.094**	0.03	−.14**	−.15**	−.14**	−.19**	−0.05	0.05	0.01	.12**	.31**

Note. $^{**}p < .01$.

dimensions, persistence, procrastination, or achievement. Correlations between these variables are presented in Table 2. Due to the high correlations between four dimensions of cost, confirmatory factor analysis was conducted, and the model fit supported the four-factor model[1], $x^2(146) = 857.24$, $p < .001$, $CFI = .97$, $TLI = .96$, $RMSEA = .07$. We thus took a multidimensional perspective on cost and treated the four dimensions as separate constructs.

Missing data

Overall, there was very little missing data, with less than 1% for all variables. An exception was students' prior achievement, which still had a relatively little missing data (7.4%). Additionally, Little's MCAR test was not statistically significant, $X^2(796) = 65.99$, $p = 1.00$, suggesting that there was sufficient evidence to conclude that data were missing completely at random (MCAR). We used the Expectation Maximization (EM) algorithm to handle missing data (Little & Rubin, 1989; Schafer & Graham, 2002).

In the following section, we report the results from the series of moderated moderation analyses, which are organized by outcome. Although all possible main effects and interactions were tested, only significant three-way interactions are reported and discussed in the results section (for an overview of all findings, see Table 3).

Persistence

Loss of valued alternatives cost

After accounting for prior achievement and task values (i.e., utility value, intrinsic value, attainment value), there was a significant three-way interaction between loss of valued alternatives cost, self-efficacy, and course level in predicting persistence, $F(1, 1018) = 6.51$, $p = .011$. The three-way interaction is illustrated in Figure 2 with differing patterns of two-way interactions across introductory- and upper-level courses. Simple slope analysis indicated that, in introductory courses, loss of valued alternatives cost had a negative association with persistence for students with low ($b = -.17$, $p < .001$), medium ($b = -.27$, $p < .001$), and high ($b = -.38$, $p < .001$) self-efficacy. The relation was stronger for students with high self-efficacy compared to medium, $t(1018) = -4.24$, $p < .001$, and low, $t(1018) = -4.24$, $p < .001$, self-efficacy. In upper-level courses, the association between loss of valued alternatives cost and persistence was not significant for students at any level of self-efficacy ($ps = .24$–$.81$).

Table 3. Summary of three-way interactions.

Independent variable	Moderator 1	Moderator 2	Outcome variable				
			Effort	Persistence	Procrastination	Choice	Achievement
Task effort cost	Self-efficacy	Course level	.12	.14	−.15	.03	.00
Outside effort cost			.03	.15	−.11	.11	.14
Loss of valued alternatives cost			.12	.19*	−.20*	.06	.07
Emotional cost			.05	.14*	−.15	.01	.02
Task effort cost	Utility value		−.05	−.10	.10	.12	−.14
Outside effort cost			−.06	−.01	.17*	.19	−.08
Loss of valued alternatives cost			−.02	−.03	.06	.15	−.14
Emotional cost			−.05	−.03	.05	.09	−.16
Task effort cost	Intrinsic value		−.05	.07	−.02	.05	−.11
Outside effort cost			−.06	.13	.02	.13	.03
Loss of valued alternatives cost			.00	.17*	−.12	.05	−.06
Emotional cost			.02	.15	−.10	.05	−.01
Task effort cost	Attainment value		−.12	−.07	.10	.17	−.21*
Outside effort cost			−.13	.01	.02	.20	−.09
Loss valued of alternatives cost			−.15	−.03	.01	.18	−.23
Emotional cost			−.04	.08	−.03	.07	−.14

Notes. Coefficients shown are *b*. *$p < .05$.

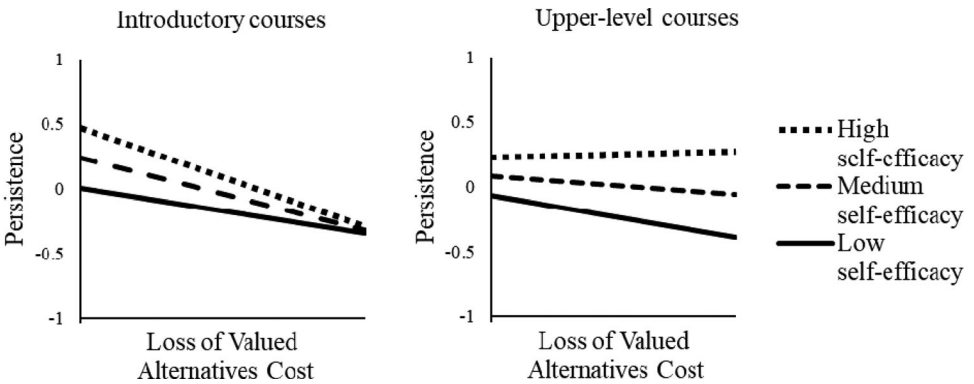

Figure 2. Interactions between loss of alternatives cost and self-efficacy across different course levels. *Notes*. All continuous variables were standardized to have a mean of 0 and standard deviation of 1. High (+1 *SD*), medium (*mean*), and low (−1 *SD*) self-efficacy were used to indicate model-implied regression lines.

After accounting for prior achievement, self-efficacy, and other task values (i.e., utility value, attainment value), there was a significant three-way interaction between loss of valued alternatives cost, intrinsic value, and course level in predicting persistence, $F(1, 1018) = 3.94$, $p = .047$. Figure 3 illustrates the relations with model-implied regression lines for students in introductory- and upper-level courses, respectively. Simple slopes analysis indicated that, in introductory courses, loss of valued alternatives cost had a negative association with persistence for students with low ($b = -.15$, $p < .001$), medium ($b = -.30$, $p < .001$), and high ($b = -.45$, $p < .001$) intrinsic value. The relation was stronger for students with high intrinsic value compared to medium, $t(1018) = -6.16$, $p < .001$, and low, $t(1018) = -6.16$, $p < .001$, intrinsic value. In upper-level courses, the association between loss of valued alternatives cost and persistence was not significant for students at any level of intrinsic value (ps = .79–.95). In other words, loss of valued alternatives cost was not associated with lower persistence for students in upper-level courses.

Emotional cost

After accounting for prior achievement and other task values (i.e., utility value, intrinsic value, attainment value), there was a significant three-way interaction between emotional cost, self-efficacy, and course level in predicting persistence, $F(1, 1018) = 3.98$, $p = .046$.

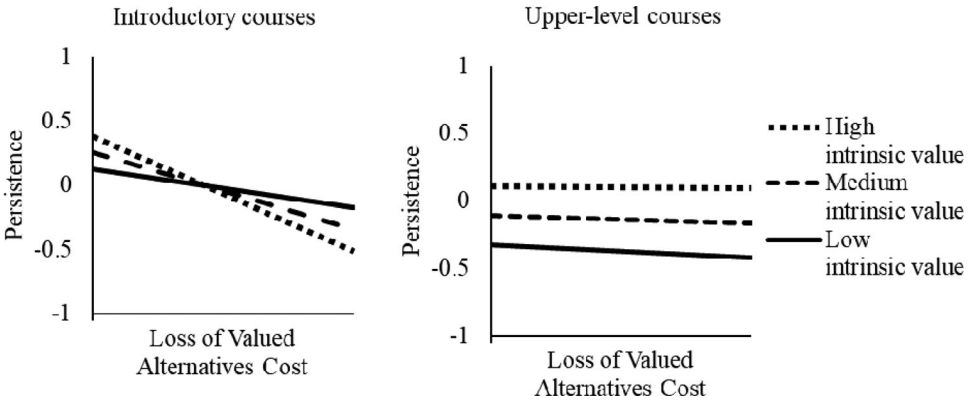

Figure 3. Interactions between loss of alternatives cost and intrinsic value across different course levels. *Notes.* All continuous variables were standardized to have a mean of 0 and standard deviation of 1. High (+1 *SD*), medium (*mean*), and low (−1 *SD*) intrinsic value were used to indicate model-implied regression lines.

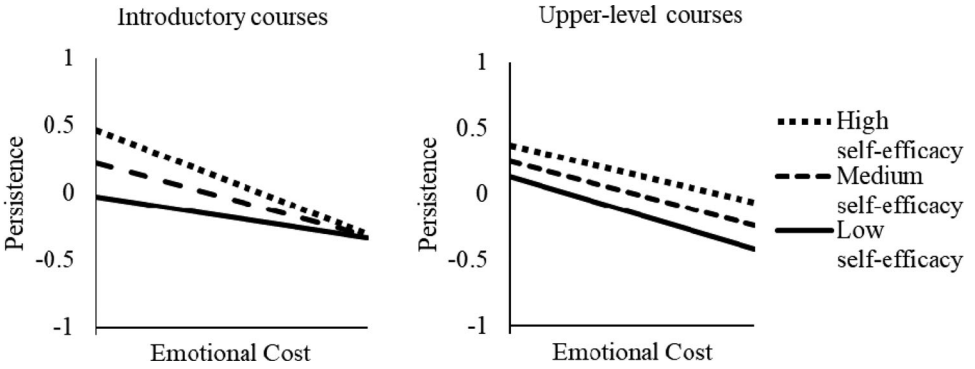

Figure 4. Interactions between emotional cost and self-efficacy across different course levels. *Notes.* All continuous variables were standardized to have a mean of 0 and standard deviation of 1. High (+1 *SD*), medium (*mean*), and low (−1 *SD*) self-efficacy were used to indicate model-implied regression lines.

Patterns of interactions with model-implied regression lines for different groups of students are illustrated in Figure 4. Simple slopes analysis indicated that, in introductory courses, emotional cost had a negative association with persistence for students with low (b = −.15, p = .001), medium (b = −.27, $p < .001$), and high (b = −.39, $p < .001$) self-efficacy. The relation was stronger for students with high self-efficacy compared to medium, t(1018) = −4.48, $p <$ .001, and low, t(1018) = −4.48, $p < .001$, self-efficacy. In upper-level courses, emotional cost also had a negative association with persistence for students with low (b = −.28, p = .04), medium (b = −.25, p = .007), and high (b = −.22, p = .02) self-efficacy, but the relation did not differ based on the level of self-efficacy (ps = .67). In other words, students from both introductory- and upper-level courses reported lower persistence when they perceived higher emotional cost but the interactive patterns were different.

Procrastination

Outside effort cost

After accounting for prior achievement, self-efficacy, and other task values (i.e., intrinsic value, attainment value), there was a significant three-way interaction between outside effort cost, utility value, and course level in predicting procrastination, $F(1, 1{,}019) = 4.01$, p = .046. Figure 5 illustrates the patterns of interactions across introductory- and upper-level courses. Simple slope

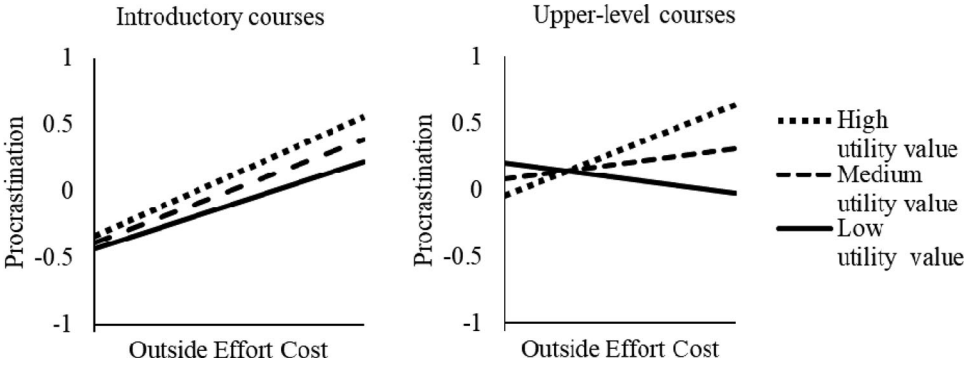

Figure 5. Interactions between outside effort cost and utility value across different course levels. *Notes.* All continuous variables were standardized to have a mean of 0 and standard deviation of 1. High (+1 *SD*), medium (*mean*), and low (−1 *SD*) utility value were used to indicate model-implied regression lines.

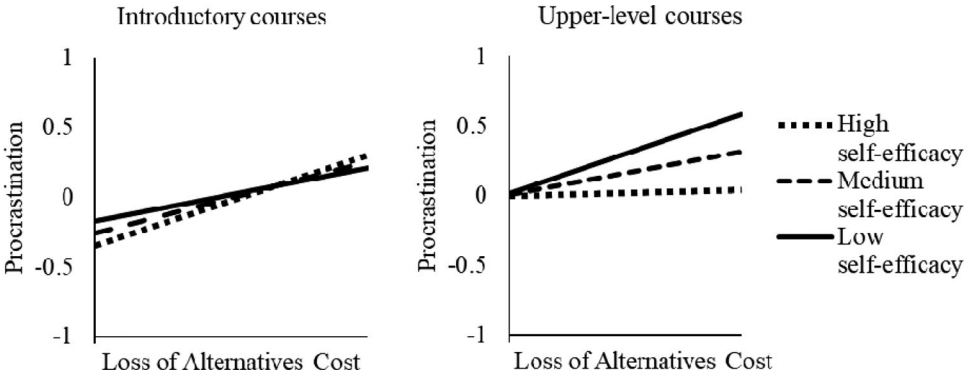

Figure 6. Interactions between loss of alternatives cost and self-efficacy across different course levels. *Notes.* All continuous variables were standardized to have a mean of 0 and standard deviation of 1. High (+1 *SD*), medium (*mean*), and low (−1 *SD*) self-efficacy were used to indicate model-implied regression lines.

analysis indicated that, in introductory courses, outside effort cost had a positive association with procrastination for students with low ($b = .33$, $p < .001$), medium ($b = .39$, $p < .001$), and high ($b = .45$, $p = .007$) utility value. The relation was stronger for students with high utility value compared to medium, $t(1018) = -2.46$, $p = .014$, and low, $t(1018) = -2.46$, $p = .014$, utility value. In upper-level courses, the association between outside effort cost and procrastination was not significant for students with low and medium utility value ($p = .44$ and .20, respectively). However, students with high utility value in upper-level courses reported higher procrastination when they perceived higher outside effort cost ($\beta = .34$, $p < .001$).

Loss of valued alternatives cost

After accounting for prior achievement and task values (i.e., utility value, intrinsic value, attainment value), there was a significant three-way interaction between loss of valued alternatives cost, self-efficacy, and course level in predicting procrastination, $F(1, 1018) = 6.08$, $p = .014$. Figure 6 illustrates the differential relations across introductory- and upper-level courses. Simple slopes analysis indicated that, in introductory courses, loss of valued alternatives cost has a positive association with procrastination for students with low ($b = .19$, $p < .001$), medium ($b = .25$, $p < .001$), and high ($b = .32$, $p = .007$) self-efficacy. The relation was stronger for students with high self-efficacy compared to medium, $t(1018) = 2.67$, $p = .008$, and low, $t(1018) = 2.67$, $p = .008$, self-efficacy. In upper-level courses, the association between loss of valued alternatives cost and

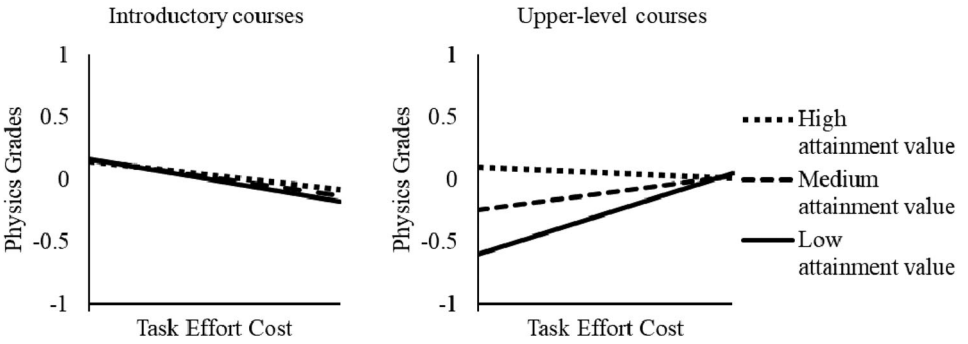

Figure 7. Interactions between loss of alternatives cost and attainment value across different course levels. *Notes.* All continuous variables were standardized to have a mean of 0 and standard deviation of 1. High (+1 *SD*), medium (*mean*), and low (−1 *SD*) attainment value were used to indicate model-implied regression lines.

procrastination was not significant for students at any level of self-efficacy (*p*s = .05–.82). In other words, loss of valued alternatives cost was not associated with procrastination for students in upper-level courses.

Physics course grades

Task effort cost

After accounting for prior achievement, self-efficacy, and other task values (i.e., utility value, intrinsic value), there was a significant three-way interaction between task effort cost, attainment value, and course level in predicting course grades, $F(1, 1019) = 4.30$, $p = .038$. The relations are illustrated with model-implied regression lines for different groups in Figure 7. Simple slope analysis indicated that, in introductory courses, task effort cost had a negative association with course grades for students with low ($b = -.17$, $p < .001$), medium ($b = -.14$, $p < .001$), and high ($b = -.11$, $p = .007$) attainment value, but the relation did not differ based on the level of attainment value (*p*s = .31). In upper-level courses, the association between task effort cost and course grades was not significant for students at any level of attainment value ($p = .08$–$.58$). In other words, task effort cost did not predict lower course grades for students in upper-level courses.

Ancillary analyses

When the interactive relation between costs, self-efficacy, and task values was not moderated by course level (non-significant three-way interactions), moderation analyses were conducted. Specifically, we examined how each dimension of cost (Box A in Figure 1) interacts with self-efficacy or a specific dimension of task values (Box B) in predicting physics outcomes (Box D), without including course level as a second moderator. Key findings indicated that students with lower self-efficacy or task values reported putting in more effort but procrastinated more and were less persistent when they perceived higher cost. Even students with high self-efficacy or task values struggled to persist and procrastinated more when they perceived higher perceptions of cost. Detailed results are summarized in the online supplemental materials (Appendix B).

Discussion

In the current study, we examined the role of cost perceptions and their interactive relations to physics outcomes across introductory- and upper-level physics courses. In particular, we explored

the critical yet underexplored question of how cost perceptions interact with self-efficacy and task values in predicting undergraduate students' engagement (i.e., effort, persistence, procrastination, and choice) and achievement in physics. The study also provided initial evidence that these interactive relations may vary based on different course levels. In the following sections, we elaborate on the two main conclusions from our findings. We also discuss their theoretical and educational implications.

Self-efficacy and task values are essential, but not sufficient

Recent studies provide evidence for the multiplicative function of EVT and suggest that high levels of competence beliefs and task values cannot compensate for one another in predicting academic outcomes (e.g., Nagengast et al., 2011; Trautwein et al., 2012). Our findings provide more fine-grained insights on the differential consequences of each dimension of cost and whether their negative consequences can be buffered with competence beliefs or task values. Overall, and consistent with prior work (e.g., Guo et al., 2015, 2017; Marsh et al., 2005; Trautwein et al., 2012), we found that having high self-efficacy and task values is predictive of engagement and achievement in physics. However, strong endorsements of these motivational beliefs were not sufficient to combat the negative consequences of perceived costs, particularly in introductory courses. For instance, students in introductory courses reported lower persistence when they perceived higher loss of valued alternatives cost for their physics course, and this negative relation was significant for students at all levels of self-efficacy and intrinsic value. In fact, contrary to our hypothesis, there was an even stronger negative relation with these outcomes for students with higher self-efficacy or intrinsic value. Similarly, students in introductory courses reported lower persistence when they perceived higher emotional cost across all levels of self-efficacy, yet the negative relation was stronger for those with higher self-efficacy. Finally, students in introductory courses reported procrastinating more when they perceived higher loss of valued alternatives or outside effort costs. Again, the negative relation was significant for students with all levels of self-efficacy or utility value, but especially strong for those with higher self-efficacy or utility value. Taken together, in introductory courses, even if students feel competent or perceive their coursework as meaningful and interesting, they appear to have difficulty persisting and procrastinate more when they believe that engaging in physics courses is costly. In terms of achievement, perceiving the physics course as a lot of work was associated with lower course grades, and this relation was found regardless of their attainment value. That is, a strong endorsement of attainment value in their physics course did not *protect* students from experiencing negative consequences of effort cost on course performance.

We find these interactive relations intriguing in two ways. First, especially in introductory courses, even the students who believe that they are capable of the work and find it valuable can show low engagement and low performance when they (a) perceive emotional stress regarding the task (i.e., emotional cost), (b) feel like they are giving up other opportunities (i.e., loss of valued alternatives), or (c) have a lot of responsibilities in other areas of their life (i.e., outside effort cost). As a result, it appears that higher self-efficacy or task values cannot compensate for the negative effects of perceiving high cost on engagement. Second, in some cases, cost perceptions had even stronger, negative relations with different components of engagement when students reported higher self-efficacy or task values. It may be the case that cost perceptions play a stronger role, and become especially *costly*, when students perceive themselves as more capable of doing the task or more strongly perceive the task as worthwhile. In contrast, when students have lower confidence in their ability to succeed in the course or find course materials useless, cost perceptions may have less powerful, unique consequences for their engagement. Perhaps perceived costs are less relevant before competence beliefs or task values reach a certain threshold. Future work should investigate this possibility.

Considering the impact and prevalence of challenges that students experience, the study has scholarly significance in providing a more nuanced understanding of the complex role of perceived cost—a relatively underexamined component of EVT—in predicting engagement and achievement. By taking a multi-dimensional perspective on cost, we were able to explore how each cost dimension was the associated with other constructs. However, due to the high interrelations between different cost dimensions, further studies are needed to examine the multidimensionality in different contexts across varying groups of students. Doing so may be especially important for outside effort cost and loss of valued alternatives, given their particularly high correlation. Despite conceptual and initial empirical evidence for the uniqueness of these two constructs, it is possible that outside effort cost and loss of alternative cost may be tapping into different aspects of cost that is stemming from the alternatives or the external context. Exploring this possibility is an important avenue for future work in order to continue contributing a more nuanced understanding of cost and its unique dimensions. Furthermore, understanding whether high levels of self-efficacy or task values are sufficient to buffer the negative consequences of perceived costs hold critical implications for education practice. This will be especially applicable for interventions focusing on increasing students' engagement in science. Indeed, utility value interventions—which help students understand the personal relevance of course material—are gaining a great deal of attention in the field (Hulleman et al., 2017) and researchers have clearly demonstrated their effectiveness (Harackiewicz & Priniski, 2018; Lazowski & Hulleman, 2016).

However, based on findings from recent work (Perez et al., 2019a) and the current study, we argue that researchers and educators should take the aforementioned interactive and non-compensatory relations into account when designing interventions guided by EVT to promote engagement and performance in science. Although increasing one component of the framework can be helpful in promoting these outcomes, the current study's findings suggest that designing interventions to promote utility value *and* mitigate cost perceptions would be more effective. Moreover, a focus on designing interventions to lower cost perceptions may be particularly valuable given that only two known studies have done so (Cromley et al., 2020; Rosenzweig et al., 2020). Despite the important contribution of this work, more studies are needed to test the effectiveness of cost-reduction interventions—especially in combination with other EVT-guided interventions—in various contexts (Linnenbrink-Garcia et al., 2018).

Comparing introductory- and upper-level courses

Considering different course levels is crucial because the surrounding learning environment plays a significant role in shaping students' motivational beliefs and behaviors (e.g., Ames, 1992; Eccles, 2009). With the goal of providing novel insight for promoting post-secondary pursuit of STEM in general and physics in particular, we investigated whether and how the relations between costs, competence beliefs, and task values differed between introductory- and upper-level courses. Interestingly, even though students from upper-level physics courses reported higher self-efficacy and task values compared to those from introductory physics courses, their cost perceptions did not differ from their counterparts in introductory courses. In other words, students in upper-level courses perceived themselves as more capable of their work in physics and found it more meaningful, yet their perceived challenges and negative appraisals of engaging in course materials were similar to those of students in introductory courses.

In addition to the mean-level differences in EVT constructs, the interactive relations were moderated by the course level. Significant three-way interactions between EVT constructs and course level were found for persistence, procrastination, and achievement but not for effort and choice. In particular, loss of valued alternatives cost and emotional cost predicted lower persistence and higher procrastination in introductory courses, yet this was not the case in upper-level courses. In other words, when students from introductory courses believed that they were giving

up other alternatives or felt stressed by their physics course, they persisted less and procrastinated more. In contrast, these cost perceptions were not associated with persistence or procrastination for students in upper-level courses. Similarly, the negative relation between task effort cost and physics course grades was found in introductory courses but not in upper-level courses. Taken together, the negative relations between cost perceptions and persistence, procrastination, and course grades were only observed in introductory courses. As a result, these findings suggest that it may be especially important to target students from introductory courses in cost-reduction interventions (e.g., Rosenzweig et al., 2020).

However, some specific patterns of interactive relations varied by course levels as well. For example, the negative relation between emotional cost and persistence was stronger for students with high self-efficacy in introductory courses and students with lower self-efficacy in upper-level courses. In addition, although outside effort cost predicted higher procrastination for students with all levels of utility value in introductory courses, it predicted higher procrastination only when students in upper-level courses reported higher utility value. Two tentative conclusions can be drawn from these findings. First, the negative consequences of costs appear to be less pervasive in upper-level courses, but students in both course levels would likely benefit from a focus on reducing cost perceptions. However, because the specific interactive patterns varied across these contexts, these findings also suggest that a "one-size-fits-all" cost-reduction intervention may not be most effective when attempting to apply it in both introductory- and upper-level courses.

Implications

Both practical and theoretical implications can be drawn from our findings. Given that cost perceptions were negatively related to many of the physics outcomes that we examined across all self-efficacy and task value levels, science educators need to place a higher emphasis on mitigating cost perceptions in addition to promoting competence beliefs and task values. Doing so may be an especially promising strategy for educators in physics to address the well-documented and enduring challenges of recruiting and retaining students in the physics major (American Physical Society, n.d.). Likewise, it is important to support students in physics to find ways to acknowledge and address the learning barriers that they are facing. For example, faculty and academic advisors could encourage students to accurately estimate the time and effort needed to complete course tasks, to ask for help or resources when they encounter challenges, and to take steps to alleviate emotional stress.

Furthermore, our results demonstrate that students' motivational beliefs and their interactive relations can vary depending on the specific course level. This finding aligns closely with EVT predictions about the importance of the broader learning environment in shaping students' motivational beliefs (Eccles et al., 1983, 1994, 2009). In addition, it suggests that conclusions may not generalize across introductory- and upper-level undergraduate science courses. Adding to the EVT literature, we conclude that interactive relations between motivational beliefs are context-specific. As a result, more research is needed in science education beyond introductory courses, given that the majority of EVT research with undergraduate samples has been conducted in large, introductory courses (e.g., Perez et al., 2019a). Taken together, the current study provides a promising foundation for future research to design targeted EVT interventions across different course levels to enhance their effectiveness in science education.

Limitations and future directions

The current study's findings should be interpreted in light of several limitations. First, despite our focus on different course levels, it was not possible in the current study to fully capture the mechanisms behind the unique patterns in those different courses. Further studies are needed to

disentangle the factors (e.g., majors and minors) that may have contributed to the differences with a larger sample size in the upper-level courses. This also reiterates the importance of examining various contexts and how the interactive relations in EVT can vary in different settings. In particular, there are many other facets of context beyond course level—including class size, class climate, or instructional practices—that should be explored in future work.

Second, our sample was mostly White males, which prevented us from exploring the roles of gender and race in the current study. The current study's sample aligns with the broader population of physics undergraduates (NSF, 2015). However, as an essential next step, further studies are necessary to generalize to other populations of students (e.g., women and students from underrepresented racial/ethnic groups). Especially given the particularly pronounced gender and racial discrepancies in physics (see NSF, 2015), it is crucial to examine the relations with more diverse populations and delve into the unique and specific experiences that different groups of students encounter. Therefore, more studies are needed to better understand how individual differences and cultural backgrounds may impact the interactive relations in EVT—especially research that addresses the intersection of different social identities (Eccles & Wigfield, 2020).

Third, in the current study it was necessary to measure cost, competence beliefs, task values, and indicators of engagement in physics at a single point in time. Although the conceptual model that we tested was directly informed by theory and prior empirical work, temporal precedence and causal relations could not be determined. Moreover, our outcomes were physics-specific to ensure conceptual coherence and alignment with the motivation constructs we included in our model. However, further evidence is needed to understand the implications of these constructs for the STEM pipeline more generally. In particular, although our choice outcome was tapping into students' likelihood of taking additional physics-related courses in the future, these decisions are often restricted in reality based on their career trajectories and majors. Future studies should thus examine how these interactive relations change over time across different fields while also considering the practical constraints that students face.

Finally, it is important to note that our results are qualified by the number of separate analyses conducted in the study. Our findings make a unique contribution to the EVT literature by focusing on how specific dimensions of cost interact with self-efficacy and task values in different course levels; in order to pursue this objective, multiple testing was necessary. Considering that we examined three-way interactions, the statistical models would have been too complex to explore the processes in a single model. Relatedly, there was not sufficient power, especially due to the small sample size in upper-level courses to accommodate multiple moderators and outcomes. Some non-significant interactions in the upper-level courses may be due to the relatively small sample size as well. Thus, further studies are needed to explore these interactive relations in different contexts within an integrated model and with a larger sample of students enrolled in upper-level courses.

Conclusion

We explored whether (a) the negative relations between cost perceptions and engagement and achievement can be buffered by competence beliefs and task values, and (b) the interactive relations are further moderated by different course levels (introductory- vs. upper-level courses) in physics. In addition to providing a more nuanced understanding of each cost dimension and the interactive relations, we contribute to the body of research by considering and incorporating different course levels as a primary focus of the study. Our findings demonstrate the complex interplay between cost, competence beliefs, and task values: the unique cost dimensions depend not only on competence beliefs or task values, but also the level of physics course within the curriculum.

Acknowledgement

This work was supported by the Center for Emergent Materials: an NSF MRSEC under Grant award number DMR-1420451. The views expressed herein are solely those of the authors and do not necessarily represent the views of NSF. We have no conflicts of interest to disclose.

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