







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” Harrison’s 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.

## ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grant Nos. 1140785 and 110784. We thank Leslie Atkins for her feedback.

- 
- [1] R.R. Hake, Am. J. Phys. **66** (1998).  
[2] S. Freeman, et al. Proc. Nat. Acad. Sci. **111** (2014)  
[3] K.J Pugh and D.A. Bergin, Ed. Res. **34** (2005).  
[4] B. W. Frank and L. J. Atkins, in *2013 PERC Proceedings*, edited by P. V. Engelhardt, A. D. Churukian, and D. L. Jones. (AIP, 2013)  
[5] K.J. Pugh, Teach. Coll. Rec. **104** (2002).  
[6] K.J. Pugh and M. Girod. J. Sci. Teach. Ed. **18** (2007).  
[7] K.J. Pugh, Sci. and Ed. **88** (2004).  
[8] B.C. Heddy and G.M. Sinatra, Sci. Ed. **97** (2013)  
[9] L.J Atkins and I.Y. Salter, in *Recruiting and Educating Future Teachers: Case Studies and Effective Practices*, edited by C.S. Sandifer and E. Brew. (APS, 2015)  
[10] R.K. Yin, *Case Study Research: Design and Methods*. (Sage Publications, Newbury Park, CA, 1989).