Perceived Cost and Physics Identity in Algebra-Based Physics for Pre-Health Majors

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Introductory algebra-based physics courses can present unique motivational challenges for pre-health students, who often perceive physics as irrelevant or intimidating. According to Expectancy-Value Theory, students' performance and persistence are shaped not only by their expectations for success, but also by the perceived value and cost of engagement. This study quantitatively examines the role of perceived cost—such as effort, emotional toll, and opportunity cost—among students enrolled in an active learning, algebra-based physics course designed for life science majors. We analyze expectancy value cost items from survey data of introductory physics students at a Large Hispanic Serving Institution. Our findings reveal that higher perceived costs are negatively correlated with physics identity and intentions to continue in the course sequence, particularly among students who have a low physics identity. Regression analysis of perceived cost before the course results in only *emotional cost* having a negative effect on students' physics identity. This negative correlation persisted in post course experience, and the added cost of *outside effort* was statistically significant in negatively affecting physics identity. These findings suggest the persisting emotional anxiety towards physics impedes students from believing they can do well in physics even before they enter the course.

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I. INTRODUCTION

Introductory algebra-based physics courses often present motivational challenges for pre-health students, who may struggle to find relevance between physics content and their professional goals [1, 2]. These challenges can result in decreased engagement, elevated stress, and lower persistence in physics course sequences [3, 4]. Within the framework of Expectancy-Value Theory [5], motivation is shaped by students' beliefs about potential success (expectancy), the perceived importance or usefulness of a task (value), and the anticipated negative aspects of participation (cost) [6].

While many studies have explored the roles of expectancy and value in physics learning, fewer have focused on perceived cost—defined as effort, emotional burden, and opportunity loss [7]. High levels of perceived cost may reduce student motivation, particularly when learners do not identify with physics or don't view it as beneficial to their intended career path [8, 9]. This issue is particularly relevant for students pursuing health-related professions, for whom physics is often seen as a requirement rather than a resource [9, 10]

For pre-health majors, their introductory physics course is their last opportunity to interact with physics and see it as relevant for their future. Our goal was to design a course experience for algebra-based students that would engage these students in increasing their physics identity and improving their success in the course. With this purpose in mind, this study explores these students' success in introductory physics from the perspective of the perceived cost of engaging with physics. Our aim is to better understand how perceived costs impact their physics identity and learn ways that the course can mitigate these fears and negative barriers to their success.

A. Expectancy-Value Theory and Student Motivation

Expectancy-Value Theory (EVT) suggests that students' motivation is shaped by two primary factors: their beliefs about how likely they are to succeed and the value they associate with the task [5, 11, 12]. The value component is particularly multifaceted and includes four distinct dimensions. First, *attainment value* refers to how personally important it is for students to do well. Second, *utility value* reflects how the task aligns with future goals or practical needs. Third, *intrinsic value* captures the enjoyment or interest students find in the activity itself. Lastly, *cost* accounts for the perceived drawbacks of engaging in the task, such as emotional strain, time demands, and the loss of other valued opportunities [1, 11].

Although the Expectancy-Value Theory is widely recognized as a foundational framework for understanding student motivation, its *cost* component has received comparatively little empirical attention [13]. Recent work has brought renewed attention to cost, suggesting it can significantly reduce motivation—even among highly motivated and successful students [9].

B. Perceived Cost as a Barrier to Engagement

Recent expansions of EVT emphasize the importance of perceived cost, defined as the anticipated negative consequences of task engagement—such as effort, emotional strain, and missed opportunities [9, 14]. Cost is further defined by four constructs: *Task Effort,* or the time and energy required to engage in the task itself; *Outside Effort,* which refers to the effort spent on other responsibilities unrelated to the task; *Loss of Valued Alternatives*, meaning the meaningful activities a student must give up to complete the task; and *Emotional Cost,* the psychological strain or stress that can result from putting forth sustained effort [13].

Perceived cost is particularly significant in physics education, where students may anticipate high cognitive demand, low relevance to their field, and fear of failure [9]. When perceived costs outweigh the benefits of task completion, students are less likely to participate meaningfully or persist in the physics course. Higher levels of perceived cost were significantly associated with decreased self-efficacy and task value beliefs, especially among non-physics majors [9]. Similarly, Flake et al. argues that cost is not simply the inverse of value or expectancy, but a unique and influential factor in student motivation that can independently shape academic decisions and engagement [13]. Additionally, students' expectations for success are often reflected in their academic identity and how they relate to the topic of study. Physics identity and how students perceive their relationship with physics significantly predicts their success in the course [1, 2].

C. Physics Identity for Pre-health Majors

For many pre-health students, physics does not align with their academic or professional identity, creating dissonance that may reduce engagement [15]. Looking towards the costs of engagement and its impact on physics identity can highlight the specific effects between these motivational constructs on student success.

Physics identity is defined by Hazari [1, 2] as the combination of four factors: interest, performance competency beliefs, recognition, and sense of belonging. These identity constructs are well established in predicting students' performance and persistence in the physics course. As such, for students underrepresented in physics (ie. women, and other minoritized gender identities, and diversly ethnic students), constructs such as recognition and sense of belonging are stronger influencers of their physics identity and success in the course [2].

Physics identity is not developed in isolation but is deeply influenced by the cultural and relational dynamics of the classroom [15]. Where culturally relevant pedagogy—such as validating students' lived experiences and creating inclusive learning spaces—can strengthen students' identification with physics and their success in the course, especially for underrepresented groups in physics [15].

However, even when courses incorporate relevant pedagogy and active, group-based learning, these approaches can introduce new forms of perceived cost and anxiety that make full participation feel risky [16]. In highly social classroom environments, students are continually exposed to peer evaluation and potential judgment—an especially daunting prospect when they already hold low self-efficacy in the subject. For these students, the fear of making public mistakes or not meeting perceived expectations can become a significant psychological cost, further inhibiting their willingness to engage.

D. The Present Study

Therefore, this study aims to empirically explore the relationship of perceived cost on students' physics identity. Within the context of an active learning classroom for algebra-based physics students and a Large Hispanic Serving Institution, we intend to identify the motivational barriers to their success in physics courses. We are guided by the following research questions in the hopes that we can determine effective pedagogical changes that mitigate costs to the students. (1) *How do students' incoming perceived cost beliefs affect their physics identity?* and (2) *How do students' experiences in an active learning physics course impact their perceived cost beliefs?*

III. METHODS

This study is a statistically quantitative exploration of students' perceived cost and physics identity measures in an algebra-based active learning physics course at a large, Hispanic serving Institution. Data was collected over three semesters (2021-2023) using a survey instrument grounded in Expectancy-Value Theory, with a focus on relative cost constructs [5].

A. Participants and Data Collection

The data included 258 undergraduate students enrolled in an introductory algebra-based physics sequence designed for life science majors. Data include two semesters of mechanics and one semesters of electromagnetism courses. Most students identified as pre-health or allied health majors, although the course services other non-health majors as well. Majority of students are juniors and seniors in their program, although the course serves all levels of classmen. Of the survey participants, 54.9% identified as female, 43.1% as male, and 1.9% as non-binary. In terms of race and ethnicity, 76% identified as Hispanic/Latinx, 25.8% as white, 9.3% as Black, 4.1% as Asian or Pacific Islander, and 2.1% as other; students could select more than one identity.

Motivational and identity surveys were administered during the first and final weeks of instruction each semester for a pre/post design and incentivized by extra credit toward their homework grade. Students had a seven-day period to finalize it at their leisure. The survey included 16 Likert-scale items adapted from the Scale of College Students' Perceptions of Cost [13], with each item rated on a 5-point scale (0 = Strongly Disagree to 4 = Strongly Agree). Survey constructs reflected four dimensions of perceived cost: Task Effort, Outside Effort, Loss of Valued Alternatives, and Emotional Cost. Additionally, we added questions to measure physics identity constructs as well.

B. Course Context: Modeling Instruction

The introductory physics course in this study used a Modeling Instruction (MI) approach [17, 18], emphasizing student-centered, active learning. Students developed, validated, and applied conceptual models through collaborative group work and guided inquiry in a studio-based format (5 credit hours). The course met three times per week for two-hour sessions combining lecture and lab, featuring evidence-based discovery, small-group problem-solving, and whole-class model synthesis. Grades were weighted: 20% homework, 22% each for the midterm, group exam, and final, and 14% formal lab reports.

The class expectations are to participate in small group discussion and problem solving guided by their worksheets. There is no expected preparation or videos prior to class time. Outside scheduled class time, students completed a weekly homework assignment—a written problem-solving question emphasizing conceptual reasoning and model-based representations. In total, the course required approximately 6 in class hours per week of engagement, and their own personal time completing homework or studying. The active learning structure demands consistent preparation and attendance, which can present a considerable time investment—particularly for students balancing employment, caregiving, or other academic responsibilities. Thus, these time and effort demands are central to understanding students' reported perceptions of cost within the courses.

C. Measures and Constructs

The cost survey items were developed and adapted for a STEM education context by Kim et.al. [7] and captured different facets of what students may perceive as barriers to success in physics. *Task Effort* assessed the perceived academic demands of the course, focusing on students' beliefs about workload and required effort. *Outside Effort* captured the impact of competing responsibilities on students' ability to engage in physics. This includes non-course-related obligations such as employment, family duties, or coursework from other classes, research. This construct was included to examine how external time constraints might impact students' ability to fully participate in the course. *Loss of Valued Alternatives* reflected the opportunity costs students perceived by taking the physics course—namely, the trade-offs between course participation and other meaningful or enjoyable activities. This factor helps capture how students weigh their investment in physics against other valued parts of their lives. *Emotional Cost* describes the psychological toll associated with participating in the course, including feelings of stress, anxiety, or discouragement. Measuring emotional cost provided insight into affective barriers that may undermine persistence and confidence in physics. Representative survey items are listed in Table 1.

In addition to perceived costs, students' attitudes towards physics and *Physics Identity* measured to capture the extent to which they saw themselves as "physics people." Other items of interest, and recognition were also part of the identity items.

TABLE 1: Measures and Constructs

Construct	Survey Items	Example item
Physics Identity	7	I see myself as a physics person
Task Effort	4	This class is too much work
Outside Effort	3	I have so many other responsibilities that I am unable to put the effort that is necessary in this class.
Loss of Valued Alternative	3	Taking this class causes me to miss out on too many other things I care about
Emotional Cost	6	I worry too much about this class

D. Data Analysis

Quantitative statistical analysis was conducted using RStudio open-source software. We ran a Factor Analysis (EFA) to examine the hypothesized four factor costs measures and the extra physics identity measures on algebra-based physics students at a large Hispanic Serving Institution. The model demonstrated an adequate fit to the data, $\chi^2(148) = 681.42$, $p < .001$, for the pre data set and $\chi^2(148) = 569.78$, $p < .001$ for the post data. A five-factor model was supported with factor loadings ranging from 0.54-0.97. The number of survey items of each construct supported by the factor loading are also listed in Table 1. These measures ranged from a 0-4 Likert scale.

To address our research questions, we ran separate linear regressions for the pre- and post-course data, using cost factors as predictors of the physics identity outcome. We also used Wilcoxon Signed-Rank Tests to identify significant shifts in cost constructs across the semester. This non-parametric test compared paired pre- and post-survey responses, revealing which perceived costs changed most through course participation. The pre-course regression model examined how incoming cost beliefs predicted students' initial identity, while the post-course model assessed how the active learning experience shaped these relationships by semester's end.

IV. RESULTS

Prior to instruction, the average physics identity score was 2.59 across seven items. Task Effort had a mean of 1.72 based on four items. Outside Effort had a lower mean of 0.93 across three items. Loss of Valued Alternative had a mean of 0.78 across three items. Emotional Cost averaged 1.25 across six items. These descriptive statistics suggest that students began the course with moderate identification with physics on a 0-4 scale and relatively low perceived costs, particularly regarding opportunity loss and external demands.

Moreover, linear regression analysis was conducted using pre-course survey data to examine how students' initial perceived costs predicted their incoming physics identity reported in Table. 2. *Emotional Cost* emerged as the strongest negative predictor ($\beta = -0.35$, $p < 0.001$), suggesting that students who reported higher emotional burdens, such as anxiety or fear of failure, were less likely to see themselves as "physics people." *Task Effort* was also a significant positive predictor ($\beta = 0.11$, $p = 0.033$), indicating that students who acknowledged the time commitment still identified with physics to a modest extent. *Outside Effort* and *Loss of Valued Alternative* were not statistically significant predictors in the model before the course. As linear regression calculates correlation rate of change, the Intercept (y-intercept) relates to the average initial pre score for physics identity.

Additionally, a second regression analysis was performed using post-course data to assess how students' cost perceptions at the end of the semester related to their physics identity, reported in Table 3. *Emotional Cost* remained the most significant negative predictor ($p < 0.001$), reinforcing its negative effect on physics identity. *Task Effort* remained a positive correlation with physics identity, consistent with pre-course findings. *Outside Effort* was also a significant negative predictor ($p = 0.004^{**}$) in the post physics identity regression that was not initially significant in the pre-survey measures. Indicating that after taking the course they had a better measure of their external time commitments in relation to the course expectations.

TABLE 2. Regression for Pre Physics Identity

Construct	β	SE	t-stat	p-value
Intercept	2.80	0.085	32.7	2e-16***
Task Effort	0.11	0.053	2.14	0.033*
Outside Effort	-0.07	0.055	-1.31	0.193
Loss of Valued Alternative	0.11	0.061	1.78	0.080
Emotional Cost	-0.35	0.059	-5.90	1.25e-08***

Sig. codes: ***0*** (***), ***0.001*** (**), ***0.01*** (*)

TABLE 3. Regression for Post Physics Identity

Construct	β	SE	t-stat	p-value
Intercept	2.986	0.085	33.05	2e-16***
Task Effort	0.133	0.059	2.245	0.025*
Outside Effort	-0.141	0.048	-2.903	0.004**
Loss of Valued Alternative	0.113	0.064	1.754	0.080
Emotional Cost	-0.402	0.050	-7.905	9.13e-14***

Sig. codes: ***0*** (***), ***0.001*** (**), ***0.01*** (*)

TABLE 4. Wilcoxon Rank Test Pre-Post.

Construct	Mean Pre	Mean Post	Pseudo Median	95% Conf. int	p-value (sig)
Physics Identity	2.59	2.47	-0.071	[2.14e-01, -3.9e-05]	0.0369*
Task Effort	1.72	1.60	-0.125	[-2.50e-01, 9.84e-06]	0.071
Outside Effort	0.93	1.31	0.666	[0.33, 0.83]	1.45e-08***
Loss of Valued Alternative	0.78	0.85	0.166	[-3.52e-01, 3.33e-05]	0.128
Emotional Cost	1.25	1.59	0.333	[0.16, 0.50]	2.35e-05***

Sig. codes: ***0*** (***), ***0.001*** (**), ***0.01*** (*)

Lastly, a Wilcoxon Signed-Rank Test, reported in Table 4, evaluates shifts in all measures. *Emotional Cost* and *Outside Effort* significantly increased over the semester ($p < 0.001$). Physics identity decreased slightly but significantly ($p = 0.037$). A Cohen's d effect size (d = 0.18) was calculated for this shift after the semester, making it a small effect. Changes in *Task Effort* and *Loss of Valued Alternative* were not statistically significant.

V. DISCUSSION

Designing a course that enhances relevance for pre-health students, supports their physics identity, and reduces perceived costs remains an ongoing challenge. In this study, physics identity declined over the semester—a common trend—but the smaller decrease compared to prior work suggests that active learning may help sustain more positive attitudes [19].

Physics identity was positively correlated with task effort pre- and post-course, indicating greater engagement supports stronger interest. Emotional cost consistently predicted lower identity, reflecting persistent anxiety toward physics, while outside effort also reduced engagement after instruction. These results highlight the need to address both emotional barriers and competing responsibilities.

In line with our goal to foster physics identity and success, these findings suggest that course designs should intentionally incorporate positive coaching, stress management, and peer support to reduce fear and anxiety. Our sister paper (in review) on growth mindset perspective highlights the importance of establishing a class community around growth mindset, grit, and communal care [20] of explicit student anxiety in physics. Breaking the stigma that physics is for an elite few is part of the negotiated classroom culture framed by the instructor. Allowing for time extension on assignments to accommodate students' outside responsibilities also support student engagement and perceived recognition from instructor. Limitations include the timing of the post-survey (completed either before or after finals by student personal choice), which may have influenced responses on post measures of effort. Further work is needed in determining conflated measures of these effort constructs and the time impact during high stress moments and exams.

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