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Developing physics identities

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A series of interviews with undergraduates yields some surprising insights into how the students come to think of themselves as physicists.

Are you a physicist? How did you become a physicist? The answers to those questions are not as straightforward as one might think. The routes into physics are as diverse as physicists themselves. The sources of our early affinities for physics range from childhood fascinations with the universe to that introductory physics class that made you ask more questions than you could answer.

Acquiring a professional identity is a fundamental part of any student's development.[1] Students are significantly more likely to persist with a program in physics—or any other discipline—when they identify themselves as students of that discipline.[2] However, developing an identity as a professional physicist and member of the physics community is a complicated process that can take a long time and involve overcoming multiple barriers.

To examine how identities change over time, we studied the experiences of 20 undergraduate physics students (3 women and 17 men) at Kansas State University over six semesters beginning with their modern physics class. Seven of the students remained in the study until the end. We interviewed each student several times, focusing on their developing experiences with physics and their perceptions of what it means to be a physicist. Our methods are described in the box on page 48.

We tracked changes in their perceptions over time as they engaged in more physics practices, such as upper-division coursework and undergraduate research. Students' experiences with different authentic physics practices changed their perceptions of what it means to be a physicist. We used those changing perceptions as a starting point to investigate the students' evolving physics identities.

Physicist as researcher?

After a detailed analysis of the first set of interviews, two categories of student perceptions emerged: Some students believed that conducting research is core to physics identity, whereas others didn't mention research at all in their interviews.[3] (The students typically perceived research to be experimental, not theoretical or computational, although we did have one student with experience in theoretical physics research.) Each of those categories broke down into three subcategories, as shown in figure 1. None of the categories is inherently good or bad; physicists could come from any of them.

Students in the "high research—doing independent research"

METHODS

Our study was both ethnographic, in that we focused on the perspective of the students, and phenomenographic, in that we sought to categorize the students' experiences. Phenomenography differs from phenomenology, although both are used to investigate individuals' experiences or perceptions of a certain phenomenon. Whereas phenomenology aims for a complete and robust description of the experiences themselves, the goal of a phenomenographic analysis is to derive a set of categories that describe the similarities and differences among participants' experiences. The categories relate to one another yet are distinguished by themes that emerge from the analysis. The themes come from the interviewees' perceptions of important aspects of the phenomenon being investigated—and also what counts as an important aspect. The emphasis in phenomenography is finding commonality among themes in multiple participants' perceptions of their experiences.

Our primary source of data was a series of semi-structured phenomenographic interviews. Although the interviews had no set script, they all touched on several talking points drawn from literature on identity formation and other disciplines. The scope of our study was to investigate what upper-division students think being a physicist entails and whether they think they are currently physicists. Depending on the students' descriptions of their experiences and perceptions, the interview and subsequent analysis could cover a wide range of influential factors, such as the roles gender or high school courses played in shaping a student's physics identity. However, gender was not a theme that emerged from our analysis, as our participants did not spend a lot of time talking about their experiences as a member of a specific gender.

To supplement what students told us in the interviews, we conducted ethnographic observations of the students in an advanced lab class. Ethnography is primarily concerned with telling the stories of a study's participants from their own perspectives; a common outcome of ethnographic research is a series of case studies that capture the richness and essence of particular participants' experiences. By combining phenomenography and ethnography, we could correlate students' perceptions of what it means to be a physicist with their interactions in class to obtain a more complete understanding of the students' changing perceptions.

category described being a physicist as being all about research, but that merely participating in someone else's research did not suffice. Their impressions were shaped by undergraduate research they had already done, which gave them a solid understanding of what research entails. For example, Sam (all student names are pseudonyms) explained that someone truly becomes a physicist "when you have your own ideas and your own project. Basically that you're working on something not being spurred by someone else telling you to do it, and you're asking for money and grants for that, I really feel that's when for sure you become a physicist."

The "high research—doing research" category was similar, except that it consisted of students who had not yet completed any research themselves, so they had only a vague idea what it might involve. Charlie made an apt comparison that highlights both the importance of research and his lack of understanding of what research is like: "I think one good indicator would be research. Like, I haven't done any research yet. There is a difference between learning something and actually doing it. Someone can learn basketball, like, read about basketball, but they are not a basketball player until they play basketball." Likewise, he said, "You can learn about physics, you can read all the stuff, but you're not actually a physicist until you actually do physics, research physics."

The final subcategory in the high research category is "high research—deep understanding." Students in that category placed equal importance on doing research and on mastering a wide range of physics subject matter. That perception seemed to stem from their experiences with their professors, whom they saw as having a command of multiple physics subject areas. Will illustrated his appreciation for his professors' depth of knowledge in his response to the question "How do you move towards being a physicist?" "Just the mastery of, especially the basics, like, I just learned magnetism and electricity, just seeing my professor do it on the board and how, how much he knew about it, and how much he knew about other areas of physics."

The "low research" subcategories cover a fascinating spread of perceptions. Among them is the "low research—deep understanding" perception, which is the same as the "high research—deep understanding" category, except the students didn't discuss the importance of research in being a physicist.

Students in the "low research—mindset" subcategory al-

		N
HIGH RESEARCH	Doing independent research Sam, Matt	2
	Doing research Abbey, Bob, Charlie, Ed, Dylan, Leo, Oliver, Percy	8
	Having a deep understanding Will, Jack, Rick	3
LOW RESEARCH	Having a physics mindset Larry, Tobey, Jed	3
	Being committed to physics Sally, Ryan	2
	Having a deep understanding Donna, Danny	2

FIGURE 1. STUDENTS' PERCEPTIONS of what it means to be a physicist broke down into two categories and six subcategories. The categories emerged from the initial interviews of all 20 students who took part in the three-year study.

ready perceived themselves as physicists. To them, the essential feature of being a physicist is having a physics mentality. As Jed put it, "Why [is this person] a physicist? Just liking it really. I mean, anyone can be a physicist if they show interest in it. I mean, people think you need a lot of schooling to be a physicist, [but] anyone can be a scientist really, it's just whether or not you have the interest in it."

Students in the "low-research—commitment" category, who were nonphysics majors or double majors, felt as though they had no right to call themselves physicists unless or until they had committed to studying the subject. Sally, a double major who had been working in a physics research group for a few months, was one such student. When asked, "What makes someone a physicist?" she responded, "I think they are a physicist when they have declared a commitment to it, em, to the subject, whether that is declaring a major or spending time studying it . . . but making a definite commitment to the subject."

The categories of perception illustrate how different experiences with physics and physicists can influence ideas about physics identity. Students in the high-research subcategories echo the idea, common among physics faculty, of the physicist as researcher. But a significant cohort of students in upper-division classes do not share that idea. Those students generally do not intend to go to graduate school in physics or ever participate in physics research. Their career paths, which diverge from the expected path for physics majors, need to be studied in more detail.

Changing perceptions

We interviewed the students approximately annually for three years, looking for changes in their perceptions of what it means to be a physicist. Seven students remained in the study until the end; figure 2 illustrates the transitions they underwent over the three years. Six of the seven ended up in either "high research—doing independent research" or "low research—having a physics mindset."

From the interview data, the shift toward the "independent research" subcategory seems to be mainly a result of the students' experiences with undergraduate research. By engaging in research and other authentic practices of the physics community, those students changed their perception of what it means to be a physicist and developed their physics identity. They aligned their perceptions of what it means to do physics to match the experiences that they had in physics research groups. Those shifting to the "having a physics mindset" subcategory adjusted their perceptions so that they could still identify as physicists even while pursuing careers outside the traditional path toward graduate school and research in physics. However, some students didn't transition at all, and some students' trajectories stopped short before the end of the study. To explore some of the causal factors that affect students' trajectories in physics, we selected three students for detailed case studies.[4]

Our focus was on so-called affective factors—how students feel about physics—rather than assessments of their technical skills. A vast range of affective factors can influence a student's choice to pursue or persist with physics: encouragement from other people, personal interest in physics, perception of the importance of physics, physics test anxiety, and attitude toward physics, among many others.[5] Of those affective factors, self-confidence and self-efficacy (belief in one's own abilities) often have the most significant and powerful influence on one's choice to persist with a subject.[6]

Through the case studies of three students—Sally, Larry, and Bob—we investigated the influence of affective factors on the students' physics trajectories. Both Sally and Bob dropped out of the study before it was complete. Their last interviews were in the semester when they both took the advanced laboratory class.

Sally: "I just kind of fell in love with it"

At the time of her first interview, Sally was a sophomore. She described her first interaction with physics as learning about energy in middle school. She took physics in high school but

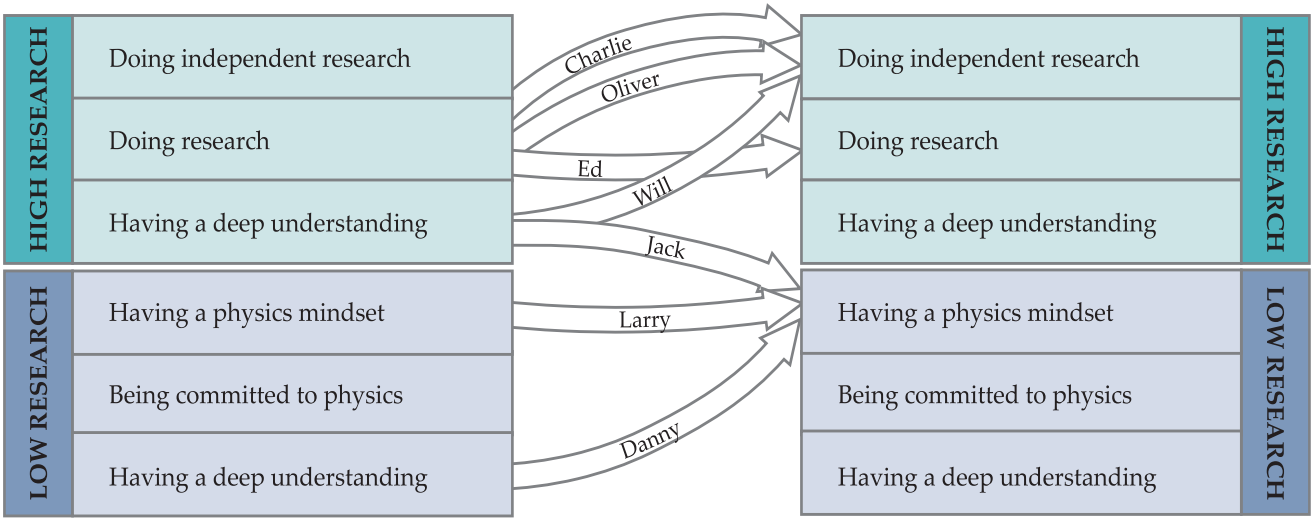

FIGURE 2. OF THE SEVEN STUDENTS who remained in the study until the end, five made transitions from one perception subcategory to another; only Larry and Ed remained in their original subcategories. Note that at the study's end, six of the seven students fell into just two subcategories.

had a "horrible teacher" whom she described as not understanding the subject matter. She recalled high school physics as a mass of equations with few or no background explanations. After a positive experience with chemistry in high school, she decided to double major in chemistry and secondary education. As part of her chemistry degree, she took two introductory calculus-based physics classes for physical scientists and engineers. Sally had a much better experience with physics at the university than in high school. The equations no longer seemed to come from nowhere, and the classroom demonstrations helped her to understand the material and connect it to real life. After her introductory physics classes, Sally decided to take the introduction to modern physics class, which was not a requirement for either of her majors. She then decided to declare a physics minor. At the time of her first interview, she was enrolled in classical mechanics and had just joined a research group in experimental atomic, molecular, and optical physics.

Sally explored the option of a major by taking classical mechanics with an eye toward eventually taking quantum mechanics. She had already made firm commitments to teaching and chemistry, but her positive attitude toward quantum mechanics—as touched on in her modern physics class—drew her to physics: "It's just so beautiful. I just love the way it describes the world at a basic level. As a chemist, I love the atomic scale. That is where I can see best—and to be able to see it explained so clearly . . . you just can't learn [that] in a Chem 1 class 'cause you just aren't at the level. To see what is actually going on, um, was just beautiful to me. I just kind of fell in love with it."

Sally's research in physics also provided her with positive affective experiences: "You spend so much time designing an experiment and trying to get everything right and trying to see this phenomenon that you're expecting . . . and you finally get it to work, and you get really excited. But in chemistry, you just mix solutions together over and over again, and you get stuff, I don't know, it's just not as exciting to me." Her positive experiences with research suggested that she would fall into one of the high-research subcategories. But throughout her interviews, she consistently downplayed the importance of research in her perceptions of what it means to be a physicist, so she is categorized as low research.

In Sally's second interview she continued to express a preference for physics. After teaching during the summer between her first and second interviews, she did not see herself teaching for the rest of her life because she would get "bored." However, she felt an emotional barrier to her possible transition into physics. She felt like an outsider in her research group because, unlike her lab mates, she had not made a commitment to physics by declaring a physics major.

By Sally's third interview, at the end of her junior year, she had declared a third major in physics. Her feelings toward physics influenced her decision: "I just spent some time thinking about that and realizing the place that physics had in my life that I hadn't fully accepted yet. Thinking about it made me realize how much I really enjoy it and actually made me consider doing physics for . . . the rest of my life." Once Sally had declared a physics major, she began to feel more at home in her research group because she no longer felt like she was seen as dabbling in physics. During her advanced laboratory course, Sally spontaneously talked about her views of physics and coursework, as shown in figure 3. Her transition into physics is complete, and she can now progress along a conventional physics trajectory.

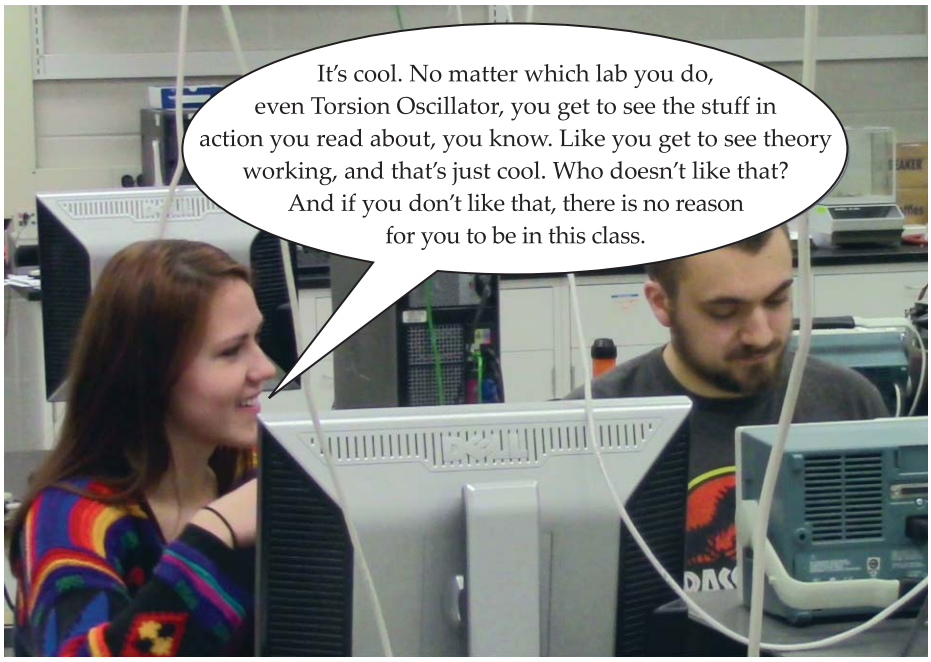

FIGURE 3. IN THE ADVANCED LABORATORY CLASS, Sally and Jacob (played by actors) talk about which experiment they want to do next. Sally wonders why anyone wouldn't want to do all of the possible experiments.

Bob: The reluctant engineer

Bob, who was 19 and a sophomore when first interviewed, had an experience that was almost the opposite of Sally's. His first experiences with physics were in his junior year of high school, which he described as neither positive nor negative. He took physics during his senior year because he was good at math, and again he recalled the experience as neither positive nor negative. Although unsure of what he wanted to do, he thought he might major in mechanical engineering and become an engineer.

In the summer before he started college, Bob became more interested in physics, and he started to read research papers in several areas of physics. He declared a double major upon matriculation. But in his interviews, Bob never displayed the same affection for physics as Sally did. Instead, he took a pragmatic stance: By choosing the double major he had more options. In his early interviews he showed a definite preference for physics: "Engineering is just applying stuff," whereas in physics, "you have the chance to see things that no one else has ever found." He spoke about engineering as being much easier and leaned toward choosing physics as his sole major. Before entering the advanced laboratory class, he was still weighing his options between the two subjects.

In the advanced laboratory, however, Bob began to struggle. He would withdraw from the equipment and group when in the laboratory (as seen in figure 4) and in his interactions with his groupmates. When another student asserted that Bob's experiment looked complicated, Bob could only shake his head and agree. "I have no idea what is going on," he said. "I'm really not good at it. [The instructor] set that up." Several weeks later, he dropped his physics major. He explained his decision by pointing to his difficulties with physics—and also to an internship he'd been offered with Boeing, which he saw as an opportunity to pursue a career in aeronautical engineering. Bob is a case of the negative affect of his perceived self-efficacy pushing him out of the physics trajectory.

FIGURE 4. BOB (played by an actor) stands off to the side while his groupmates work on an experiment. His arms are crossed, and he's not engaging. That demeanor was typical of Bob's interactions in the advanced laboratory.

Larry: Physicist as teacher

In contrast to Sally and Bob, Larry majored solely in physics. At the time of the first interview, Larry was 19 and a sophomore. He became interested in physics early in middle school when his teacher used to show videos of Bill Nye, the "Science Guy," in class. Later, Larry became fascinated with Neil deGrasse Tyson and credited him as an influence in his decision to pursue physics. In particular, he pointed to Tyson's ability to present complicated physics concepts to the public. Several times during the interview, Larry remarked that Tyson "loves to help everyone understand," and that he believed he shared the same attribute. Larry took physics in his junior year of high school and advanced placement physics in his senior year. Although he found the courses interesting, they did not live up to his expectations as they did not touch on the modern applications of the subject and did not cover anything in any great depth.

Like Sally, Larry talked about physics being fun and mentioned his passion for the subject. Across his interviews, Larry stayed in the "low research—mindset" subcategory. He was consistently positive about physics, he was happy with his choice to pursue the subject, and he loved talking about physics. He remarked that his love of talking about physics "might be a good indication that I should go into teaching."

When Larry got to the advanced laboratory, he began to display some negative affect toward some of the practices involved in completing the laboratory projects or in doing research. "I'm not as interested in research," he said. The advanced lab class was "going better than I thought it would. I wasn't anticipating enjoying it at first. I think research has the potential to be very frustrating. I just feel research being nonidealized could just be really stressful, a sort of aggravating process." In class, Larry wavered between his frustration with the laboratory practices and the positive affect he derived from solving complex calculations and analysis-based laboratory problems. Larry's positive affect for talking about physics continued to his last interview. He rejected the idea of getting research experience and instead seemed somewhat intent on pursuing teaching. Nonetheless, he continued to view himself as a physicist because he had a physics mindset. Larry's rejection of the necessity of research leaves us with a new question: Will Larry consider himself a physicist when he starts teaching high school physics? Based on his definition of a physicist, we believe that he will.

Hidden lessons

Do research physicists believe that high school teachers are physicists? If not, can those teachers still effectively guide students into the community of physicists? Open questions such as those highlight the need to pursue more stories like Larry's, Bob's, and Sally's to better understand the role identity formation and affect have on students' relationships with physics.

In education research, the "hidden curriculum" refers to the learning goals that a teacher values but does not make explicit in the design a course. Without a doubt, ideas about physics identity are often part of the hidden curriculum of physics classes. Work like ours helps to clarify that learning goal—and raises some important questions. What might classrooms designed to engage students in more authentic practices look like? Could we offer students more opportunities to engage in the central practices of the community of practicing physicists? By doing so, we may afford students more accurate and diverse pictures of what being a physicist entails and help more students on their trajectories into physics.

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