What Predicts Success in Undergraduate Physics?

The Importance of Belonging and the Complexity of Cost

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Abstract

As pursuit of higher education in physics continues to remain low relative to other science, technology, engineering, and mathematics (STEM) disciplines, there is an urgent need to advance understanding of precursors of retention in this field. As a result, the current study explored the relation between motivational antecedents (belonging and identity development), beliefs (self-efficacy, task values, and cost perceptions), and outcomes (motivational engagement and course grades) in a sample of undergraduate physics students. Findings from multiple mediation analyses revealed complex yet informative relationships between these variables. Particularly notable were the (a) pervasive role of belonging and (b) importance of motivational beliefs, including cost, in mediating associations between antecedents and outcomes. Scholarly contributions and implications are discussed.

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There is a pressing need to cultivate skills in science, technology, engineering, and mathematics (STEM) among American students, especially given the continued growth in the number of` STEM positions and accompanying shortage of qualified individuals to fill them (Wang & Degol, 2013). Despite efforts to retain students, many who initially aspire to pursue STEM ultimately fail to do so. Retention within physics is particularly alarming. For example, students earned more than 20 times more Bachelor's degrees in the biological sciences compared to physics in 2012 (National Science Foundation, 2015). A more nuanced understanding of precursors and pathways to STEM in general and physics in particular is thus essential.

Much theory and research has established the critical role of motivation processes in predicting STEM engagement and achievement (e.g., Chow, Eccles, & Salmela-Aro, 2012; Meece, Wigfield, & Eccles, 1990; Perez, Cromley, & Kaplan, 2014). We aimed to further extend this literature in the current study by investigating the role of motivational antecedents and cost, an understudied process within the expectancy-value framework (e.g., Eccles et al., 1983; Wigfield & Eccles, 2000), in predicting undergraduate physics engagement and achievement. We begin this section by reviewing expectancy-value theory and its application to STEM outcomes. We focus this discussion on cost, and in doing so highlight questions about it that are currently unanswered. Next, two motivational antecedents –belonging and identity development – that we argue may be particularly important predictors of motivation and its outcomes are discussed. We then briefly discuss student engagement and the need to examine how it is predicted by motivation and its precursors. Finally, we present the current study's objectives and hypotheses.

Expectancy-Value Theory and STEM Outcomes

The current study is primarily grounded in *expectancy-value theory* (e.g., Eccles et al.,1983; Wigfield & Eccles, 2000), which proposes that academic choices and achievement are influenced by students' *expectancies for success*, or "beliefs about how well they will do on upcoming tasks" (Wigfield & Eccles, 2000, p. 70) and *task values*. Eccles and colleagues (1983) distinguished between four different task values: *attainment value,* or the personal importance of doing well on a task; *utility value*, or the perceived usefulness of a given task; *intrinsic value*, or how enjoyable a student perceives a task to be, and *cost*, or perceptions about what one is sacrificing by engaging in a task. Within a given academic domain, students with more favorable expectancies, attainment, utility, and intrinsic value, and lower cost perceptions are theorized to perform better in the domain and are more likely to continue pursuing it (Eccles et al., 1983; Wigfield & Eccles, 2000). Expectancy-value theory identifies expectancies – and closely related constructs, such as students' *self-efficacy* (Wigfield, & Eccles, 2000), or "judgments…of capabilities" to successfully complete a given task (Schunk, 1991, p. 207) – as particularly strong predictors of performance. They are also theorized to be "necessary but not sufficient" predictors of subsequent choices, pointing to the critical role of values in predicting choice outcomes ranging from course enrollment patterns to eventual career decisions (Eccles, 2007; 2009, p. 84). A great deal of empirical support for these predictions, especially in STEM disciplines, has accumulated over the past several decades, and consistently demonstrates the powerful role of student expectancies and attainment, intrinsic, and utility value in predicting continued STEM pursuit and success (e.g., Chow et al., 2012; Perez et al., 2014; Wang & Degol, 2013).

How cost operates within this dynamic framework of processes is less well understood. Eccles et al. (1983) were the first to discuss cost, and in doing so distinguished between three dimensions: (1) the amount of *effort* required to succeed at a given task, (2) the lost *opportunities* to engage in other valued tasks; and (3) the *psychological consequences* resulting from engaging in a given task or domain (Perez et al., 2014). Despite the hypothesized importance of each dimension, cost remained largely understudied in the empirical literature until the past decade (Flake, Barron, Hulleman, McCoach, & Welsh, 2015). For example, Perez et al. (2014) were the first to demonstrate the relation between distinct cost perceptions and students' intentions to leave STEM, with effort and opportunity cost emerging as negative predictors of continued STEM pursuit. Conversely, psychological cost was unrelated to this outcome. Cost has also been measured as an outcome in recent relevance intervention work (Gaspard et al., 2015). which revealed three cost dimensions that were conceptually similar to those identified by Perez et al. (2014). However, unlike utility, intrinsic, and attainment value, student perceptions of cost remained unchanged following the intervention (Gaspard et al., 2015), pointing to its elusive nature.

Another recent study (Flake et al., 2015) further extended this literature by developing a new measure of cost and using it to examine associations with other constructs. In completing this scale development process, a modified definition of cost ("Negative appraisals of what is invested, required, or given up to engage in a task", p. 237) and four unique dimensions were proposed. These dimensions are conceptually similar to those initially theorized (Eccles et al., 1983) and empirically established (Perez et al., 2014), but an additional distinction was made between effort cost pertaining to the specific task ("task effort cost") and apart from it ("outside

effort cost"). Preliminary evidence of a negative association between unique dimensions of cost and long-term interest, general motivation, and achievement was established (Flake et al., 2015).

Taken together, there is ample support for the importance of students' expectancies and intrinsic, attainment, and utility values in predicting pursuit of and achievement in STEM. However, critical gaps surrounding the role of cost remain. For example, conclusions across recent studies (e.g., Flake et al., 2015; Gaspard et al., 2015; Perez et al., 2014) indicate that cost has multiple dimensions, but there is not agreement about how many dimensions exist and which ones are particularly important for predicting – or precluding –success in STEM disciplines. Furthermore, evidence suggests that perceptions of effort and opportunity cost are predictive of intentions to withdraw from STEM (Perez et al., 2014), yet support for its association with other outcomes that are closely linked to STEM retention is either mixed (e.g., achievement; see Flake et al., 2015; Perez et al., 2014) or remains unexplored (e.g., academic engagement). Third, previous work has not yet examined the unique role of a given cost dimension in predicting academic outcomes above and beyond other theorized cost dimensions, yet doing so is essential for a more nuanced understanding of these constructs and the educational implications that will emerge from it. Finally, expectancies and values do not develop in a vacuum, but rather are shaped by students' prior experiences and the broader academic context (Eccles & Wigfield, 2002; Wang & Degol, 2013; Wigfield & Eccles, 2000). However, little work has examined the role of cost in these relationships. In the current study, we aimed to address each of these four gaps in the literature. We elaborate on the importance of exploring the relation between motivational antecedents, self-efficacy, task values, and outcomes, and focus especially on relations involving cost in the following section.

Belonging and Identity Development as Antecedents to STEM Motivation

Theory (e.g., Eccles et al., 1983; Wigfield & Eccles, 2000) and empirical findings (e.g., Freeman, Anderman, & Jensen, 2007) converge on the conclusion that student motivation is shaped by both prior experiences and the broader academic context. We argue that two processes –a sense of belonging and identity development – may be particularly important for understanding STEM success in higher education and the role motivation plays in this relationship.

Belonging. A student's *belonging*, or "sense of being accepted, valued, included, and encouraged by others….in the academic classroom setting…" (Goodenow, 1993a, p. 25), is theorized to be a "fundamental human motivation" (Baumeister & Leary, 1995, p. 497) in general and a critical antecedent of academic outcomes in particular. A large empirical literature has accumulated over the past several decades that supports these predictions by consistently demonstrating the role of belonging in promoting student motivation, including expectancies and values (e.g., Freeman et al., 2007;), engagement (e.g., Furrer & Skinner, 2003; Won, Wolters, & Mueller, 2017), achievement (e.g., Goodenow, 1993a), and retention (Hoyle & Crawford, 1994).

Despite this large and growing literature, researchers have less commonly explored belonging among college students, especially in relation to motivation, (with some notable exceptions; see Freeman et al., 2007; Won et al., 2017; Zumbrunn, McKim, Buhs, & Hawley, 2014). Furthermore, no known studies have either measured its relation to cost or examined belonging within an undergraduate physics context. However, doing so in this environment and investigating its relation to the motivational, engagement, and achievement processes that follow may be particularly important for two reasons. First, the general college climate presents a precarious context for belonging to flourish: close, interpersonal relationships with both peers

and instructors are central components of belonging (Goodenow, 1993a), yet it is common for students to enter college with few if any friends, and the considerably larger college class sizes present a significant barrier to forming close relationships with instructors. Second, the pronounced retention rates in physics both during and following undergraduate study (NSF, 2015), coupled with research demonstrating the critical role of belonging in both directly and indirectly buffering attrition (e.g., Tinto, 1987; Good, Rattan, & Dweck, 2012), suggest that it could provide an essential piece to the puzzle of ultimately improving retention in physics.

Identity development. Distinct theoretical perspectives converge on the prediction that a student's identity in a given domain will have important implications for motivation, which should ultimately influence achievement and decisions to continue pursuing it (Eccles, 2009; Oyserman, 2007; 2015). From an expectancy-value perspective (Eccles, 2009), academic choices represent opportunities for expressing aspects of identity; choices and identity should thus be reflective of one another. For example, if an undergraduate student self-identifies as a physicist, this should positively predict his or her decision to study physics in graduate school. Expectancies and values, especially attainment value and cost, are theorized to mediate this relationship (Eccles, 2009).

There has been a recent focus on identity and its relation to motivation (e.g., Elmore & Oyserman, 2012; Kaplan & Flum, 2009), yet less work has explored consequences of the identity formation process. Informed by Erikson's (1968) model, Marcia (1993) distinguished between four types of identity development. *Achieved* identity development, theorized to be the most adaptive, involves a period of exploration and self-reflection, followed by a strong commitment to a given domain or set of goals. *Foreclosed* identity development is similar to the former type in the sense that a similar commitment has been made, but the period of exploration is absent;

instead, it is the decision or preference of influential others (e.g., parents) that leads a student to this commitment. *Moratorium* identity development reflects an individual that has sufficiently explored a given domain, but has not yet committed to it. *Diffused* identity development is predicted to be the least adaptive of all, with individuals neither exploring nor committing to a given domain.

Like belonging, examining identity development and its academic consequences within an undergraduate STEM environment may yield valuable insight for understanding success in and continued pursuit of these disciplines. Importantly, college-aged students are characterized as *emerging adults*, a developmental stage that is sandwiched between adolescence and adulthood (Arnett, 2000). Given that questions related to one's identity are central to emerging adulthood (Arnett, 2000), identity development may be especially salient to college-aged students, and thus particularly predictive of motivation, engagement, and achievement. Furthermore, the general college environment arguably encourages additional reflection about one's academic identity by inundating students with relevant questions about it (e.g., "Which courses are you taking?" "What major are you choosing?" "Are you going to select a minor?" "Will you consider graduate school?"). Finally, given student reports of parental pressure to pursue STEM rather than another domain (e.g., Museus, 2013), identity development types in undergraduate STEM contexts may be more likely to resemble one that is foreclosed and thus less adaptive (Marcia, 1993).

Conclusions from prior research align with these arguments. For example, the only known study to examine both identity development and cost within an undergraduate STEM context revealed distinct trajectories between individuals endorsing an achieved versus foreclosed identity development type: the former predicted more favorable competence beliefs,

values, and lower perceptions of effort cost relative to the latter (Perez et al., 2014). In the current study, we examined whether these relations would emerge in a similar context after accounting for students' sense of belonging in physics. We focused on achieved and foreclosed identity development for reasons similar to Perez et al. (2014). In particular, these two identity development types both involve commitment to a given domain. As a result, focusing on achieved and foreclosed identity development permitted a focused comparison of the unique exploration processes associated with each.

Engagement in Physics

Investigating how these antecedents directly and indirectly through motivation processes predict engagement in physics is of central importance for understanding long-term retention in this domain, especially given its well-documented association with outcomes closely related to retention (e.g., Connell, Spencer, & Aber, 1994; Skinner et al., 1998) We define engagement as "active, goal-directed, flexible, constructive, persistent, focused interactions…" (Furrer & Skinner, p. 149), and focus on three components of engagement (see Wolters, 2004): (1) *effort* in the physics course; (2) *persistence* in physics coursework; and (3) *choice* to continue pursuing physics. The current study will be the first to examine cost as a mediator in the relations between identity development, belonging, and engagement outcomes.

Overview of Research Questions and Hypotheses

Inspired by the importance of improving retention in both STEM disciplines generally and physics in particular, coupled with unanswered questions related to how motivational antecedents and processes can successfully do so, we conducted the current research to advance understanding of these complex relationships. With a sample of students enrolled in undergraduate physics courses reporting their beliefs and behaviors about physics across a

semester, we attempted to investigate the following questions, with corresponding hypotheses summarized directly below each one.

Do foreclosed identity development, achieved identity development, and sense of belonging in physics each predict subsequent engagement and achievement?

Consistent with theory (e.g., Eccles, 2009; Marcia, 1993) and prior research (Perez et al., 2014), we hypothesized that endorsements of a foreclosed and achieved identity development process would be associated with engagement (as indicated by reports of effort, persistence, and choice) and achievement in physics in opposing directions. Given the less adaptive process students experience when developing identity in a foreclosed manner (Kaplan & Flum, 2010) and thus without exploration, foreclosed identity development was expected to predict lower levels of engagement and performance in physics. Endorsing an achieved identity development process, on the other hand, was expected to promote heightened engagement and performance in physics. Finally, consistent with the well-established relation between belonging and both engagement (Furrer & Skinner, 2003; Won et al., 2017) and achievement (Goodenow, 1993a), we hypothesized that a sense of belonging in the student's undergraduate physics course would positively predict subsequent engagement and achievement in it.

Do self-efficacy and values in physics collectively mediate these relationships?

In light of theoretical predictions that self-efficacy and values are critical mediators of the relation between antecedents (e.g., identity; Eccles, 2009) and consequences, coupled with empirical evidence supporting these predictions (e.g., Perez et al., 2014), self-efficacy and values were together expected to mediate the hypothesized associations. We predicted that full mediation would emerge for the identity development processes given the dynamic relationship between them and self-efficacy and values (Eccles, 2009; Wigfield & Eccles, 2000). We instead

expected these processes to only partially mediate relations between belonging and engagement and achievement, with belonging emerging as a direct predictor of each outcome above and beyond its hypothesized indirect influence through self-efficacy and values.

Do self-efficacy and values in physics individually mediate these relationships?

In addition to investigating whether self-efficacy and values collectively mediate the relationships between identity development, belonging, engagement, and achievement, a central objective was to examine whether they did so independently of one another. The unique role of cost was of particular interest, given that only one known study has examined its influence above and beyond other motivation processes within a higher education STEM context (Perez et al., 2014) and none have compared its distinct dimensions within a single model. Consistent with prior theory (Eccles et al., 1983; Eccles, 2009) and research (e.g., Meece, et al., 1990; Perez et al., 2014) pointing to the critical role of efficacy beliefs in predicting performance, self-efficacy was hypothesized to positively and uniquely mediate the relations between identity development, belonging, and achievement. However, given the less consistent role of values in predicting achievement (Eccles & Wigfield, 2002), they were not expected to mediate the relations involving achievement above and beyond self-efficacy. Self-efficacy and all values were expected to uniquely mediate relations with all three components of engagement.

Method

Participants

Participants were 161 students (81% male, M_{age} = 20.6) enrolled in one of four undergraduate physics courses at a large, Midwestern university. One course was the second in the introductory physics sequence, while the remaining three were intermediate level. Two of the four were honors courses. Students were primarily European American (70%) and Asian

American (24%); the remaining participants were Hispanic (3%), African American (.6%), or self-identified with multiple races or another race (3%). The majority of students were physics majors (79%), with representation from each year of undergraduate study (14%, 29%, 38%, and 14% were freshman, sophomores, juniors, and seniors, respectively).[1]

Procedure

Students completed two online surveys at the beginning (Wave 1) and end (Wave 2) of the Spring 2016 semester as part of a larger, ongoing longitudinal study. They reported identity development and belonging at Wave 1 and self-efficacy, task values, and motivational engagement at Wave 2 (see below for a detailed description of survey items). Final grades were retrieved from student record data shortly after the semester ended. Students were given course credit as compensation for completing each survey, and they were given an option of completing an alternative physics assignment if they did not wish to take part in the current study.

Measures

Identity Development. Four items (two for each construct) measured *foreclosed* identity development (e.g., "I might have thought about a lot of different majors, but there's never really been any question since my parents said what they wanted", $\alpha = .81$) and *achieved* identity development ("It look me awhile to figure it out, but now I really know what I want in a major", $\alpha = .87$). Items were adapted from Bennion and Adams (1986) and measured on a six-point scale ranging from "Strongly disagree" to "Strongly agree".[2]

[1] The remaining students reported a distinct stage of undergraduate study (e.g., graduate student; continuing education, etc).

[2] Unless otherwise specified, "Strongly disagree" and "Strongly agree" were the scale anchors for each of the remaining measures.

Belonging. Belonging in physics was measured by eight items on a five-point scale ranging from "Strongly disagree" to "Strongly agree" adapted from Goodenow (1993b; e.g., "My instructor(s) in this physics class respect me", $\alpha = .83$).

Self-Efficacy. Five items on a seven-point scale ranging from "Not at all like me" to "Very true of me" were adapted from the Patterns of Adaptive Learning Scales (Midgley et al., 2000) to measure students' self-efficacy for physics (e.g., "In physics, I can do even the hardest work if I try", $\alpha = .93$).

Task Values.

Attainment, utility, and intrinsic value. Seven items total were administered to measure attainment, utility, and intrinsic values for physics (adapted from Eccles & Wigfield, 1995). Two measured intrinsic value (e.g., "How much do you like doing physics?", $\alpha = .84$), three measured attainment value (e.g., "How important is it to you to get good grades in physics?", $\alpha = .76$), and two measured utility value (e.g., "How useful is learning physics for what you want to do in the future?", $\alpha = .62$). Given the lower-than-acceptable Cronbach's alpha associated with utility value, this variable was excluded from analyses.[3] Items were measured on a seven-point scale with varying anchors (see Eccles & Wigfield, 1995).

Cost. Twelve items were adapted from Battle and Wigfield's (2003) measure of cost. Because dimensions of this construct and scale are less well-established than the others measured in the current study, we first conducted an exploratory factor analysis with a principal axis factoring extraction method to determine its structure. Doing so resulted in a three-factor solution, which corresponded to the "effort cost" ($\alpha = .76$), "opportunity cost" ($\alpha = .75$), and "psychological cost" ($\alpha = .69$) dimensions identified in previous work (Perez et al., 2014). All

[3] Results that include utility value are available upon request.

items were measured on a five-point scale, with "Strongly agree" and "Strongly disagree" as scale anchors. Table 1 summarizes all items and corresponding factor loadings.

Motivational Engagement. Adapted from Wolters (2004), students responded to 12 items total (four for each construct) to measure three dimensions of motivational engagement in physics: effort ("I always work as hard as I can to finish my physics assignments in this class", $\alpha = .80$), persistence ("Even if my physics work in this class is dull or boring, I keep at it until I am finished", $\alpha = .69$), and choice ("I look forward to taking more physics classes in the future", $\alpha = .86$). Students responded on a seven-point scale, with "Strongly agree" to "Strongly disagree" as scale anchors.

Achievement. To measure achievement, each student's final grade in the physics course in which they were enrolled for the current study was retrieved directly from his/her records. Grades were converted to a traditional four-point grade point average scale for analyses.

Data Analytic Approach

We conducted four separate multiple mediation analyses and adopted a bootstrapping approach (Preacher & Hayes, 2008) in SPSS using the PROCESS Macro (Hayes, 2013) to investigate the current study's research questions. In particular, each multiple mediator model included the hypothesized antecedents (belonging, foreclosed identity development, and achieved identity development), motivation processes (self-efficacy, attainment and intrinsic values, and effort, psychological, and opportunity cost), and a single outcome (effort, persistence, choice, or physics course grade), which were entered into the models as predictor, mediating, and dependent variables, respectively. These models permitted an estimation of the (a) *direct effect* of each predictor on the dependent variable, above and beyond any mediating effects and effects of other predictors, (b) *total indirect effect*, or the collective effect of all

mediators in the relation between the predictor and dependent variable, (c) *total effect*, or the sum of the direct effect and total indirect effect (Preacher & Hayes, 2008), and (d) *specific indirect effect* of each proposed mediating variable in the relation between the predictor and dependent variable, holding all other mediating variables constant.

As recommended, we used 5,000 bootstrap resamples of sampling distributions to generate bootstrap confidence intervals for the specific indirect effects (Hayes, 2013; Preacher & Hayes, 2008). Furthermore, given that students were nested within one of four courses and a total of five sections[4], statistical assumptions pertaining to the independence of student observations were violated (e.g., see Snijders & Bosker, 2012). As a result, dummy variables were included in each model to remove clustering effects from point and standard errors (Hayes, 2013).

This data analytic approach was selected for two main reasons. First, using one multiple mediation model for each outcome rather than a series of single mediation models permitted investigation of specific indirect effects *above and beyond* other possible mediators of interest (Preacher & Hayes, 2008). Especially given the largely unexplored role of cost in these relationships, investigating not only whether it mediates these relationships but also whether and how it does so above and beyond self-efficacy and other task values is of central importance. Second, examining total and specific indirect effects via bootstrapping does not require multivariate normality of (a) paths involving the indirect effects and (b) sampling distributions of indirect effects as more conventional approaches to mediation do (e.g., see Baron & Kenny, 1986; Preacher & Hayes, 2008). Given that these paths and distributions are rarely normal (Preacher & Hayes, 2008), bootstrapping should yield more trustworthy conclusions.

[4] One of the courses contained two sections, resulting in participating students being enrolled in one of five sections.

Results

Means and standard deviations and correlations are presented in Tables 2 and 3, respectively; Figure 1 summarizes the relationships between all variables. Below, we present the results from each mediation model. Although the effects are discussed separately for each of the predictors (belonging, foreclosed identity development, and achieved identity development), the other two were included as covariates in the model. As a result, they should be interpreted as the effects of a given predictor while holding the other two predictors constant.

Do Belonging and Identity Development Predict Engagement and Achievement?

Table 4 presents all total, total indirect, and direct effects for belonging, foreclosed identity development, and achieved identity development, respectively. As expected, the total effect coefficients indicated that students' sense of belonging in their physics course positively predicted their subsequent engagement and performance in it (.49 to 1.10, $p < .0001$).

Do Self-Efficacy and Values Collectively Mediate These Relationships?

All total indirect effects of belonging were also positive and significant, supporting hypotheses that self-efficacy, intrinsic and attainment values, and cost together mediate these associations ($ab = .29$ to .95, $p < .05$). Consistent with predictions, belonging directly predicted students achievement ($c' = .29$, $p = .02$) above and beyond its indirect influence through motivation processes. However, the direct effects of belonging on effort, choice, and persistence failed to reach significance. Contrary to predictions, each dimension of engagement was thus fully mediated by self-efficacy, values, and cost. Unexpectedly, the total, total indirect, and direct effects on foreclosed and achieved identity development all failed to reach statistical significance. Using multiple mediation models also permitted investigation of specific indirect

effects of each motivation variable above and beyond the effects of other mediating variables in the model, which are discussed next.

Do Self-Efficacy and Values Individually Mediate These Relations?

Tables 5 and 6 present the relations between (a) independent and mediating variables and (b) mediating and dependent variables, respectively. Despite the significant and expected positive relation between foreclosed identity development and effort cost (a = .20, p = .01), no specific, indirect effects emerged in any of the identity development models. As a result, we focus on results from the belonging mediation models below.

Effort. Intrinsic value, attainment value, and self-efficacy all uniquely mediated the relation between belonging and effort (ab = .27, .40, and -.16, respectively, p <.05). Consistent with hypotheses, belonging positively predicted intrinsic value (a = 1.00, p <.0001), which lead to greater effort (b = .27, p = .001). A similar expected pattern emerged for attainment value, with a greater sense of belonging leading to higher levels of attainment value (a = .92, p <.0001), which predicted more effort in physics class (b = .43, p = .0004). Belonging was positively associated with self-efficacy as hypothesized (a = .87, p <.0001), yet more self-efficacy unexpectedly led to less effort (b = -.18, p = .02). No dimensions of cost individually mediated the relation between belonging and effort above and beyond the other motivation processes in the model. Unexpectedly, student perceptions of opportunity cost positively predicted effort after controlling for other mediating variables (b = .25, p = .02), but it did not mediate the association between belonging and effort.

Choice. Self-efficacy and intrinsic value separately mediated the relation between belonging and choice (ab = .14 and .61, respectively, p <.05). Consistent with hypotheses, belonging was positively associated with self-efficacy and intrinsic value, which both ultimately

led to heightened choice (a = .16, p = .02 and a = .61, p <.0001, respectively). Furthermore, the unique mediating effect of effort cost did not reach statistical significance, yet the predicted negative relations between belonging and effort cost (a = -.68, p <.0001) and effort cost and choice (b = -.23, p = .04) were observed. No other variables yielded significant, specific indirect effects in the relation between belonging and choice.

Persistence. Self-efficacy, attainment value, and psychological cost each uniquely mediated the relation between belonging and persistence *(ab* = .14, .18, and .17, respectively, p <.05). As reported above, belonging positively predicted self-efficacy and attainment value, which in turn led to heightened persistence (b = .17, p = .02 and b = .20, p = .06 respectively), However, the latter relation failed to reach statistical significance. Furthermore, as expected, a greater sense of belonging in physics class predicted lower levels of perceived psychological cost: for every one-unit increase in belonging, there was a corresponding .59-unit decrease in psychological cost (p <.0001). Perceived psychological cost in turn predicted lower levels of persistence in physics class, holding all else constant in the model (b = -.29, p = .003).

Achievement. Contrary to predictions that only self-efficacy would uniquely mediate the relation between belonging and achievement, it was attainment value, intrinsic value, and psychological cost that each uniquely did so (ab = .26, -.15, and .07, respectively, p <.05). As previously reported, belonging was positively associated with both attainment and intrinsic value, the former of which ultimately led to a positive association between attainment value and course grade (b = .28, p = .0004). Contrary to expectations, intrinsic value negatively predicted course grade (b = -.15, p = .03). Also as previously reported, belonging negatively predicted psychological cost, which in turn led to lower course grades (b = -.13, p = .07). Despite

significantly and uniquely mediating the relation between belonging and course grades, the relation between psychological cost and course grade did not reach significance.

Discussion

The current study investigated the role of identity development processes and students' sense of belonging in predicting engagement and achievement in an undergraduate physics course. It was also a central objective to examine the extent to which motivation processes – with a particular focus on student perceptions of cost – collectively and independently mediated these relationships. In doing so, we attempted to (a) advance understanding of how and why undergraduate students experience success in physics, and (b) ultimately shed light on strategies for improving retention in this discipline, both during and following the pursuit of a Bachelor's degree. Four multiple mediation analyses were conducted to investigate these questions, with three engagement dimensions (effort, persistence, and choice) and the student's course grade in physics as a single outcome in each analysis. These models together revealed a pattern of complex yet informative findings, which can inform both theory and education practice. We first provide an interpretation of the current study's findings, then highlight implications for theory and education practice that emerge from them, and conclude by discussing limitations and recommendations for future research.

Interpretation of Findings

Belonging and identity development as predictors of engagement and performance. Hypotheses related to the role of belonging in predicting three dimensions of engagement – namely, effort, choice, and persistence – and achievement were largely supported, with significant, indirect relationships emerging among all four outcomes. Furthermore, belonging was directly and positively predictive of achievement in physics above and beyond its indirect

influence through motivation processes. Taken together, these findings support previous conclusions that belonging plays a critical role in promoting optimal motivation, engagement, and achievement (Freeman et al., 2007; Furrer & Skinner, 2003; Goodenow, 1993a; 1993b). The current study also extends these conclusions as the first to both examine its relation with unique dimensions of cost and the extent to which cost mediates its relationship with engagement and achievement.

The sole significant relationship that emerged involving achieved and foreclosed identity development aligned with hypotheses, with endorsement of foreclosed identity development predicting heightened perceptions of effort cost. This trend supports prior theory (Eccles, 2009; Marcia, 1993) and research (Perez et al., 2014) revealing the unfavorable consequences of foreclosed rather than achieved identity development. However, arguably the most interesting finding involving identity development was its lack of significant effects. After controlling for belonging, neither achieved nor foreclosed identity development predicted engagement or performance in physics. These nonsignificant findings are surprising, especially in light of previous work noting its importance (Perez et al., 2014). Two noteworthy differences between recent research (Perez et al., 2014) and the current study stem from the context and developmental stage of participants. While the majority of students in the former study were freshman in a gateway course (Perez et al., 2014), only 14% in the current study were freshman, and most courses were intermediate. Perhaps identity development processes are particularly powerful predictors upon the transition to a new academic context (college) and developmental period (emerging adulthood), especially given that identity exploration is a pronounced feature of emerging adulthood (Arnett, 2000). It is plausible that enrollment in a gateway course, which by definition is particularly high stakes and social comparative in nature, further fuels this

relationship by making questions related to identity more salient (Eccles, 2009). Conversely, identity exploration may be less central to students' academic experiences when they have already successfully experienced these contextual and developmental transitions. It would be beneficial to further explore these possibilities in future studies.

Motivation processes as mediators. As hypothesized, motivation processes mediated the relationship between belonging and all outcomes explored in the current study. This finding provides additional support for predictions guided by an expectancy-value framework (Eccles et al., 1983), which theorizes that student perceptions of their broader academic environment – in this case, their sense of belonging – will shape student competence beliefs and task values in a given domain, which in turn will predict their performance and subsequent pursuit of it.

Investigating the unique mediation effects of each motivation variable yielded a pattern of interesting findings, many of which aligned closely with hypotheses. For example, intrinsic and attainment value individually mediated the relation between belonging and effort, with belonging positively predicting both values, each of which in turn predicted heightened effort in the student's physics course. Similar patterns emerged for other dimensions of engagement, with (a) self-efficacy and attainment value and (b) self-efficacy and intrinsic value individually mediating the associations with belonging, persistence and choice, respectively. Several observed patterns, however, did not converge with hypotheses. For example, it was surprising that self-efficacy failed to uniquely mediate the relation between belonging and achievement in the student's physics course. Perhaps the mismatch in level of measurement is responsible, given that students reported their self-efficacy for physics in general, but the course-specific grade was measured. Furthermore, the nature of the specific mediating effect of intrinsic value in the relation between belonging and course grade was unexpected: belonging was positively

associated with intrinsic value as expected, but higher intrinsic value predicted lower course grades. This trend may reflect the controversy surrounding mastery-approach goal orientations and its relation with achievement (Hulleman, Schrager, Bodmann, & Harackiewicz, 2010). Relatedly, it may also suggest that valuing course content for intrinsic reasons is not adaptive within an undergraduate physics climate. Considering practices commonly adopted within undergraduate STEM classrooms – such as norm-referenced grading – that closely align with a performance, rather than mastery goal structure (Ames, 1992), further supports this interpretation, given that outperforming others rather than deeply learning the material is emphasized within the former environment (Ames, 1992).

Importantly, the current study revealed some novel and noteworthy patterns about the role of cost. Consistent with findings from some (Flake et al., 2015) but not all previous research (Perez et al., 2014), psychological cost independently mediated the relation between belonging and course grade. Furthermore, cost also played an important role in shaping engagement above and beyond the influence of other motivation processes. For example, psychological cost uniquely explained the relation between belonging and persistence, with a lower sense of belonging in physics class predicting heightened perceptions of psychological consequences of pursuing physics, which ultimately led to less persistence. Effort cost also had consequences for engagement: in addition to less belonging predicting heightened effort cost perceptions, these perceptions also attenuated student attitudes about enrolling in future physics courses. However, the unique, mediating effect of effort cost did not reach statistical significance. This can likely be explained by the small sample size, a shortcoming to which we return in the Limitations section below. Finally and interestingly, opportunity cost did not mediate any of the relations that were examined in the current study, yet it was unexpectedly positively predictive of student

reports of effort in their physics class. These trends suggest that a perceived loss of opportunities may be less affected by belonging and consequential to performance or pursuit of STEM, and could even benefit students. Taken together, the current study's findings align with prior research and theory (e.g., Battle & Wigfield, 2003; Eccles, 1983; Eccles, 2009; Flake et al., 2015; Perez et al., 2014) in its conclusion that cost is a meaningful predictor of academic engagement and achievement. The specific nature of these relationships in some cases diverge from the extant literature and in other cases uniquely extend it. The implications that emerge from these and other conclusions are discussed next.

Implications

Theoretical. The current study provides additional evidence for (a) the unique importance of cost in predicting students' academic beliefs and behaviors in STEM and (b) its multidimensional nature, with cost dimensions from the current study mapping on to theoretical distinctions first proposed by Eccles et al. (1983) that have since been empirically identified in recent work (Perez et al., 2014). Furthermore, the current study was the first to include effort, psychological, and opportunity cost within a single model, permitting investigation of whether each dimension uniquely mediated the hypothesized relations above and beyond the remaining two. Doing so led to a second theoretical implication: each aspect of cost is not only theoretically and empirically distinct, but also influences academic outcomes differently. While effort and psychological cost both appear to be detrimental to engagement in physics, the former had negative implications for choice, and the latter for persistence. Furthermore, the current study's findings suggest that psychological cost in particular predicts compromised achievement. These conclusions align with previous arguments that effort cost may be a particularly important dimension for predicting STEM retention (Perez et al., 2014), but diverge from previous

conclusions about the role of psychological and opportunity cost. Future studies should continue exploring the nature of cost and the predictive power of its unique dimensions.

Education practice. Two implications for education practice emerge from the current study's findings. First is the central and pervasive role of believing that one belongs in predicting motivation, engagement, and achievement within a physics environment. Even in light of prior theory (e.g., Baumeister & Leary, 1995; Goodenow, 1993a) and research (e.g., Freeman et al., 2007) documenting its importance, the current study's findings were striking, with belonging predicting every motivation variable examined in the current study except for opportunity cost and directly predicting achievement. These findings suggest that a student's sense of belonging may be a powerful criterion for continued pursuit of STEM in general and physics in particular. As a result, fostering every student's sense of belonging should be a central objective of undergraduate physics instructors, especially in light of its widespread benefits across motivation, engagement, and achievement outcomes.

The current study's findings also support and extend previous conclusions that student perceptions of what and how much they are sacrificing by pursuing a given discipline – in addition to how confident they feel and how much they value it—have notable consequences for their subsequent engagement and achievement in the discipline. From this contribution, a second implication for education practice emerges: minimizing cost perceptions should uniquely benefit student success in STEM. Educators are thus encouraged to prioritize doing so along with working to maintain favorable competence beliefs and task values. Furthermore, psychological cost may be the most important cost dimension to counteract in a STEM environment. The current study's findings indicate that creating an environment that fosters a strong sense of belonging is a promising strategy for removing both psychological and effort cost barriers to

success and simultaneously promoting self-efficacy and task values. Future research would benefit from identifying additional practices that educators could adopt to minimize cost perceptions, a point to which we return below.

Limitations

Despite the current study's noteworthy contributions, they should be interpreted alongside three limitations. First, the research design does not permit causal inferences. While findings indicated that belonging predicted subsequent engagement and achievement, and motivation processes mediated these relations, it is impossible to determine from the current study whether belonging directly influenced these outcomes. Especially given the dynamic nature of context, motivation, engagement, and achievement (Eccles et al., 1983; Wigfield & Eccles, 2000), experimental manipulation is needed to draw causal inferences about these constructs and their relations. It would be beneficial for future work to extend the current study's findings by conducting intervention research, especially to investigate the unexplored effect of belonging on cost perceptions.

Second, the current study's small sample size not only underpowered findings, but also introduced other caveats. For example, we initially intended to adopt a structural equation modeling (SEM) approach to analyze the data, given that doing so would have permitted (a) all four outcomes to be included within a single analysis and the relations between them modeled and (b) the removal of unshared measurement error from survey items by modeling variables as latent (see Hoyle, 2011; Hoyle & Gottfredson, 2015). Therefore, despite the benefits of adopting the current study's multiple mediation approach (Hayes, 2013; Preacher & Hayes, 2008), future research would benefit from exploring similar questions with an SEM framework.

Third and relatedly, the current study's sample included very few students from historically underrepresented groups in STEM disciplines. Notably, there were less than 30 females in the sample and only one African-American student. Despite this representation being reflective of typical proportions in undergraduate STEM environments (e.g., NSF, 2015), it qualifies the current study's conclusions given that it is unclear whether they would generalize to individuals from underrepresented minority groups. Furthermore, it precluded examining critical moderators of the relationships between antecedents, motivation, and physics outcomes, such as gender or ethnicity. Doing so will be essential in future research, especially for questions related to belonging (Goodenow, 1993a; Good et al., 2012), which we discuss in more detail next.

Recommendations for Future Research

The current study's findings, implications, and limitations together provide promising avenues for future research. The current study demonstrated the unique role of cost – and particularly psychological cost – in predicting undergraduate physics outcomes. However, more nuanced conclusions about the nature of this relationship (e.g., to whom do these conclusions apply? And under what circumstances?) remain unanswered. As a result, a critical next step is to explore whether conclusions generalize beyond the current study's largely European-American and male sample, with a particular focus on individuals from historically underrepresented groups in STEM. Relatedly, the current study corroborated and extended previous research by demonstrating that self-efficacy, values and cost uniquely predict undergraduate physics outcomes, yet whether self-efficacy and other values interact with cost is unknown. For example, it is possible that favorable values buffer the effects of cost, or conversely, that its maladaptive consequences become more pronounced with less value for or self-efficacy in a given domain. Especially in light of recent work demonstrating the interactive

nature of competence beliefs and values (Guo, Marsh, Parker, Morin, & Yeung, 2015), exploring similar questions involving cost would be valuable and yield more nuanced recommendations for educators. Complementing the extant, uniformly variable-centered literature on cost with a person-centered approach in future studies would shed similar insight.

Furthermore, given that a central objective is to determine how motivation processes, along with their antecedents and outcomes, predict STEM retention, conducting long-term, longitudinal research – for example, research that at minimum spans the four years of college– is an essential next step. Not only would doing so contribute understanding of how these processes operate to predict longer-term pursuit of STEM, but it would also permit investigation of how their influence changes at different stages of college. Also in light of the central objective to predict long-term STEM retention, it will be important for future research to measure behavioral data; specifically, rather than solely focusing on short-term achievement and reports of engagement like the current study, or reports of intentions to continue pursuing STEM (Perez et al., 2014), it will be critical to examine the choices students ultimately make.

Finally, several measures of cost have been developed over the last several decades as interest in the construct steadily grown (e.g., Battle & Wigfield, 2003; Flake et al., 2015 Gaspard et al., 2015). As a result, a deeper understanding of cost should emerge from directly comparing these measures in a single study. A direct comparison of distinct measures, or inclusion of them within a single statistical model, should continue to inform researchers about the dimensions of cost, what predicts them, and their consequences for STEM retention.

Conclusion

The current study aimed to contribute a more nuanced understanding of cost and its relation with antecedents and outcomes in an undergraduate physics environment. In doing so,

conclusions point to the (a) widespread importance of belonging and (b) unique role of cost – especially psychological cost – in predicting student engagement and achievement in physics. Findings offer noteworthy strategies for improving retention in physics, and also provide a valuable foundation for future research.

References

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology, 84,* 261-271.

Anderman, L. H. (2003). Academic and social perceptions as predictors of change in middle school students' sense of school belonging. *Journal of Experimental Education, 72,* 5-23.

Arnett, J. J. (2000). Emerging adulthood: A theory of development from the late teens through the twenties. *American Psychologist, 55*, 469-480. doi: 10.1037//003-006X.55.5.469

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51(6), 1173.

Battle, A., & Wigfield, A. (2003). College women's value orientations toward family, career, and graduate school. *Journal of Vocational Behavior, 62,* 56-75. doi: 10.1016/S0001 8791(02)0037-4

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin, 117*(3), 497 529.

Bennion, L., & Adams, G. R. (1986). A revision of the extended version of the objective measure of ego identity status: An identity instrument for use with late adolescents. *Journal of Early Adolescent Research, 1,* 183-198.

Chow, A., Eccles, J. S., & Salmela-Aro, K. (2012). Task value profiles across subjects and aspirations to physical and IT-related sciences in the United States and Finland. *Developmental Psychology, 48*, 1612-1628. doi: 10.1037/a0030194

Connell, J. P., Spencer, M. B., & Aber, J. L. (1994). Educational risk and resilience in

African-American youth: Context, self, action, and outcomes in school. *Child Development, 65,* 493-506.

Eccles, J. S. (2007). Where are all the women? Gender differences in participation in physical science and engineering. In S. J. Ceci & W. M. Williams. (Eds.). *Why aren't more women in science?: Top researchers debate the evidence.* (pp. 99-210).

Eccles, J.S. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educational Psychologist, 44*(2), 78-89.

Eccles (Parsons), J., Adler, T. F, Futterman, R., Goff, S. B., Kaczala, C., M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motivation* (pp. 75-146). San Francisco, CA: Freeman.

Eccles, J.S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, 53(1), 109-132.

Eccles, J.S., & Wigfield, A. (1995). In the mind of the actor: The structure of adolescents' achievement task values and expectancy-related beliefs. *Personality and Social Psychology Bulletin, 21*, 215-225.

Erikson, E. H. (1968). *Identity: Youth and crisis*. Oxford, England: Norton.

Elmore, K. C., & Oyserman, D. (2011). If 'we' can succeed, 'I' can too: Identity-based motivation and gender in the classroom. *Contemporary Educational Psychology, 37,* 176 185. doi: 10.1016/j.cedpsych.2011.05.003

Flake, J. K., Barron, K. E., Hulleman, C., McCoach, B. D., & Walsh, M. E. (2015). Measuring cost: The forgotten component of expectancy-value theory. *Contemporary Educational Psychology, 41,* 232-244. doi: 10.1016/j.cedpsych.2015.02.002

Freeman, T. M., Anderman, L. H., & Jensen, J. M. (2007). Sense of belonging in college freshman at the classroom and campus levels. *The Journal of Experimental Education, 75*, 203-220.

Furrer, C., & Skinner, E. (2003). Sense of relatedness as a factor in children's academic engagement and performance. *Journal of Educational Psychology, 95,* 148-162.

Gaspard, H., Dicke, A., Flunger, B., Brisson, B. M., Hafner, I., Nagengast, B., & Trautwein, U. (2015). Fostering adolescents' value beliefs for mathematics with a relevance intervention in the classroom. *Developmental Psychology*, *51*, 1226-1240. doi: 10.1037/dev0000028

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology, 102,* 700-717.

Goodenow, C. (1993a). Classroom belonging among early adolescent students: Relationships to motivation and achievement. *Journal of Early Adolescence, 13*(1), 21-43.

Goodenow, C. (1993b). The psychological sense of school membership among adolescents: Scale development and educational correlates. *Psychology in the Schools, 30,* 70-90.

Guo, J., Marsh, H. W., Parker, P. D., Morin, A. J. S., Yeung, A. S. (2015). Expectancy-value in mathematics, gender, and socioeconomic background as predictors of achievement and aspirations: A multi-cohort study. *Learning and Individual Differences, 37,* 161-168. doi: 10.1016/j.lindif.2015.01.008

Hayes, A. F. (2013). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. New York, NY: Guilford Press.

Hoyle, R. H. (2011). *Structural equation modeling for social and personality psychology.*

Washington DC: Sage Publication Ltd.

Hoyle, R. H., & Crawford, A. M. (1994). Use of individual-level data to investigate group phenomena. *Small Group Research, 25,* 464-486.

Hoyle, R. H., & Gottfredson, N. C. (2015). Sample size considerations in prevention research applications of multilevel modeling and structural equation modeling. *Prevention Science*, 16(7), 987-996.

Hulleman, C. S., Shrager, S. M., Bodmann, S. M., & Harackiewicz, J. M. (2010). A meta-analytic review of achievement goal measures: Different labels for the same constructs or different constructs with similar labels? *Psychological Bulletin, 136,* 422 449. doi: 10.1037/a0018947

Kaplan, A., & Flum, H. (2010). Achievement goal orientations and identity formation styles. *Educational Research Review*, 5(1), 50-67.

Marcia, J. E. (1993). The status of the statuses: Research review. In J. E. Marcia, A. S Waterman, D. R. Matteson, S. R. Archer, & J. L. Orlofsky (Eds.), *Ego Identity: A handbook for psychosocial research* (pp. 22-41). New York, NY: Springer.

Midgley, C., Maehr, M.L., Hruda, L., Anderman, E.M., Anderman, L., et al. (2000). Manual for the Patterns of Adaptive Learning Scales (PALS). Ann Arbor, MI: University of Michigan.

Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology*, 82(1), 60.

Museus, S. D. (2013). Unpacking the complex and multifaceted nature of parental influences on Southeast Asian American college students' educational trajectories. *The Journal of Higher Education, 84,* 708-738. doi: https://doi.org/10.1353/jhe.2013.0031

National Science Foundation, National Center for Science and Engineering Statistics. 2015. *Science and Engineering Degrees: 1966–2012.* Detailed Statistical Tables NSF 15-326. Arlington, VA. Available at http://www.nsf.gov/statistics/2015/nsf15326/.

Oyserman, D. (2007). Social identity and self-regulation. In A. W. Kruglansi & E. T. Hissings (Eds.), Social Psychology: Handbook of Basic Principles (second edition). New York: Guilford Press.

Oyserman, D. (2015). Identity-based motivation. In R. Scott & S. Kosslyn (Eds.) *Emerging Trends in the Social Sciences.* John Wiley & Sons.

Perez, T. Cromley, J. G., Kaplan, A. (2014). The role of identity development, values, and costs in college STEM retention. *Journal of Educational Psychology, 106,* 315-329. doi: 10.1037/a0034027

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods, 40,* 879-891. doi: 10.3758/BRM.40.3.879

Schunk, D. H. (1991). Self[8]efficacy and academic motivation. *Educational Psychologist, 26,* 207[8]231.

Skinner, E. A., Zimmer-Gembeck, M. J., Connell, J. P., Eccles, J. S., & Wellborn, J. G. (1998). Individual differences and the development of perceived control. *Monographs of the Society for Research in Child Development, 63,* 1-231.

Snijders, T. A. B., & Bosker, R. J. (2012). *Multilevel analysis: An introduction to basic and*

advanced multilevel modeling. London: Sage Pulications, Inc.

Tinto, V. (1987). *Leaving college: Rethinking the causes and cures of student attrition.* Chicago: The University of Chicago Press.

Wang, M. T., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy–value perspective to understand individual and gender differences in STEM fields. *Developmental Review*, 33(4), 304-340.

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology, 25*, 68-81. doi: 10.1006/ceps.1999.1015

Wolters, C. A. (2004). Advancing achievement goal theory: Using goal structures and goal orientations to predict students' motivation, cognition, and achievement. *Journal of Educational Psychology, 96,* 236-250. doi: 10.1037/0022-0663.96.2.236

Won, S., Wolters, C. A., & Mueller, S. A. (2017). Sense of belonging and self-regulated learning: Testing achievement goals as mediators. *The Journal of Experimental Education*. Advance Online Publication. DOI: 10.1080/00220973.2016.1277337

Table 1

Summary of Cost Items and Factor Loadings

Item	Factor Loading	Cost Dimension Label
Taking physics seems like it really requires more effort than I'm willing to put into it.	0.73	Effort
Considering what I want to do with my life, taking physics is just not worth the effort.	0.72	Effort
When I think about all the work required to get through physics, I'm not sure it is going to be worth it in the end.	0.66	Effort
I worry that I will waste a lot of time and money before I find out that I don't want to continue in physics.	0.47	Effort
My self-esteem would suffer if I tried physics and was unsuccessful at it.	0.62	Psychological
I'd be embarrassed if I started taking physics courses and found out that my work was inferior to that of my peers.	0.54	Psychological
I'm concerned that I'm not a good enough student to do well in physics.	0.47	Psychological
It frightens me that the physics course work at [school name] will be harder than my previous physics courses.	0.47	Psychological
I worry about losing track of some valuable friendships by taking physics.	0.93	Opportunity
I'm concerned that taking physics may cost me some treasured friendships.	0.74	Opportunity
I wish I had left more time for fun during college before I jumped into something as intense as physics.	0.42	Opportunity
I worry that spending all the time pursuing physics will taking time away from other activities I want to pursue.	0.36	Opportunity

Note. The above items were adapted from Battle & Wigfield (2003).

Table 2

Means, Standard Deviations, and Sample Sizes for All Variables

Variable	*M*	*SD*	*N*
Foreclosed Identity	1.56	0.88	161
Achieved Identity	4.20	1.15	161
Belonging	3.60	0.60	161
Self-Efficacy	5.21	1.39	161
Intrinsic Value	5.35	1.29	161
Attainment Value	5.85	1.09	161
Effort Cost	2.30	0.92	161
Opportunity Cost	2.38	0.89	160
Psychological Cost	3.03	0.92	161
Engagement (Effort)	5.37	1.24	161
Engagement (Persistence)	5.03	1.11	161
Engagement (Choice)	5.63	1.43	161
Physics Course Grade	3.18	0.72	154

Table 3

Pearson Correlations Between All Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Foreclosed Identity	–												
2. Achieved Identity	.13	–											
3. Belonging	−.05	.30**	–										
4. Self-Efficacy	−.12	.20*	.41**	–									
5. Intrinsic Value	.02	.27**	.47**	.62**	–								
6. Attainment Value	−.07	.30**	.53**	.53**	.72**	–							
7. Effort Cost	.17*	−.26**	−.48**	−.52**	−.57**	−.58**	–						
8. Opportunity Cost	.09	−.12	−.09	−.28**	−.24**	−.23**	.49**	–					
9. Psychological Cost	.08	−.05	−.38**	−.26**	−.16*	−.10	.41**	.37**	–				
10. Engagement (Effort)	−.01	.22**	.32**	.18*	.48**	.52**	−.27**	.06	−.01	–			
11. Engagement (Persistence)	.00	.26**	.49**	.46**	.46**	.45**	−.42**	−.13	−.38**	.46**	–		
12. Engagement (Choice)	−.08	.17*	.46**	.63**	.77**	.63**	−.61**	−.32**	−.22**	.33**	.39**	–	
13. Physics Course Grade	−.07	.15	.40**	.26**	.21**	.38**	−.23**	−.05	−.25**	.25**	.38**	.18*	–

Note. * = p <.05; ** = p <.01

Table 4

Summary of Total, Total Indirect, and Total Direct Effects

Variable	Effect	Point Estimate	Outcome
Belonging			
	Total	0.69*	Effort
	Total Indirect	0.51*	Effort
	Direct	0.18	Effort
	Total	0.85*	Persistence
	Total Indirect	0.58*	Persistence
	Direct	0.26	Persistence
	Total	1.10*	Choice
	Total Indirect	0.95*	Choice
	Direct	0.15	Choice
	Total	0.49*	Course Grade
	Total Indirect	0.29*	Course Grade
	Direct	0.20*	Course Grade
Foreclosed ID			
	Total	-0.13	Effort
	Total Indirect	-0.01	Effort
	Direct	-0.12	Effort
	Total	-0.01	Persistence
	Total Indirect	0.07	Persistence
	Direct	0.06	Persistence
	Total	-0.13	Choice
	Total Indirect	-0.12	Choice
	Direct	-0.01	Choice
	Total	-0.07	Course Grade
	Total Indirect	-0.03	Course Grade
	Direct	-0.04	Course Grade
Achieved ID			
	Total	0.11	Effort
	Total Indirect	0.04	Effort
	Direct	0.07	Effort
	Total	0.10	Persistence
	Total Indirect	0.02	Persistence
	Direct	0.08	Persistence
	Total	0.01	Choice
	Total Indirect	0.12	Choice
	Direct	-0.11	Choice
	Total	0.01	Course Grade
	Total Indirect	0.002	Course Grade
	Direct	0.01	Course Grade

Note. ID = identity development. * = $p < .05$

Table 5

Relations Between Independent and Mediating Variables

Independent Variable	Mediating Variable	IV to MV Estimate
Belonging	Self-Efficacy	0.86*
	Intrinsic Value	1.00*
	Attainment Value	0.92*
	Psychological Cost	-0.59*
	Effort Cost	-0.68*
	Opportunity Cost	-0.08
Foreclosed Identity	Self-Efficacy	-0.19
	Intrinsic Value	-0.04
	Attainment Value	-0.13
	Psychological Cost	0.04
	Effort Cost	0.20*
	Opportunity Cost	0.11
Achieved Identity	Self-Efficacy	0.09
	Intrinsic Value	0.11
	Attainment Value	0.11
	Psychological Cost	0.06
	Effort Cost	-0.10
	Opportunity Cost	-0.08

Note. IV = independent variable. MV = mediating variable. All estimates represent the relation between a given independent and mediating variable holding the remaining independent variables constant. * = $p < .05$.

Table 6

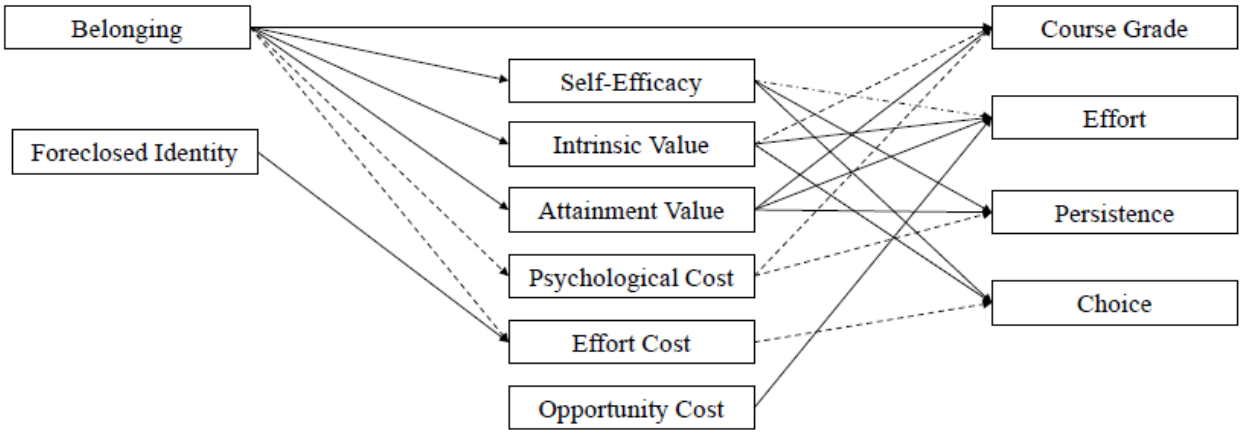
Relations Between Mediating and Dependent Variables

Mediating Variable	Dependent Variable	Mediating Variable to Dependent Variable
Self-Efficacy	Effort	-0.18*
Intrinsic Value	Effort	0.27*
Attainment Value	Effort	0.43*
Psychological Cost	Effort	-0.02
Effort Cost	Effort	-0.01
Opportunity Cost	Effort	0.25*
Self-Efficacy	Persistence	0.17*
Intrinsic Value	Persistence	0.06
Attainment Value	Persistence	0.20
Psychological Cost	Persistence	-0.29*
Effort Cost	Persistence	-0.06
Opportunity Cost	Persistence	0.15
Self-Efficacy	Choice	0.16*
Intrinsic Value	Choice	0.61*
Attainment Value	Choice	0.05
Psychological Cost	Choice	0.03
Effort Cost	Choice	-0.23*
Opportunity Cost	Choice	-0.11
Self-Efficacy	Course Grade	0.06
Intrinsic Value	Course Grade	-0.15*
Attainment Value	Course Grade	0.28*
Psychological Cost	Course Grade	-0.13
Effort Cost	Course Grade	0.05
Opportunity Cost	Course Grade	0.04

Note. MV = mediating variable. DV = dependent variable. All estimates represent the relation between a given mediating and dependent variable, holding the remaining mediating and all independent variables constant. * = $p < .05$.

Figure 1

Relation Between Antecedents, Motivation Processes, and Outcomes



Note. Solid lines indicate positive relations and dashed lines indicate negative relations. Nonsignificant pathways were removed for simplicity. Achieved identity was removed from the figure because it did not predict any other variables in the mediation model.