# Identity, pedagogy, and topical interest as supports for transformative experiences

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**Abstract.** Students rarely develop school-prompted interest in science in ways that lead to out-of-school engagement. Existing research has highlighted that positive science identities foster this out-of-school engagement. We have been investigating a form of out-of-school engagement called transformative experiences – a construct that characterizes moments where students engage in free-choice transfer of science concepts to everyday settings in ways they find meaningful. Based on interviews conducted with undergraduate students who had indicated deep out-of-school engagement based on a transformative experience survey, we compare and contrast three cases that illustrate a broader spectrum of factors that may contribute to students' engagement outside of class. While our analysis corroborates previous findings concerning the role that science identity can play, our analysis sheds new light on ways in which topical interest and classroom dynamics can also foster transformative experiences.

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## I. INTRODUCTION

In contrast to the strong research base on interactive engagement strategies and how they support students' *in-class* engagement and learning outcomes [1,2], little is known about how to support students in extending their engagement to settings *out-of-class.* Studies suggest that students rarely develop school-prompted interest in ways that lead to out-of-school engagement [3]– a trend that appears to hold true even in settings that focus on interactive engagement and conceptual change [4,5]. The work described in this paper focuses on a particular form of out-of-school engagement called a *transformative experience* (TE)– a construct that characterizes moments where students engage in free-choice transfer of science concepts to everyday settings in ways they find meaningful [6]. This paper contributes to an understanding of how TEs are supported by identifying distinct sources of support for students' TEs. To do so, we present three contrasting cases of students who had meaningful TEs around course content. While our analysis corroborates previous findings concerning the role that science identity plays in fostering TE, our analysis sheds new light on ways in which topical interest and students' classroom experience can foster TE.

## II. BACKGROUND

Several factors have been proposed to support TEs, including students' social context, depth of understanding, and science identity [3]. Social context includes the degree to which students' peer group and family life support science learning, while depth of understanding reflects individual students' mastery of content. In qualitative studies in physics, students' science identity–related to whether students see themselves as both capable and interested in science–has been linked to students having transformative experiences [7].

Instruction has also been shown to influence the prevalence and depth of TEs. One instructional approach, known as the Teaching for Transformative Experiences in Science (TTES) model, involves instructors deliberately framing science content in terms of their experiential value, modeling transformative experiences, and scaffolding students' re-envisioning of everyday phenomena [5]. In several biology education studies, TTES has produced modest gains on TE surveys [5,8] when compared to traditional instruction. Certain responsive inquiry courses have also been implicated in strongly fostering TEs [4, 9].

## III. DATA SOURCES AND METHODS

Our study draws from multiple sources of data, including quantitative and qualitative survey data and one-on-one interviews with students enrolled in undergraduate physics and physical science courses. In total, the corpus of data considered was drawn from fourteen undergraduate students who completed at least one TE survey and subsequently participated in an interview. From these fourteen, three were selected for cross-case analysis [10] based on *inherent interest* to the research study (i.e., cases with a significant depth of TE) and *contrastive value* (i.e., showcasing differences in how students' TE emerged).

The first and third cases center around two students who were enrolled in a second-semester, algebra-based physics course that uses some interactive engagement strategies. Both students took a paper-and-pencil version of a TE survey [4] that was administered shortly after having completed course work related to optics and the nature of light. Both students participated in interviews as part of a survey validation study, during which students retook the survey and explained their choices.

The second case centers around a student enrolled in a physical science course for elementary education majors with a strong focus on inquiry. Two separate TE surveys

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were administered online–one focusing on content related to the phases of the moon and another related to energy. Both surveys were administered near the end of the semester and included prompts to provide written comments. The protocol for this interview was more loosely structured, asking students a series of questions about the extent to which they thought about, talked about, noticed examples of, and became interested in the topics.

## IV. THREE CONTRASTING CASES

Each case represents a student who had significant TEs around course content. In the first case, a student with a strong science identity has TEs across many content areas related to his career aspirations, largely irrespective of how courses are taught. In the second, a student with a particular course experience engages in TEs in ways that mirror classroom practices, not only with respect to topics covered in class but broadly in her everyday life. In the third, a student who does not particularly enjoy his physics course, experiences a concentrated interest in one specific course topic for which he has TEs. In each case, we support a claim that each student engaged in significant TEs around course content and then explore claims regarding the degree to which TEs were supported from different sources.

### A. Robert's science identity as a source of support

Robert was enrolled in a second-semester introductory physics course. On a TE survey addressing a major course topic–optics and the nature of light–Robert indicated favorable agreement to 100% of the survey items (in comparison to a 52% class average). His out-of-school engagement often stemmed from spontaneous extensions of class assignments, which prompted him to extend his knowledge toward more independent learning:

*"We were talking about resolution. There was one problem I remember in particular, where, uh, there was a car driving and it was some odd distance away, and you want to know the exact moment when the headlights split, but what I was thinking about at that time was what the index of refraction of the actual headlight casing was. It was really bugging me, so I just spent an hour researching the difference between glass and plastic headlights."*

Robert also repeatedly indicated that he thought about topics outside of class by trying to put himself in the mindset of scientists:

*"I like to put myself (like I said earlier) in the mind-set that the earlier scientists were in and when they were trying to distinguish how light could work in different forms so to speak, I just found that amazing. Like how Planck and Einstein just, really, they just saw things in a different way and that revolutionized how we see light."*

Although the survey and interview specifically targeted optics and the nature of light, Robert spontaneously indicated in the interview several times that his interest and engagement spanned all physical science and mathematics.

*"I strongly agree that [knowledge of optics and the nature of light makes my current out of school experience more meaningful and interesting], not just on optics and the nature of light but on physics in general, and chemistry for that matter, and mathematics. Any science really. I just love learning about the world."*

Although he professed strong interest in any science, Robert also expressed disinterest in courses that he thought were based on memorization such as his statistics and biology courses. Robert's passion and interest in math and physical science can be understood as part of a broader physical-sciences identity he espouses. Additional evidence speaking to this identity includes career goals to pursue academic research in an energy-related field; a double major in chemistry and physics; and a strong mastery-orientation toward science learning (e.g., reading course material long before a course even begins and working problems for the purpose of testing his own understanding). Robert also spoke of intentionally choosing his peer group to support his interest in science (*"I intentionally surround myself with people like that –people who really want to understand things–and I want to surround myself with people with common goals so we can all discuss."*)

Our claim that Robert's science identity serves as a strong source of support for TEs helps to account for his deep engagement across many topics and courses. In regard to course pedagogy as a potential source of TE, however, Robert spoke very little about how his classes were taught. Only when asked specifically did Robert add, *"Primarily for me it's about the content, but I really don't like classes that involve clickers because I don't really see that as a good way to learn or be interactive in the class."*

Robert's case is largely consistent with prior claims that science identity is a source of support for TEs. Specifically, his science identity supports having TEs across many topics and courses related to his identity, rather than stemming from any particular pedagogy or course experience. Identity also likely supports Robert's TEs indirectly, through the influence his identity has on shaping his social context (i.e., choosing to surround himself with like-peers). Finally, we note that the particular manifestations of Robert's TE resonate with aspects of his identity (e.g., striving to put himself in the mindset of scientists and engaging in independent learning). In this regard, we might think of Robert as a stereotypical case, in which deep interest and engagement in science is not separate from science identity.

### B. Madison's course experience as a source of support

Madison was enrolled in a physical science course for elementary education majors. The course covered three topics in significant depth, including energy and phases of moon. On TE surveys of those two topics, Madison also indicated favorable agreement to 100% of the survey items on both surveys (in comparison to an 90% class average for the moon and 75% for energy). Madison's TEs often took the form of talking about and engaging her family in what she was learning:

*"With electricity and light bulbs, I know I learned a lot of different things, so I went home and was talking with my husband, and then it would go on to my kids, and we would turn the light bulb or something, or we would talk about the flashlight and different things…*

*"The kids also thought it was neat that I was looking at the moon, so whenever the moon was out and I wasn't looking at it they'd holler at me, 'The moon's out, come here, come here!' So we'd have to go outside and find the moon."*

While Robert and Madison are similar in regard to both having TEs across multiple content areas, Madison did not enter the class with a particularly strong science identity. When asked about whether she was interested in science before the class, Madison said,

*"Not as much as I am now. And I don't know if interested would be the word. It would be more like I wasn't intrigued, is that a better word? … Now when I see something, I question it. And before, you know, you may just kind of question it a little bit, or why is it working and just walk away. But now, I have to know, why those colors are there, or I'll look at the moon and go okay tomorrow it's going to be here."*

Madison attributed her engagement outside of class as resulting from the manner in which the course was taught. During the interview she repeatedly recalled the way that the course was structured in relation to her engagement. Specifically, she mentioned two aspects of the course: a sense of belonging related to discussions with peers and having to figure things out for herself.

*"The way this course was taught got me interested in the topic, not just interested in retaining the information for a good grade. I have done well on my homework and papers not because I studied hard the night before but because I wanted to be in class and listen to what everyone else was thinking. … Others wanted to hear my ideas just as much as I wanted to hear theirs…*

*"I think it was because [talking is] what we did in class, and because I didn't have any answers. We talked about it in class–that's how we learned in class. The class just talked about things and threw out ideas and we never had answers, which I think was good because we had to figure them out by talking them out… So it made me have to think more about my ideas, and so when I would go home, I was still thinking about them."*

Our claim that course pedagogy served as a strong source of support for Madison's TEs is consistent with the general notion that course pedagogy can influence students' TEs. This claim is further bolstered in two ways. First, TE survey scores were uniformly high for nearly all students in the class, not just with Madison. Second, the particular way that Madison's TEs manifested (i.e., talking science with family) parallels her engagement in class (i.e., talking science with peers). Further, Madison explicitly drew connections between the manner in which the course was taught and her willingness and interest in engaging with her everyday world differently:

*"I think it's just the openness. Like, here's a topic but I'm not going to tell you where to go with the topic. And then it really makes you question everything. Like think about, well there was so much I didn't know about the moon, or so much I didn't know about that light bulb, and so much I didn't know about the box, and the light, well what else don't I know about? And, it's just the way the class is structured, makes you question, not just the three things we talked about, but everything. Okay, why if I turn the water faucet on is water going to come out. I thought that the other day. Or little things. Or why if I turn the pencil sharpener this way does it sharpen, but I can't turn it the other way… It makes you think about everything you're doing."*

While Madison developed interests in course topics, she appropriated ways of talking and engaging scientifically that she brought to bear outside of school even to unrelated topics. Her experience changed not only the way that she views the world through the lens of scientific concepts, but the way that she approaches new and foreign topics as well.

### C. Harrison's topical interest as a source of support

Harrison was enrolled in the same second-semester physics course as Robert. On the TE survey addressing optics and the nature of light, Harrison indicated favorable agreement to 93% of the survey items. During the interview, Harrison indicated frequently seeing examples from his everyday life:

*"I see the light bulb and I think oh, black body, you know, it's getting brighter and the spectrum. When I see glasses I think oh, is that convex or concave, does that mean they are near-sighted or far-sighted? Um, and a camera, I think converging lens. You know light, I think, it's really, I don't know… I can't help but do it. Now that I learned about it, it's everywhere."*

Turning to Harrison's identity as a potential source of support for TEs, Harrison identifies more strongly with the biological sciences. As a bio-chemistry major, he described his careers aspirations as wanting to enter the medical profession. Like Robert, Harrison describes himself as very studious *("I like to study whenever I can.")* and expresses interest in courses that relate to his (biological) science identity:

*"I think about chemistry a lot. I think about sweet tea as like a mixture of sugar that's you know the solute and the tea, which is the solvent. I think about the chemical receptors on your tongue that can taste the sweetness and how manufactured artificial sweeteners on your tongue fit those receptors better than actual sugar."*

Harrison did not share those same feelings about physics, at least not generally so. While Harrison felt passionate about optics ("*This is a topic that I really enjoy…without a* *doubt this has been my favorite subject.")*, he did not feel that way about other course topics (*"I'm not necessarily too interested in how circuits work, or how capacitors can discharge.")*. In fact, Harrison stated that physics was his least favorite course, in part, because of the pedagogical choices of the instructor:

*"I feel as though [the instructor] lectures too long, when we have the [readings] available to us. We spend less time doing physics than him–listening to him talk about physics. And I would much prefer to learn physics by doing it rather than having a repeat of [what] I just read."*

Harrison's frustration with how the course was taught makes it unlikely that pedagogy served as a strong source of support for his TEs. His biological sciences identity may help to account for his interest in topics closely aligned with his career aspirations, but understanding why Harrison's TEs occurred in an isolated physics topic is more difficult to ascertain. It is certainly possible that Harrison's interest in optics stems from its relationship to biology and medicine. Harrison, however, identifies his engagement with the topic as stemming from long-standing interests and questions he has had since childhood:

*"Since I was a kid, you know, I had all these questions. Well how come if you walk in front of this mirror and you look like your face is this wide, and you walk in front of another one and you're ten feet tall. So, now that I have learned about optics and think about why that is."*

Concerning the circuits as a topic, Harrison noted, "*I never really thought about that before,"* adding that he could see how knowing about circuits could be "useful". To this distinction, Harrison seemed most excited to talk about applications of optics with an aesthetic sense rather than a practical one, speaking at length during the interview about an artist who had designed a glass sculpture based on the science of refractive indices.

Harrison's case is rather different in that his TEs with physics centered on a single topic in a class he did not care for. Rather than being able to cleanly identify either pedagogy or science identity as a strong source of support for his TEs, Harrison's engagement in this one topic seems more driven by the idiosyncrasies of his curiosities about the everyday world around him.

## V. DISCUSSION

We believe that these cases make several valuable contributions to our field's understanding of transformative experiences, but also out-of-school engagement generally.

First, the cases help to identify and illustrate distinct sources of support for TE. Ultimately, similar scores on TE surveys can arise for different reasons. Identity, classroom experience, and topical interest each played a significant role in one of the cases, but marginal roles in the others.

Second, the cases capture different manifestations of TE, suggesting that similar scores on TE surveys can be indicative of very different engagement behaviors. Our cases reflect engagements as varied as "imagining the mindset of a scientist", "talking science with family", and "noticing science examples everywhere".

In presenting these cases, we have also tried to draw parallels between the form that student's engagement took and its source of support. In "imagining the mindset of scientists", Robert's out-of-school engagement mirrored aspects of the very science identity that supported it. In "talking science with family," Madison's out-of-school engagement mirrored aspects of the classroom practices that supported it. In "noticing science examples everywhere" Harrisons' TEs mirrored aspects of his everyday wonderings that supported it. It is plausible that TEs might generally take on different forms when they are supported in different ways.

We conclude by noting a key difference between the cases of Robert and Harrison and that of Madison. While the former can be understood in terms of a *transfer in* of pre-existing interests, which were subsequently extended, enriched, or transformed; Madison's case can be understood as representing the *transfer out* of newly developed interests. Given that Madison's transfer out of engagement can be traced back to aspects of instruction (rather than primarily to individual traits of Madison), future research should aim to understand in more detail the pedagogical practices that foster TE for all students, not just those students who may be predisposed.


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