Becoming a Physicist: The Roles of Research, Mindsets, and Milestones in upper-division student perceptions

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As part of a longitudinal study into identity development in upper-level physics students a phenomenographic research method was used to examine students’ perceptions of what it means to be a physicist. The results revealed four different categories of perception of what it means to be a physicist, with a clear distinction in the level of exclusivity students associate with being a physicist and differences of importance of research and its association with being a physicist. We find a relationship between students’ perceptions of physicists and students’ goal orientation. The paper highlights a need for faculty to not just emphasize the importance of research to students’ academic development but also to further demonstrate and explain what research entails and the role it plays in a physicist’s identity.

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I. INTRODUCTION

The growth of physics lags behind the growth of all other STEM fields\cite{4}. The retention of students who have already made the choice to become a physicist is also low. Merely fixing this retention problem would substantially ameliorate the lackluster growth rate for physics. The development of a professional identity is a fundamental part of student development; the development of an appropriate subject-specific identity has a strong influence on retention of students in a discipline\cite{2}. However, becoming a physicist and identifying oneself as belonging to the physics community is a complicated process.

Previous research on identity development in physics has focused on gender differences in identity development or on the lack of physics majors of color\cite{4,5}. Recently this focus has shifted to look specifically at how a student transforms from a student who studies physics to being a physicist\cite{2}, broadening the perspective from underrepresented groups to physics majors in general. This identity formation process is important to understand as the development of students’ identities will help students to cope with the continuous change and uncertainty they will face in life in the twenty-first century\cite{2,4} and their interactions within the community of practicing physicists. The level of progress over time in the development of a physics identity can also influence students’ persistence in the study of physics. Previous research also implies a strong link between the students’ identification with being a physicist and whether or not the students have chosen a physical science career\cite{2,3,4}.

However, different students have different perceptions about what it means to be a physicist, and therefore they anticipate different end points to their identity formation processes. This natural variation in the population of physics majors injects an element of uncertainty into research on identity formation. These varying perceptions could influence how students approach and reflect upon their development as a physicist; they may also influence the students’ efforts to become more central members of the community of practicing physicists. The influences may be both explicit and implicit in the students’ minds and discourses. If misaligned perceptions between physics students and physicists continue until the end of a student’s undergraduate career, those students may be inadequately prepared for life after graduation. The lack of preparedness may be especially acute for students pursuing a career path focused on becoming a central member of the community of practicing physicists.

II. ONTOLOGIES FOR IDENTITY

The literature on identity development posits two different ontologies for identity: identity-as-property and identity-as-activity.

In the property ontology, identity is a thing that people have. It develops over time, can be recognized by oneself or others, and tells you what “kind of person” you are\cite{15}. Research using this ontology has identified many factors which affect the formation of a student’s identity within physics. A natural methodology for identifying aspects of identity in this methodology is to conduct interviews or surveys with physics students. The works of Gee\cite{15}, Car lone (and collaborators)\cite{16}, and Hazari (and collaborators)\cite{17} sit within this strand.

Within Car lone’s identity framework\cite{16} (as expanded by Hazari\cite{18}), the primary components of influence on a student’s identity development are: (i) interest (personal desire to learn/understand more physics and voluntary activities in this area); (ii) competence (belief in ability to understand physics content); (iii) performance (belief...
in their ability to perform required physics tasks); and (iv) recognition (being recognized by others as a physics person).

Subsequently Potvin and Hazari \(^\text{17}\) found that interest and recognition to be the main influence on a student self-identifying as a physics person. They also indicated that they believe that identity is a “quasi-trait” which can change over time given certain experiences and that the four components of interest, competence, performance, and recognition are “contingent on students’ perceptions of what physics is.” The data from which the Hazari\(^\text{18}\) framework was developed was from mainly high school students and focuses on these students identifying as a “physics person.” The study presented in this paper uses the Hazari et al. framework as a guide but it is in the context of upper-division physics when students are making the identity transition from identifying oneself as a physics person to self-identifying as a physicist who is a member of the community of practicing physicists.

In this context, the four main components presented may not have the same influence or presentation in upper-division identity development. Potvin & Hazari\(^\text{17}\) modified the recognition component from Carlone and Johnson\(^\text{16}\) to be focused on self-recognition and whether a student felt recognized by others as a physics person. However, in the context of upper-division, recognition can manifest in multiple ways not just in the form of self-recognition. An example of this would be a student being recognized as being a member of a physics research group. Another example would be interest, which may transform from what inspired a student to pursue science or physics to how this now established interest manifests in students’ motivations. We believe that an exploration of students’ perceptions of what physics is, what it means to be a physicist, and how these perceptions change over time will result in a more complete understanding of the important influences that aid in the development of a subject-specific identity by undergraduate physics students.

Alternately, in the activity ontology, research focuses on the practices of identification within a discipline. In this ontology, we see identity in the activities that participants perform, and the ways participants position themselves with respect to the central practices of a discipline. To examine the elements of identity, it is necessary to observe how people work together in authentic settings\(^\text{20}\). Observations can be supported through interviews with participants. Research using this ontology has covered wildly diverse communities, from insurance agents\(^\text{19}\) to engineering students\(^\text{21}\). Within physics programs, research has examined groups from Hispanic students in introductory physics\(^\text{22}\) to physics majors in advanced laboratory\(^\text{20}\).

When students are learning physics in university, they are working towards the ultimate goal of becoming a member of the generalized community of practicing physicists.\(^\text{4}\) On the way to accomplishing this goal, students will join and also leave multiple communities of practice, several of which are sub-communities of the generalized community of practicing physicists. An individual participates in several overlapping communities of practice\(^\text{1}\) at the same time. Engaging in these multiple communities results in a learning process where students will experience different perspectives (attitudes, principles, and expectations\(^\text{3}\)) that make up a professional physicist identity. As students participate in these diverse physics-related communities, their shift from identifying themselves solely as learners-of-physics to identifying themselves as belonging-to-physics\(^\text{21}\).

Both ontologies for identity are fruitful and interesting for research. They naturally have overlapping domains. Taken together, they suggest that an individual’s interest and motivation to become a physicist both affect and are affected by her participation with other physics-interested and physics-identified people. The research in this paper examines students’ perceptions of the physics community and the field of physics, especially as they relate to the students’ positioning of themselves within the field. The reflection on their attitudes and expectations is influenced by their current and prospective roles in their various physics communities.

### III. PROFESSIONAL IDENTITY DEVELOPMENT

There is a complementary relationship between communities of practice and professional development theory. Professional development has been defined in terms of the acquisition of the necessary skills (or practices) to allow an individual to engage in a particular field\(^\text{22}\). Professional learning communities help contribute to an improvement in an individual’s professional development\(^\text{23}\) and the development of subject-specific identity\(^\text{24}\). Professional development is a process a student must engage in to become a more central member of a learning community; in turn, a learning community promotes professional development.

Professional development studies in academia in the past have typically focused on the professional development of teachers\(^\text{25}\). In this domain, high-quality professional development encompasses a cyclic three-step process where teachers assimilate knowledge they generate through their practice, apply this new knowledge to interactions with students and peers, and re-gather for reflections and feedback\(^\text{26}\). The final, reflective step feeds back into the initial step, and without it the cycle is incomplete.

A typical physics undergraduate degree path is not usually considered a professional development program because physics is a liberal art. However, we can compare the professional development of physics students to teachers along two axes: their engagement in and reflection on authentic practice and their perceptions of what being a physicist entails.
A. Authentic practice

Physics students do not often engage in many authentic practices of professional physicists. If they do not often engage in authentic practice, they have few opportunities to generate new knowledge through engagement in it. Furthermore, there is a considerable lack of formal opportunities for physics students to engage in meaningful reflection on their professional development in concert with central members of a community of practicing physicists. This interaction is key to their development of professional identity. It is through reflection and evaluation of these reflections that a student’s identity is continually informed, formed, and reformed.

One method which current undergraduate physics programs tackle (although perhaps not explicitly) is the lack of reflection with a central member of the community through undergraduate research. Undergraduate research experiences are a form of professional development that can be integrated into a science degree program that can have a major impact on the development of a student’s identity. Students felt that the development of a collegial working relationship with faculty while working on undergraduate research projects both helped support the development of professional identity and also increased their perceived level of self-efficacy in relation to their ability to complete a research project. Professional colleagues taking a genuine interest in their work was a significant indicator of helping students to feel a part of the scientific community. This recognition from central members of the community helps students feel like “science people,” promoting their further interest and participation in authentic science practices.

B. Perceptions

A large body of research explores physicists’ and physics students’ perceptions of learning physics and physics as a field of academic study. Often this research has focused on students’ perceptions of learning physics or their perceptions of various teaching practices. Other studies have focused on students’ conceptions of the subject of physics itself at various levels.

These perceptions about what constitutes physics co-occur with perceptions about learners’ own selves. In the area of identity development, there is a body of work focused on the perceptions of female students either studying or conducting post-graduate research in physics or allied fields. In teacher professional development, teachers’ perceptions of their professional identity reflect their personal knowledge of this identity. A teacher’s professional identity is a combination of her self-perceptions along three themes: as subject matter experts, as pedagogical experts, and as didactical experts. A student-teacher’s perception of the practice of teaching is intricately tied to how the practice in question is performed and developed by individuals and the community. Her perceptions of what the practice entails will govern her participation in the practice itself. However, there are only a limited number of qualitatively different ways in which a practice can be perceived and therefore carried out, and therefore there are only a limited number of qualitatively different ways to teach in a community.

As with teaching, so with physics. Physics students’ perceptions of the practice of physics are intricately tied to the practices they engage with, their perceptions of themselves as (potential) physicists, and their perceptions of who physicists are and what they do.

IV. MASTERY VS. PERFORMANCE

When students talk about their perceptions of physics and what it means to be a physicist, they can be focused on internally-motivated mastery goals or on externally-rewarded performance goals. Their perception of their identity is tied up in the kinds of achievement goals they articulate. Achievement motivation research has been quite prevalent in the last 20 years particularly in the area of academic motivation. A mastery goal orientation results in students who focus upon developing their abilities, their accomplishment in challenging tasks, their development and mastery of new skills. They tend to have an emphasis towards understanding learning materials and the setting of their standards of achievement. Students with a performance goal orientation compare their abilities against others, using social comparison standards to make judgements of ability and tend to focus on being evaluated. The performance orientation has subsequently developed into two different types of performance goals: achieving success or avoiding failure. This distinction is important when examining achievement in specified tasks but less informative when talking about the link between performance orientation and perceptions of physicists, because fear-avoidant goals tend to push people away from a practice and our research participants are people who remain in the practice.

A given person may exhibit both kinds of goals at once with respect to different areas in her life, and even a blend of goals within one area at different times. However, people tend to choose one kind of goal at time within an area. In this research, we examine how physics students goal orientation intersects with their perceptions of what it means to be a physicist, and how those people shift between categories over time.

V. METHODOLOGY

The phenomenographic research methodology was introduced in Marton and Saljo’s seminal research study.
experiencing students’ approaches to learning. Since then, the phenomenographic methodology has become a widely used methodology for research on learning and teaching. A phenomenographic study usually focuses on a relatively small number of subjects and identifies a limited number of qualitatively different and logically interrelated ways in which a phenomenon or situation is experienced or perceived.

This idea of qualitatively different ways of experiencing a phenomenon has been validated and reinforced by the theory of variation and awareness. This theory states that there are a limited number of qualitatively different ways in which something that is experienced can be understood. The limit is set by the constituent parts or aspects of the experience that are discerned and appear simultaneously in people’s awareness. A particular way of experiencing something reflects a simultaneous awareness of particular aspects of the phenomenon. Another way of experiencing it reflects a different awareness of different aspects. Therefore, it is the variation in the way in which aspects of a particular phenomenon are discerned that constitutes an individual’s experience of that phenomenon.

To transfer the theory of variation to our study, an investigation into students’ identity development would be an examination of the variation in the critical aspects of the elements that influence identity development and the critical aspects of the intention underlining these elements. The typical outcome of a phenomenographic study is the researcher’s interpretation of a person’s experiences in relation to an aspect of the world (in this case the development of their physics identity) and is typically presented as a set of categories. The categories presented in the results sections of this paper are the variation in how this group of students perceives their attitudes towards and expectations of physicists.

A. Data collection

The primary data for this analysis comes from semi-structured interviews with students who were recruited from upper-level physics courses in electromagnetism, mechanics, modern lab, and advanced lab at Kansas State University (KSU). We developed a 45-minute semi-structured interview protocol drawing on identity formation, epistemological sophistication, and metacognition literature. Interviews, which were videotaped, began with a discussion of the student’s prior history with physics up to the time of the interview and segued into questions about present physics experiences in class, their attitudes in physics, future career plans and finally a discussion on physicists. Twenty-one students initially chose to participate in the study who were all enrolled in upper-level physics classes and ranged from sophomore to senior. This initial set of interviews was carried out over a two-week period near the end of the spring semester. The sample was comprised of 3 female and 18 male interviewees.

The second set of interviews was conducted after a period of 3-6 semesters, depending on the availability of the students. In this second set of interviews, we used a similar 45-minute semi-structured interview to explore similar topics. Significant differences in interview protocols centered on students describing their physics related experiences between the first interview and the second interview and less time spent on their prior history. Of the 21 students who chose to participate in the first set of interviews, only seven were available to be reinterviewed. The sample was comprised of seven male interviewees.

B. Data analysis

For each set of interviews, the responses to the questions were analyzed initially by an individual researcher and the robustness of the categories was tested by a fellow member of the research team. A detailed discussion of the robustness testing and the analysis process follows below:

Each transcript was repeatedly read, often in one sitting, in order to become acquainted with the transcript set as a whole. For each sitting, the focus of awareness was on one particular aspect of the transcript. For example, on one occasion the focus may have been on how the students described their first experiences with physics. On another occasion careful attention would be paid to aspects of physics that the students had an affective response to and on yet another occasion, the focus would be students’ conceptions of when they will be a physicist. The next step was to make a set of notes that recorded all information that was perceived to be critical to the students’ perceptions of physicists. The analysis then moved to seeking out the critical similarities and differences between the notes on each student. However, the focus was not solely on the notes and instead involved working concurrently with the notes, transcripts, and videos as the notes often lacked the depth of completeness and body language that the videos contained. We identified cases of agreement and variation of discerned critical aspects within the notes/transcripts pertaining to the students’ perceptions of physicists. The variation of critical aspects was then utilized to preliminarily form descriptions (an outcome space) of the different perceptions of physicists. For each category constituted, the groupings of notes were re-examined to find cases of both agreement and contrast within the notes. This process was to ensure that the categories accurately described the variations in perceptions of physicists of this set of students faithfully and empirically.

The last step was to give the transcripts and preliminary categories to another member of the research group who then examined the robustness of the categories with discussion and further development of the categories resulting. Finally, extracts and statements were taken from the transcripts that would give substance and support to
TABLE I: Categories of students’ perceptions of physicists

| Goal orientation | Importance of research |
|------------------|------------------------|
| Mastery          | Physicists are researchers who answer unanswered questions and generate new knowledge. (N=8) |
|                  | Physicists are people with a certain mindset; anyone with that mindset is a physicist. (N=3) |
| Performance      | Physicists are scientists who practice physics and are knowledgeable about physics. (N=7) |
|                  | Physicists are people who are committed to physics, such as by having a physics degree or declaring a physics major. (N=3) |

We repeated the same process for the second set of interviews, focusing on whether or not students’ perceptions changed. The previously identified themes were used to analyze what aspects of their perceptions had changed over time and what reasoning (if any) students gave for this change. This analysis involved examining each student’s two separate interviews together as a set and identifying the important aspects of being a physicist perceived in the first interview and examining how the perception of these aspects changed over time. A similar analysis process described previously was conducted with transcripts analyzed with a particular focus on one theme and then reanalyzed with a focus on another theme to compare and contrast changes in perceptions.

The completeness of the variation in students’ perceptions of being a physicist in the second set of interviews is limited due to the sample size. An important example of this limited completeness is apparent in the lack of high performance/low research category of perception discovered in the second set of interviews. The missing category of perception is not to be interpreted as a perception that disappears with time; it instead implies that with the limited sample size available to us, we can no longer discover this perception within this set of data. However, a complete variation in the perceptions of being a physicist is not the focal point of the analysis of the second set of interviews, and our data are as complete as possible given this population of students.

In section VI we present the categories of perception discovered from the second set of data and provide extracts and statements taken from the transcripts that would give substance and support to the categories. In section VII we present extracts and statements taken from the second set of transcripts that support our analysis of students’ shifts in perception.

VI. CATEGORIES

The phenomenographic analysis of the interview data resulted in four distinct categories of description for students’ perceptions of physicists. (Table I)

A detailed description for each category is presented in the succeeding subsections. Each category presents relevant quotes from the students taking part in the interviews, chosen to illustrate the origin of the categories in the data and to provide a more thorough description of the category.

A. Physicists are researchers who answer the unanswered questions. (High Research/Mastery)

The dominant descriptors of this category of description is that physicists answer the unanswered questions and they do so by conducting “new” research.

Int: To you, what is a physicist?

Abbey: Hmm, that’s a good question. I would say a physicist is someone who is trying to answer some of the unanswered questions, trying to prove the impossible.

The above quote is a typical description of what it means to be a physicist with students referencing their passion to answer questions (not all of them reference “unanswered” questions) or the ability of the research field of physics to do so. To use the phrasing of one of the students, the study of physics and hence being a physicist can be quite “grandiose.” A double major in physics and chemistry describes why he has a preference for becoming a physicist:

Ed: Sometimes it feels with chemistry, it’s not quite on the cutting edge quite like physics is. There’s research, but it’s not quite as grandiose, I suppose, as you might see in physics.

This impressiveness that they relate to physics research is also evident in their assertion that one is not a physicist unless they are doing new research or discovering something new about the physical world.

Percy: I think learning is a necessary thing, but otherwise it has to mean something... you have to find something out, find something new, find out something new

Int: That would be research then, would it?

Percy: Yeah.
Int: So, you have to do some research?

Percy: Yes, to be a true physicist.

The high research/performance (described below) category of description shares the aspect of research as part of its description, but the students in the high research/mastery category have a more complete understanding of what research entails. To them a physicist is someone who is researching a very specific branch of physics who is trying to answer a question, a question that originated from the physicist and will be answered by conducting experiments designed by that physicist who will then publish their work. The final important detail of this perception of physicists is that all who contributed to this description do not perceive themselves to be physicists, yet they describe themselves as “aspiring physicists” or “up and coming physicists,” even those that have had previous research experiences.

Int: So, at this moment in time what would you classify yourself as?

Charlie: A learning physicist. I could never classify myself as a physicist now, maybe a potential physicist.

Students from this group are much more likely to talk about the need to understand the physics that they are studying.

Int: Do you appreciate the two now (engineering and physics) or are you more leaning towards the one now?

Danny: Um . . . I really . . . I appreciate both of them, because I really like the practical side of it. That’s why I kept engineering as a major because I just . . . being able to apply it practically, I really like that. But at the same time, having . . . having a more complete understanding of why these things happen . . . um . . . I just really enjoyed that so.

This focus on understanding, the inherent interest in physics they display, and the idea that they will not be a physicist until they have contributed new knowledge to the physics community all link this perception towards a mastery orientation.

B. Physicists are scientists who practice and are knowledgeable of physics. (High Research/Performance)

The high research/performance category of description shares the aspect of research as part of its description, but the students in the high research/mastery category have a more complete understanding of what research entails and students described that physicists must be active in the field of physics, or in their terms be a practicing physicist.

Int: To you, what is a physicist?

Donna: A physicist is someone who actively works in physics.

. . . .

Int: So, to you what is a physicist?

Oliver: A physicist is a professor, someone who does research, someone who is active in the field.

. . . .

Dylan: Well, they both do research. You know, Dr. [Connors] does something with optics, I can’t remember exactly what, but its mostly the research I think that makes them a physicist. I mean, you get your degree and everything, but it’s actually doing something that makes you a physicist.

Above is a combination of three separate quotes and what is indicated in these quotes and in the rest of the interviews with these students is an obvious lack of knowledge of what exactly research is, a lack of specifics. None of the students that fell into this category had any sort of prior research experience and they used words like “active” or “do something” when talking about research and did not elaborate on what this meant or make reference to possible research areas in physics. This was a very apparent distinguishable difference from the previous category of high research/mastery. Another distinguishable difference relatable to the performance as opposed to a mastery orientation were the descriptions of physicists as having a lot of knowledge of physics.

Int: What makes someone a physicist in your mind?

Rick: Knowing enough about . . . not just knowing about physics theory, but also being able to apply it and teach it. And I guess the best way to measure that would be getting a degree, that’s what they are there for.

To the students of this category of description, an attainment of a certain amount of knowledge must occur in order for one to be considered a physicist. The description of obtaining a degree being the indicator of being a physicist is relatable back to a performance orientation and achieving a socially constructed goal which is evaluated by an authority. Interestingly none of the students who were placed in this category would consider themselves physicists just like the high research/mastery category of descriptions.

C. Physicists are people with a certain mindset (Low Research/Mastery)

The first set of categories both had the theme of research as an important element. Research inherently
adds a degree of exclusivity to these two categories which is not matched in the next two categories (low research). The low research/mastery category of being a physicist is the most inclusive of the categories as the students in this category of description indicate that anyone who is interested in physics can be a physicist.

**Int:** Why are they a physicist?

**Jed:** Why are they 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 physicist, anyone can be a scientist ... really it's just whether or not you have that interest in it in my opinion.

**Int:** Given that definition you must consider yourself a physicist then?

**Jed:** Yes, I definitely do.

This is a very opposing view to the previous categories of description and concurrent with this belief is the fact that all the students who contributed to the description of this category believe themselves to be physicists. Another significant departure from the previous descriptions is that you don’t have to do research to be a physicist.

**Int:** What makes a physicist to you?

**Larry:** Well first off, you have to be involved in physics somehow. I don’t think you necessarily have to be, like, doing research actively to be a physicist. I just think you have to have an appreciation for physics and be involved with it in some capacity.

There is no amount of knowledge that has to be reached or level of research or schooling to be obtained, you just have to be involved and have an appreciation for physics. Another student describes himself as an “aspiring physicist,” but unlike students in the other categories when asked how one gets from being aspiring to just being a physicist they reply:

**Toby:** I really think it’s one of those things that you don’t stop aspiring to know more, it’s just human curiosity, so I don’t know if you ever really stop being an aspiring physicist.

The links between this category and mastery orientation are very similar to those in high research/mastery in that they share the belief and emphasize a passion or inherent interest in the subject. Their descriptions of being involved in physics indicates a much more self goal setting orientation and these students also emphasized understanding physics. The general theme of this category is that the only requirement to be a physicist is to have an appreciation or interest in physics.

**D. Physicists are people who are committed to physics (Low Research/Performance)**

This category of description is unusually specific with a focus on physicists being people who are committed/serious about the subject. This category could be inclusive of students from high research/performance and high research/mastery except as one would imagine that one would have to be committed to physics in order to make it to the point where they are researching physics and have an understanding of a certain body of physics knowledge. The big distinction is that the students in this category indicate no relationship to research and being a physicist and it is much more simplistic in that if you have decided to pursue physics as a course of study then you are a physicist. So from this perception the majority of people who fall into the other categories are physicists merely because they have declared physics as their major.

**Int:** What makes someone a physicist?

**Sally:** I think they are a physicist when they have declared a commitment to it, um to the subject, whether that is declaring a major or spending time studying it... but making a definite commitment to the subject.

... **Int:** Do you consider the people, 'cause you said people who are doing a degree in physics, so do you consider them physicists?

**Ryan:** Um, yeah if I know that they are serious about what they are doing, which most people who are into the physics department are, at least if they last a couple of semesters.

So according to this category of description a person is classified as a physicist if they have declared it as a major or spent a good percentage of their time studying the subject. We are examining what it means to be a physicist or in essence what are students’ perceptions of the minimal requirements to be a physicist so commitment by itself as a category of description is acceptable. These students use a lot of phrasing like commitment or serious and talk about being in a physics department or studying it as a degree which places this category towards a performance orientation. If an important factor for being a physicist is studying the subject as a major then these students would place importance on the comparing of standards to make judgements of ability and would focus on being evaluated. This is essentially one of the main structures of a degree and hence these students are more performance orientated than mastery.
VII. CHANGE IN PERCEPTION OVER TIME

After the second set of interviews were conducted the students were placed into the respective category of perception again based on their responses to the interview questions. In the case of the seven students, two had made a complete transition from one perception to another, two were in the process of making the transition from one category to another, and three had remained in their previously assigned category.

In the next two sections, "Transitioning Students" and "Stable Students," we examine how the students’ perceptions of being a physicist changed and comment on how these transitions or lack of transition may have occurred.

VIII. TRANSITIONING STUDENTS

The following students demonstrated either a complete or partial transition from one perception of being a physicist to another. In the case of Will and Jack, a transcript was not used previously to demonstrate their initial perception and so the transcript from their first interview or their reflections on their first interview are included in order to fully demonstrate the transition. Both Will and Oliver make complete transitions while Jack and Danny are in the process of making a transition as indicated in Figure 1

A. Will

Will was placed into the high research/performance category of perception in his initial interview as he spoke of the importance of research but did not expand on what research may entail or how it was important to being a physicist. Will also emphasized in his first interview, that the attainment of a certain amount of knowledge was an important aspect of becoming a physicist as indicated in the following extract from his first interview:

Int: How do you move from a potential physicist to being a physicist?

Will: Well, we just learned magnetism in electricity [course] and just seeing my professor do it on the board, and how much he knew about it, and how much he knew about other areas of physics that he went into . . . just the amount of knowledge.

In between the first interview and the second interview, Will joined a research group. His views on what it means to be a physicist change from a performance-based achievement perception to a mastery-based achievement perception.

Will: To be good at physics you need to do research . . . so then you have more opportunities to do more research, to contribute new knowledge, to discover something and share it, and have people say, “Yeah, I think you really did it.”

Will’s experiences of being a researcher have changed his perceptions of knowledge from a certain amount that has to be obtained to something that has to be discovered and shared with the community of practicing physicists. Before this experience, research was something of an unknown quantity that had to be ticked off on the way to becoming a physicist. Will’s research experience also indicated the importance of independence while doing research:

Will: The constant directing yourself, like choosing the problem to solve . . . I’m learning that is a whole thing by itself, choosing the right problem to solve.

Independence is a common theme in the discussions of those who obtain a research experience between interviews (see Oliver and Charlie) and indicates an important outcome of authentic practice.

The following extract from Will would seem to also indicate that his perception of his undergraduate research experience was that it helped him to engage in the more authentic practices of a physicist.

Between the first and second interviews, Will joins a research group. Will enjoys research, but didn’t expect to like it:

Will: It’s weird. I like [doing research] more and more, the more I do it, but it’s weird. It’s not one of the sexy things when I thought about doing physics.

When he reflects on the differences between research and coursework, he highlights the open-endedness of research:

Will: I’m learning a lot [in research] . . . it’s not like in a classroom when you’re given problems and you have to figure them out. It’s a real physicist’s experience where you have to look up papers and try to understand some guy talking about something that you have never heard of before and trying to mine relevant information out of that. That is what you are trying to do and not really having a set path, I guess, having to make it up yourself, thinking critically about data and how to acquire it.

Participating in the authentic practices of physics brings Will closer to the community of practicing physicists. He is aware of the change between research practices and classroom practices, calling research a “real physicist’s experience.” Because of his experience in the lab, he can be more articulate about what research entails:

Will: Interpreting [data] things, it’s really hard to make the distinction between this is good enough and this is not good enough. Like I have scattering patterns, and I have to decide did I actually get something this time and is it close enough to what the theory says to say, I get it.
B. Oliver

Oliver demonstrates a similar transition in category as that of Will as he previously emphasized the importance of research without expanding on why it is an important part of being a physicist other than it is important to do it. After a research experience between the two interviews Oliver indicates the same shift from high research/performance to high research/mastery that Will has demonstrated.

Oliver: If you want to do physics as a career then you have to be involved in research and perpetuating the field in some manner.

Oliver no longer dictates an emphasis on just doing research, he qualifies it so that it has to add to the physics community in some manner. He is able to describe what research entails and like Will places an emphasis on the need for independence in one’s research in order to transition from being a student to being a physicist.

Oliver: I think when their research becomes more independent, I think that’s a good distinction point. Grad school is basically to learn how to do your own experiments. As soon as you stop working for your mentor and you’re branching off into your own direction, I think that’s maybe the point [you become a physicist].

An emphasis on independence is understandable when looking at students who are transitioning from a performance-based perception of achievement to a mastery-based perception of achievement. Performance is associated with an external evaluator telling you that you have achieved successfully whereas a mastery perception is much more internal goal setting, which is equitable with having independence over one’s research. The transition these students demonstrate is also understandable from the perspective of the experiences that they have engaged in between interviews. These students have engaged in practices that expose them to the realities of research in physics and research in physics typically has the norm associated with it that you are trying to further the community of practicing physicists understanding of the concept/phenomenon being investigated. This prevalent norm in research groups may influence students to change from a performance perception of achievement to a mastery perception.

As opposed to the complete transition these students have made the next two students demonstrate a transition that would seem to be still in progress as they reflect on past views while arguing new perceptions.

C. Jack

In Jack’s first interview his views on being a physicist were much more performance achievement based as he argued for being a physicist as the acquirement of a qualification and the obtainment of a certain amount of knowledge. In the following extract he reflects (accurately) on the previous interview and his previous perceptions:

Jack: I’m pretty sure my answer was a physicist is someone who gets like a degree, goes for the Phd or masters in physics something like that… and I still have the achievement type idea. I try and shy away, but I still have that thought in my head… and a lot of it’s content knowledge, but it’s not a necessity to being a physicist.

The previous extract indicates a person who is currently in conflict with his previous perceptions of being a physicist as he reflects on his previous thoughts while assessing that they may not conform to the way that he is
thinking now. Jack seems to be transitioning from high research/performance into a perception of physicists as being low research/mastery. In the same interview he describes being physicist as being a certain way of thinking and emphasizes the physicist as the problem solver:

**Jack:** Honestly, what I view the physics major has really given me . . . it’s given me a lot of things, but the most important thing is, really, really, really gotten good at problem solving . . . kind of what I look at as a physicist now, is he is a master problem solver.

Both Jack and the next student discussed, Danny, do not dismiss research as being unimportant, but they do underplay its importance in being a physicist.

**D. Danny**

Danny in his first interview was classified as high research/mastery and in his second interview he continues to emphasize understanding the material instead of obtaining a certain amount of knowledge. However, he seems to be in the midst of a transition to low research/mastery as he deemphasizes the need for research without dismissing it completely:

**Danny:** I don’t think you need a PhD to be a physicist. I think you need to put a lot of time into it, equivalent to maybe a PhD . . . I think the biggest thing separating someone who is motivated to learn and (someone) who is a physicist is experience and intuition. Your intuition about problems and also being up to date on you know, what is real and what is the current research at, I think that’s part of being a physicist as well.

Danny’s thoughts about intuition and its role in problem solving would seem to indicate a shift towards the idea of physics as being a way of thinking and approaching problem solving. For both Danny and Jack these transitions away from an emphasis on research are perhaps not surprising as Danny is a double major with his other major being engineering and Jack is in the process of changing to a double major with his other major also being engineering. The dual nature of their studies and their indication in the second interview that they wanted a future profession that blended the worlds of physics and engineering might indicate a negotiation process with themselves where they still want to be considered physicists in the future even if they decide to not pursue research as a career.

**IX. STABLE STUDENTS**

Of the seven students reinterviewed three of these students demonstrated stability in their perception of being a physicist. Comparing the perceptions that the previous students who demonstrated transitions to the perceptions of the students who had stable perceptions indicates that all transitions involve movement into either of the two perceptions that these next three students held stable. In the following section we examine how persistence in perception is demonstrated for each student.

**A. Charlie**

Between the first and second interview Charlie’s views on being a physicist have not changed significantly. He still views research as being an important part of being a physicist. He also continues to maintain a mastery achievement goal as he considers not just achieving a level of knowledge or achievement as the point in which he will feel like a physicist but it is instead when he uses what he has learned as a potential physicist to advance physics.

**Charlie:** I guess my idea of a physicist is just much different than knowing physics knowledge. I guess it’s what you do with the knowledge and you’re specifically using the knowledge to advance physics, specifically using it for physics, doing research now.

Like Will and Olivier, Charlie also argues for the importance of independence as being an important stepping stone to becoming a physicist. Although Charlie had previously discussed the importance of research, it was a discussion centered on it being a way of contributing something new to the physics community. That aspect of his perception repeats but also added to this is the idea that one becomes a physicist when you are conducting research somewhat independently:

**Int:** So there is an aspect of independence to it then?

**Charlie:** Yeah, if you can do it on your own, like not entirely, no physicist is going to do it entirely on their own, if you don’t have to go back and ask what do I do now, or how do I do that, then that determines you as more of a physicist.

Charlie’s research experiences since the last interview have made him realize that doing research can mean many things and to be a physicist is more encompassing than just actually participating in the process. Instead, it is making decisions on that process and direction, independent of a supervisor.

**B. Ed**

Between the first interview and the second interview, Ed’s perception of what it means to be a physicist has remained relatively stable. Like Charlie, there is still a focus on research and its ability to answer unanswered questions. He highlights the mastery centered goal of
the obtainment of a publication as an indicator of being a physicist:

Ed: I’m pretty sure I said this last time, but a publication is a benchmark. Once you’re published, if you’re not a physicist then, you are pretty close to becoming one.

As indicated in the quote, this was his perception during the previous interview and this has not changed in the period between the two interviews. What has changed in his perception is how the answers to the unanswered questions realistically comes about:

Int: Has it changed at all the way you view physics?

Ed: Definitely. As I mentioned, we wait five hours for things to cool up, cool down, and when you factor that it in, I suppose it’s not as glamorous than when you are coming right in and saying, “Wow, they are making all of these discoveries every single day.”

Ed now has an experience-based perception of what it means to be a physicist and although this experience has not altered his perception of what it means to be a physicist, it has altered his perception of how the discoveries that physicists make actually occur.

Although neither Ed’s or Charlie’s demonstration shows a transition between categories, they do demonstrate small and important shifts in their descriptions of what it means to be a physicist. Their shifts helped us refine the high research/mastery category to include independence. People in this category perceive physicists to be independent investigators who understand and contribute something new, answering unanswered questions in the community of practicing physicists.

Ed and Charlie’s developments in this area come from their experience as undergraduate researchers. While undergraduate research may be a category changer for some students, it causes Ed and Charlie to deepen their commitment to this category and to refine their beliefs within it.

C. Larry

Larry is probably the most stable student between the first set of interviews and the second set. He is persistent in his perception that he is a physicist at this point in his academic career and that being a physicist is viewing the world in a particular way or having a particular mindset.

Larry: It’s sort of like a mindset (being a physicist) where you have a difficult situation, then establish what you know and work those assumptions…try to analytically figure out a solution.

As with a lot of students who believe that being a physicist is a mindset, Larry alludes to this mindset being an approach to problem solving that is unique to a physicist, and that often informs that person’s view of the world. Larry’s career plans to become a high school physics teacher are unchanged at the time of the second interview. His perception of being a physicist is very accommodating for those studying physicists who wish to enter into the teaching profession.

In the second set of interviews, Larry displays a more nuanced view of what it means to have this mindset, softening his rejection of the need for research.

Larry: Yeah, I think so. It doesn’t hurt your case if you’re doing research, but I feel like, um, sort of like as long as you are synthesizing knowledge, um, then that’s like the main criteria.

He no longer completely dismisses research as not being important (it “doesn’t hurt”), and it may actually be helpful as an activity for “synthesizing knowledge.” However, doing research is still not necessary to be a physicist.

In the interval between the first and second interviews, Larry did not participate in research, nor was he exposed to another new kind of experience in physics. His perception has remained fairly consistent and unchanged, but his increased experience with the same kind of practice has subtly altered his stance within the category.

X. DISCUSSION

A. The importance of research

Undergraduate research experiences in the sciences have shown encouraging effects on a variety of outcomes for students. Research-like experiences which bring authentic practice into the classroom or connect students to practicing physicists in other ways are also important. Faculty at KSU strongly promote the idea of joining a research group or summer research program, starting with the first-year seminar for all physics majors and continuing regularly throughout their course-work.

The majority of students interviewed in this research study fell into high research categories. Students in both high research categories believe that doing research is important to becoming a physicist: physicists are people who do and have done research in physics.

The two high research categories are split by their approaches to mastery and performance. Students in the high research/performance category do not understand what doing research entails: they are inarticulate about the act. Because many high research students initially fall into the high research/performance category, this lack of understanding suggests that the idea of the physicist as researcher is being promoted, but not in any great detail.

However, students in the high research/mastery category were generally more articulate about the practice
of research, and the reinterviewed students showed more nuanced views about the role of research in becoming a physicist. After conducting research of their own, students demonstrate a fuller understanding of the realities of conducting research in physics and its importance. This would indicate that an undergraduate research experience can be a pivotal experience in a student’s trajectory to becoming a member of the community of practicing physicists. For six out of the seven students reinterviewed, research participation either resulted in a change in perception of what it means to be a physicist or further refinement of their current perception.

Students’ gains in confidence can be attributed to their change in perception that the research they conduct as undergraduate researchers can make a useful contribution to the field. When students engage in undergraduate research, they are being guided into being more central members of the community of practicing physicists through engagement in the authentic practices of that community. It also is a time when a student’s perceptions of what authentic practice looks like for a physicist are formed and transformed from their previous perceptions as indicated by Will. It follows then that perceiving oneself as a physicist and physics in a particular way might encourage students to engage in different practices or engage in their current practices in a more authentic way. This change in perception could enable a trajectory to a more central membership.

B. Differing trajectories

While most upper-division physics students are on a trajectory to becoming a member of the community of practicing physicists, some are not. We examined students’ professed career goals in light of their categorization. Students in the low research category are more likely to have intended career paths outside of physics research.

Two students in the low research / performance category are chemistry majors with research experience (in chemistry and physics, respectively). The fact that they have participated in research suggests that they, like their peers, should place high importance on research for becoming a physicist. Their experiences in (and affiliation with) chemistry may influence them to have a different perception of the relationship between research and being a physicist. They may relate research to all sciences (not just physics), and so it did not come up in their descriptions of being a physicist.

In the low research/mastery category, two out of the three students intend to be physics teachers, not active researchers. With this career intention, these students are less likely to place an importance on research especially when it comes to being a physicist. Similarly, Danny and Jack are in the process of transitioning from a high research perception to a low one. Their intended career paths hope to blend physics and engineering together. In the case of both of these groups, they have an inclusive perception of being a physicist so that they still feel allowed to belong to the community. Their classmates in high research categories have an opposite perception that becomes more exclusive as they progress in their undergraduate research.

This mismatch between “what counts” as being a physicist is important for students’ persistence in the field. When faculty members push the importance of doing research, they push a particular view of what it means to be a physicist. Students who identify with physics, but have different career intentions may feel alienated by faculty insistence on the role of research. For students like Danny and Larry, faculty insistence on the importance of physics may be a negative norm. They may feel as if they are failing to align with the norms of the overarching community of practice and therefore no longer belong.

C. Goal orientation

Research importance is one axis of our categories; goal orientation is the other. The relationship between goal orientation and students’ perceptions of physicists emerged from our data.

Research in goal orientation, while not conclusive, suggests that mastery orientation causes better learning outcomes. This is congruent with research which suggests that internal motivation is a better predictor of persistence than external motivation. In the literature, goal orientation is usually based around specific tasks as opposed to whole subjects, so the relationship indicated in this study needs to be explored in future studies. We suspect that students who have an overall mastery or performance orientation in physics nonetheless exhibit the opposite orientation on some aspects of their physics life.

As students gain more experience with physics and participate in tasks that they perceive as more authentic and meaningful, these new experiences will influence their perception of what it means to be a physicist. Some of these experiences will be more pivotal than others: an undergraduate research experience seems to be more influential than merely taking more classes.

XI. CONCLUSION

This research presented four categories of perceptions of being a physicist and highlighted the relationship between the perceptions discovered and goal orientation. Two of the categories focused on research as being a key part of students’ perception of being a physicist. Although students may believe research is important, without a research experience they do not necessarily understand what research typically encompasses and instead is viewed as a goal to achieve. Perceiving research as a goal to achieve rather than an essential experience to
be learned from could have adverse effects on the development of a student’s identity, their approach to research experiences, and ultimately their commitment to pursuing physics. Participation in the authentic physicist practices (such as those inherent in research) are an important influence on students’ transitions from a performance goal orientation to a mastery orientation.

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