Giving Students a Voice: Deconstructing Undergraduates Chemistry and Physics Persistence using Expectancy-Value Theory

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Abstract:

College Introductory STEM courses impact students' persistence. Guided by Eccles' Expectancy-Value (EV) theory, we examined undergraduates' open-ended explanations for major persistence plans. Students (N=2,737; 45.6% women; 16.4% White, 22.6% Latino/a, 46.5% Asian, 14.5% other; 43% 1st-generation college-going students) reported certainty in their major choice and a subgroup (N = 361) explained why their plans changed at the end of introductory physics and chemistry courses. Nearly half became more or less certain. EV constructs naturally emerged in students' explanation, with decreases in expectancy or values the most frequently mentioned. EV explanations related to whether students became more or less certain about their major choice. Findings underscore the meaningfulness and validity of EV theory for understanding undergraduates' STEM persistence.

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1. Objectives and theoretical framework

Extensive research and instruction efforts have been devoted to improving undergraduates' persistence in college STEM majors. The Eccles Expectancy-Value (EV) theory suggests that expectancy-value beliefs can help in better understanding STEM persistence. More specifically, a student's belief about their ability to do well in STEM fields ("expectancy") and the subjective value they attach to the field will determine whether they will persist in STEM careers[1]. Students are more likely to choose and persist in STEM majors, if they think their major is interesting, useful, personally meaningful (i.e., attainment value), and not costly (i.e., the student does not have to suffer from heavy loss or burden by choosing the major), and if they believe they can do well in their major[2]. Past studies have shown that expectancy and value beliefs strongly predict students' STEM performance, participation and career choices[3, 4, 5]. In particular, values are found to be a stronger predictor of engagement and participation, and expectancy more strongly predicts performance and achievement [6, 7]. In this study, we will examine how various EV beliefs relate to changes in college students' major plans, specifically students' intention to change their major.

Introductory courses are often students' first impressions of their major in college. Thus, these courses have considerable influence on students' attitudes towards their science majors and their persistence. In these courses, students gain knowledge about the work content and pace of the major, the classroom climate, the interpersonal interactions with the instructors and with other students and many more aspects of the major[8, 9]. The experience affects students' certainty about the major they intend to study upon entering college[10]. However, previous quantitative studies have mostly focused on the finalized decisions of major choice over a longer period of time (such as the majors declared or course enrollment at the end of freshman year). This overlooks the process through which the decision unfolds over time, especially influential time points which ultimately culminate in a change in their major decision. Furthermore, existing literature is mainly based on the association between persistence and EV beliefs, which are measured by Likert scale items. More direct evidence for the ways in which EV beliefs spontaneously emerge in students' thought processes is needed. Thus, the current study focuses on students' personal explanations for changes in their major plans after their introductory courses. Having college students articulate their reasoning not only reduces researchers' confirmation bias, but also provides direct evidence for how EV beliefs influence students' adjustment of their major plans.

In this study, we address these gaps in the literature by investigating three research questions:

1. How does the participation in introductory science courses affect students' persistence decisions, specifically students' certainty about the major they intended to study?
2. Do students provide EV-related reasons for a change in their major plan, based on their own explanations?
3. Do students' EV-related reasons for a change in their major plan differ depending on their certainty about the major they intended to study?

2. Methods and Data Sources

Participants are 2,737 undergraduates in introductory chemistry and physics classes during academic years 2017-18 and 2018-19 from a large public Hispanic- and Asian-serving (HSI-designated) university in the southwestern U.S. (45.6% women; 16.4% European American/White, 22.6% Latino/a, 46.5% Asian, 14.5% other racial/ethnic groups; $Mean_{age}$ = 18.84

years old [*SD* = 0.91]; 43% 1st-generation college students). Students were enrolled in introductory chemistry (N = 1,604) and physics (N = 1,133) course sequences that are required for a variety of natural and health science majors in the university. We recruited the students through the course instructors. All students in the classes received an invitation to an online questionnaire at the end of the class, each student offered a $5 gift card as an incentive to participate in the survey. The survey included questions about students' motivational beliefs about their class, majors and careers.

Persistence in Major. Students were asked "How has this course affected your major choice?" Students chose from three response options: "It made me less certain about my original major", "It had no effect", and "It made me less certain about my original major".

Explanations for Persistence. Students were asked "Have your career plans changed since the beginning of the quarter?" (0=no, 1=yes). If students answered yes, they were asked how and why their plan has changed and provided with a text-entry box for entering open-ended explanations.

The open-ended responses were coded in a concept-driven manner: a coding scheme for five EV constructs (i.e., expectancy, interest, attainment value, utility value and cost.) was created beforehand to identify EV-related themes within the responses. Examples of each construct are shown in Table 1. The coding scheme was piloted and refined with a separate dataset. The coding scheme included four categories: 1) EV-related explanations, 2) non-EV reasons (e.g., become aware of new major options), and 3) no explanations given and 4) "I don't know". Within EV explanations, we allowed one response to be identified with multiple EV beliefs (e.g., expectancy and utility value are mentioned in one response). For EV explanations, we also coded whether the belief increased or decreased.

To answer our research questions, we first examined the frequency that students' certainty in their major plans changed. Then we counted how often different categories of explanations appeared (e.g., EV-related, non-EV, no explanations and "I don't know), as well as various EV reasons. Next, we tested whether EV beliefs differentially related to increase or decrease in the certainty of major using the Chi-square test of Independence and the Fisher's Exact Test for robustness check. For each analysis, we examined whether the results varied between chemistry and physics classes to test for potential subject differences.

3. Results

To answer our RQ1 about the impact of the introductory course on students' persistence decisions, nearly half (41%, N = 1121) of the students reported change in their certainty about their majors: 25% became less certain about their majors (N = 623), and 20% became more certain (N = 498).

A sub-group of 361 students responded to the open-ended question about how and why their major plan changed during the quarter (Table 2). Answering our RQ2, coding of the open-ended answers showed that EV themes emerged in 43% of the provided explanations (N = 156). Among EV-related explanations, decrease in values[1] was the most prevalent reason for change in major plans (N = 87, 56% of all EV explanations), followed by decreases in expectancy (N = 27, 17%) and increases in values (N = 24, 15%). A small percentage of students (8%) mentioned both expectancy and values in their explanations (N = 12), and in all of them both expectancy and values declined. Twenty-two students provided non-EV reasons, such as wanting to explore majors that

[1]Value includes four components: interest, utility, attainment value and costs. However, the direction of change in cost is the opposite to that of the other components of value[14]: an increase in cost is treated as a decrease in value.

they hadn't been aware of. Interestingly, 47% of all written explanation only provided descriptions of how major plans changed without explanations (N = 171).

Across EV-cited reasons, interest was the most common, followed by expectancy and utility value (Table 3). The majority of EV explanations contained one EV construct (N = 128, 82%), 15% explanations contained two EV constructs (N = 24) and 3% contained three (N = 4). Across all EV beliefs, declines of motivational belief (i.e., declines in expectancy, interest, attainment value and utility value, increases in cost) were more common than increases.

Among students' EV-related explanations, 94 students (60.3%) felt less certain about their major plans, 49 (31.4%) remained equally certain and 13 (8.3%) felt more certain (Table 4). To answer RQ3, we found an association between the EV reasons that students gave and how their major plans changed, χ^2 (8, N = 156) = 20.92, p = .009; p = .003, Fisher's Exact Test. "Decrease in expectancy" and "decrease in expectancy and values" were overrepresented in the explanations when students became less certain and "increase in values" were underrepresented. In comparison, there was no particular pattern of EV explanations when students became more certain about their major choices. "Increase in values" was overrepresented and "decrease in expectancy and values" were underrepresented when students did not report changes in their major plans.

All of the findings above did not vary across chemistry and physics classes.

4. Scientific significance

To our knowledge, our study is the first to test how EV beliefs explain change in major plans using open-ended responses. Our findings suggest that EV-themed beliefs naturally emerge when students explain why they want to change their STEM majors. This finding is particularly noteworthy as students spontaneously offered EV-related explanations even when they were not prompted to address the EV constructs. The constructs are an inherent part of students' STEM persistence decision-making processes, showing its ecological validity. Moreover, if we exclude responses that did not contain in-depth explanations, the vast majority of explanations can be coded as EV constructs. EV concepts are representative and primary reasons in students' consideration. Together, based on students' open-ended explanations, our findings support the meaningfulness and effectiveness of EV concepts for understanding why students choose to persist or leave STEM majors.

A small number of students mentioned multiple EV constructs in their explanations. Among these responses, we didn't find a conflicting combination of EV beliefs, such as an increase in interest with a decrease in expectancy. EV beliefs changed in the same direction (namely, declined in our study) in all these cases. This finding converges with findings of the consistent positive correlations between expectancy and value beliefs using Likert-scale instruments[11, 12].

Among EV beliefs, values were more commonly mentioned than expectancy, compatible with quantitative findings that values are a stronger predictor for achievement choices than expectancy[6, 7]. Overall, interest is the most prevalent reason, suggesting its primary importance in STEM persistence decisions. This finding may also reflect the ethos of "pursuing your passion" in career decisions in the American culture. For instructors and researchers, efforts to promote interest and cultivate student engagement might be more fruitful directions.

The way that the direction of change in EV beliefs relates to persistence decisions converges with quantitative findings that students who become disengaged are more likely than chance to have declines in expectancy and/or subjective values. Moreover, decreases in expectancy were more likely to be mentioned when students became hesitant than when students were equally or more certain about their major choices. This finding might suggest that declines in expectancy may be particularly relevant to disengagement from STEM majors.

More declines were reported than increases. This result could be a response bias due to the way the question was asked. Students were only prompted to give explanations if they indicated major plan changes. Therefore, those who became more certain or remained equally certain about their major plans would not answer the open-ended question. Adjustment of the question design in ongoing data collection will allow us to further explore the questions by asking all students to give explanations.

Our sample is very diverse in students' sociocultural backgrounds. The diversity not only contributes to our understanding of the minority population, but also points to the need to investigate the heterogeneity within minority groups, such as the gender, racial/ethnic, or social class differences. Relatedly, future research could include other STEM subjects, such as biology and math to examine within-STEM variation[13]. Our findings didn't vary across chemistry and physics subjects, suggesting the consistency of the EV constructs between these two disciplines.

This study is our first step to leverage a mixed method approach to study EV beliefs in STEM career decisions. It provides promising results for the strengths and robustness of EV concepts as well as rich information for how students become disengaged or more engaged in the early stage of their STEM career paths in college.

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Table 1
Sample responses of explanations

Construct	Example
Expectancy	“Not sure if I can do well in physics.” “I realized I can do more than I think I can.”
Interest	“I lost interest in engineering.” “I took the class this quarter and I really enjoyed the material more than any of my other courses!”
Attainment value	“I realized I didn't really fit in the health sciences” “I decided that is was not the path for me”
Utility value	“It seems to offer a lot more career opportunities” “I have decided to choose this major so that I can have a good science background to prepare me for medical school”
Cost	“The road is long and the payoff is not that great.” “the classes I’m taking are affecting my mental health.”
Other reasons	“I went to clubs and learned more about the majors.”

Table 2
Frequencies and Percentages of Reasons for Change in Major Plans by Subject

	All	Chemistry	Physics
EV reasons	156 (43%)	102 (47%)	54 (37%)
Decrease in expectancy	27 (7%)	18 (8%)	9 (6%)
Increase in expectancy	6 (2%)	4 (2%)	2 (1%)
Decrease in values	87 (24%)	57 (26%)	30 (21%)
Increase in values	24 (7%)	15 (7%)	9 (6%)
Decrease in expectancy and values	12 (3%)	8 (4%)	4 (3%)
Other reasons	22 (6%)	12 (6%)	10 (7%)
Unclear	171 (47%)	93 (43%)	78 (54%)
"Don't know"	12 (3%)	9 (4%)	3 (2%)
Total	361 (100%)	216 (100%)	145 (100%)

Note. The distribution of reasons did not differ between chemistry and physics classes,

Table 3
Frequency of EV Constructs

	All	Chemistry	Physics
Expectancy	45	30	15
Increase	7	5	2
Decrease	38	25	13
Interest	67	40	27
Increase	16	10	6
Decrease	51	30	21
Utility value	35	23	12
Increase	11	6	5
Decrease	24	17	7
Attainment value	31	23	8
Increase	2	1	1
Decrease	29	22	7
Cost	10	2	8
Increase	8	2	6
Decrease	2	0	2
Contain 1 EV construct	128	87	41
Contain 2 EV constructs	24	14	10
Contain 3 EV constructs	4	1	3
Total	156	102	54

Table 4
EV explanation across different changes in major plans

	Decrease in expectancy	Increase in expectancy	Decrease in value	Increase in value	Decrease in expectancy and value	Total
It made me less certain about my original major.	21^{+}	3	51	8^{-}	11^{+}	94
It had no effect.	6	3	26	14^{+}	0^{-}	49
It made me more certain about my original major.	0	0	10	2	1	13
Total	27	6	87	24	12	156

Note. $^{+}/^{-}$ denotes overrepresentation and underrepresentation of the cell, with adjusted residual scores ≥ 1.96 and ≤ -1.96. EV explanation is associated with the type of change in major plans, $\chi^2 = 20.92$, $p = .009$; Fisher's exact test: $p = .003$. The relationship did not differ between chemistry and physics classes.