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Making Sense of Persistence in Scientific Purgatory: A Multi-Institutional Analysis of Instructors in Introductory Science, Technology, Engineering, and Mathematics (STEM) Courses

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ABSTRACT
Prior research points to a variety of factors that influence student persistence in science, technology, engineering, and mathematics (STEM) degree programs. Little attention, however, has been given to how STEM faculty understand these processes and subsequently frame their role in supporting students. To address this gap, this article reports on an analysis of the interpretive frames through which instructors of introductory STEM courses make sense of the factors that influence student persistence and success in STEM degree programs. Interview data were collected from 73 instructors of introductory STEM courses at six predominantly white institutions of higher education across the United States. The coding of interviews included concept and theoretical coding using cluster analysis, multidimensional scaling, and correspondence analysis. The coding process identified six unique interpretive frames through which instructors made sense of student persistence. These frames varied greatly in the ways that students were perceived to have agency in shaping their persistence and success in STEM, as well as the steps that can be taken to ameliorate social inequalities in these outcomes. The findings thus have important implications for how researchers and program designers frame strategies that can support student persistence outcomes in STEM degree programs.

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Persistence and degree attainment among undergraduates majoring in science, technology, engineering, and mathematics (STEM) fields continue to be central concerns among policymakers and educators. Much like the trends at the K-12 levels, considerable attention has turned to instructors' roles in undergraduate STEM programs as a source of explaining variation in these student outcomes. In particular, improving the quality of introductory courses that serve as gateways to STEM majors has been emphasized (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012; Suresh, 2007). These

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courses have attracted attention for multiple reasons, such as high failure rates (King, 2015), a so-called "chilly climate" (Seymour & Hewitt, 1997), and a reliance on overly didactic modes of instruction (Wieman, Perkins, & Gilbert, 2010). Unsurprisingly, then, transforming instructors' practices has become a drumbeat among policymakers and STEM education reformers (Malcom & Feder, 2016).

Much of the resultant work on instructors of introductory courses has focused on teaching practices (e.g., Freeman et al., 2014; Smith, Vinson, Smith, Lewin, & Stetzer, 2014). This work has deepened our understanding of how instructors engage students in and out of the classroom, and how such practices support student learning outcomes in STEM degree programs. However, missing from this literature is a formal investigation of introductory instructors' own sense-making about what it takes to succeed in these fields. In particular, it is unclear whether instructors in these crucial courses perceive racial, gender, and economic inequities as barriers or opportunities toward bolstering the quality and diversity of students and professionals in STEM. This is surprising given the extent to which instructors are seen as perhaps the most crucial levers of change to reach such outcomes (President's Council of Advisors on Science and Technology [PCAST], 2012).

Here, we argue that a deeper understanding of the interpretive frames that instructors of introductory courses use to make sense of student persistence is a necessary component of the broader efforts to transform the quality of these courses and bolster STEM persistence generally. In building our argument, we draw from theories that emphasize how individual actors utilize interpretive frames to make sense of the world and guide their decisions within organizational contexts (DiMaggio, 1997; Holland & Quinn, 1987; Swidler, 1986; Weick, 1995). Our use of these perspectives draws inspiration from a rich body of work that has sought to understand how policymakers' and educators' sense-making practices shape policy ideas and implementation (e.g., Bastedo, 2009; Coburn, 2001; Weatherley & Lipsky, 1977). The central insight from this research is that practitioners' interpretive frames about their professional environments are a central yet overlooked component of educational change.

While our conceptual approach has broad application, we focus specifically on instructors of introductory or "gateway" courses to STEM degree programs at predominantly White institutions (PWIs). Our emphasis on these contexts is a response to calls from policymakers and reformers to develop a greater understanding of sense-making about success and advancement among instructors teaching these consequential courses (Malcom & Feder, 2016). Although previous research suggests that instructors' tacit theories about teaching and learning in these courses play an important role in students' persistence decisions (Chang, Cerna, Han, & Saenz, 2008; Seymour & Hewitt, 1997), there has yet to be a systematic analysis of sense-making about student persistence among instructors in these spaces. The context of PWIs is also important as researchers and policymakers continue to confront the challenges associated with efforts to diversify the racial and ethnic contexts of STEM fields (Estrada et al., 2016; Garcia & Hurtado, 2011). Crucial to these efforts is to analyze the interpretive frames of success within institutional spaces where being White holds normative status (Bonilla-Silva & Forman, 2000). In the context of STEM fields, it is equally important to investigate instructors' sense-making about the role of gender and socio-economic resources, as these dimensions of social inequity have been an ongoing struggle in science and technology fields (Ceci, Williams, & Barnett, 2009; Davies & Guppy, 1997; Goyette & Mullen, 2006)

To learn about instructors' interpretive frames and sense-making about student persistence in these contexts, we conducted an analysis of in-depth, one-on-one interviews with 73 instructors of introductory STEM courses at six PWIs across the United States. Our analysis was guided by the following questions:

(1) What are the interpretive frames through which instructors of introductory STEM courses make sense of patterns of persistence and degree completion in their respective fields?
(2) How do instructors make sense of the experiences and outcomes among women, people of color, and economically disadvantaged students in these fields?
(3) To what extent do these interpretive frames vary across different disciplinary and institutional contexts, as well as the gender and racial identities of introductory STEM instructors?

These questions were explored through a multi-stage coding process that sought to build instructors' interpretive frames from the ground up by analyzing patterns in their explanations of student persistence.

Literature review

The last decade has seen an approximately 10% increase in the number of students entering undergraduate programs intending to enroll in a STEM area of study (Eagan, Hurtado, Figueroa, & Hughes, 2014). Upon entry, a variety of factors influence whether students persist in a STEM field to graduation or leave for other areas of study. These factors include the alignment of aspirations (Astin & Astin, 1992), first-year STEM course-taking (including performance in those courses) (Maltese & Tai, 2011), interactions with peers (Ost, 2010) and faculty (Gayles & Ampaw, 2014), and the quality of instruction in STEM courses (Freeman et al., 2014; Seymour & Hewitt, 1997). However, researchers have found strong evidence that these latter factors are often moderated by students' ascribed characteristics, such as gender (Gayles & Ampaw, 2014; Seymour & Hewitt, 1997), race and ethnicity (Cole & Espinoza, 2008), and socioeconomic status (Dika & D'Amico, 2016).

Science, Technology, Engineering, and Mathematics (STEM) culture and student persistence

While research in this area has focused on structural pathways into and through STEM majors, there is a growing body of work focusing on the cultural forms and individual sense-making practices within these pathways and the implications they may have for student persistence (Adamuti-Trache & Andres, 2008; Crisp, Nora, & Taggart, 2009; Johnson, 2012; Smith, Lewis, Hawthorne, & Hodges, 2013). Much of this literature emphasizes faculty beliefs and assumptions about teaching and learning, with conceptions often ranging from student-centered to learner-centered (Hora, 2014; Marbach-Ad, Ziemer, Orgler, & Thompson, 2014; Prosser, Trigwell, & Taylor, 1994; Sunal et al., 2001). These sense-making processes can be thought of as components of culture once analyzed in the context of social spaces such as educational institutions or disciplines (Bourdieu, 1984; Martin, 2000).

Faculty sense-making about student performance have important implications for a variety of outcomes. For instance, recent evidence suggests practitioner-based beliefs that innate ability is required for success were strongly predictive of gender and racial underrepresentation in a variety of fields (Leslie, Cimpian, Meyer, & Freeland, 2015). Others have found that, after controlling for grades, increases in fixed beliefs related to ability were strongly associated with departure from biology majors (Dai & Cromley, 2014). Moreover, findings from the latter study indicated that the increase in these beliefs were associated with the cultural messages found in introductory courses. Similar findings have emerged from the K-12 literature, especially regarding teachers' differential assumptions about social class, race, and student ability (e.g., Gershenson, Holt, & Papageorge, 2016; Rist, 1970).

As researchers have illuminated the role of sense-making in shaping persistence, there has been a call for a basic understanding of sense-making about ability, success, and advancement circulating through the sciences in general (Anderson et al., 2011) and introductory courses in particular (Malcom & Feder, 2016). The emphasis on introductory courses is motivated by evidence that many students who leave the sciences do so during the first year of college while such courses are taken (Chang et al., 2008). In one of the first in-depth analyses of persistence in STEM, Seymour and Hewitt (1997) identified a "chilly climate" in introductory courses as a major factor leading students to leave the sciences. Since then, researchers have attended to the role of instructional practices in shaping student outcomes in introductory courses

(Freeman et al., 2014; Gasiewski et al., 2012). However, less attention has been spent analyzing sense-making about these processes among instructors in these courses. This is an important limitation in the literature since instructors' practices are linked to their own understanding of how students succeed in these demanding fields (Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; Gibbons, Villafañe, Stains, Murphy, & Raker, 2018; Kane, Sandretto, & Heath, 2002; Seymour & De Welde, 2016).

Sense-making in educational institutions

Although little work has focused on the sense-making practices of instructors in introductory STEM courses, broader attention to meaning and interpretation in higher education has a long and rich history (Bergquist, 1992; Clark, 1962; Kezar & Eckel, 2002; Tierney, 1988). The primary advantage of focusing on micro-level sense-making is the ability to investigate the situated meanings and actions of students, faculty, and staff in higher education settings to understand processes by which macro-structural outcomes occur (Iloh & Tierney, 2013). This approach is relevant to policymaking and program development because it allows stakeholders to understand how actors interpret practices and meanings in academic settings (Fryberg & Markus, 2007).

Theories about sense-making abound and overlap across numerous disciplines. Sociologists such as Swidler (1986), for instance, have argued that individual actors selectively make use of symbolic forms to construct interpretive frames, make sense of situations, and subsequently develop strategies for practice (see also DiMaggio, 1997). Anthropologists have made nearly identical arguments through the concept of "cultural models," or the schemes of perception that constitute actors' taken-for-granted assumptions about the world (e.g., Holland & Quinn, 1987).[1] These perspectives share in common a rejection of the notion that culture provides a uniform set of values and beliefs that determine sense-making and action (*á la* Parsons, 1951). Instead, actors selectively draw upon cultural forms in ways that are contingent upon the interactions between their interpretive frames about situations and their positions within social and physical spaces (Bourdieu, 1990).

A significant portion of the work using these cognitive approaches to sense-making has focused on the production of social inequities within educational institutions (Calarco, 2014; Drayton, 2014; Fryberg & Markus, 2007; O'Brien, 2010; Tyson, 2006), as well as to better understand how educators make sense of educational reforms (e.g., Coburn, 2001; Weatherley & Lipsky, 1977). In addition, these perspectives have been used to examine interpretive frames about teaching and learning among instructors in STEM fields (Hora, 2014; Lund & Stains, 2015; Stains, Pilarz, & Chakraverty, 2015; Stains & Vickrey, 2017). For example, previous research found that undergraduate STEM instructors espoused a variety of tacit theories about how students learn new concepts, and that these interpretive frames (or cultural models) about teaching and learning influenced instructional decisions and practices in and out of the classroom (Ferrare & Hora, 2014; Hora, 2014). In addition, the interpretive frames through which instructors made sense of teaching and learning varied within STEM, suggesting that it is nonsensical to speak of a monolithic "STEM culture" when it comes to teaching and learning.

The insights derived from analyses of sense-making through interpretive frames offer important implications for the objectives in this paper. First, since actors engage in sense-making in contingent and relational ways (i.e., vis-à-vis other actors and institutional contexts), analysts should expect to observe heterogeneity in the interpretive frames espoused by instructors of introductory STEM courses. Rather than a uniform understanding of persistence and success in STEM fields, we should instead expect to find that, in the aggregate, instructors make sense of these processes through a multitude of interpretive frames. Second, through these different frames, we should also see instances of hybridized sense-making that emerges through attempts to reconcile the tensions among competing explanations in institutional contexts. Finally, these theoretical insights also mean that educators and academic program designers can draw upon instructors' interpretive frames as tools to situate meaningful interventions in persistence pathways.

Data and methods

The present study utilized data from a multi-institutional case study (Yin, 2008) of student persistence at six PWIs across multiple geographic regions of the United States, including the Mountain West, Midwest, and East Coast. The PWIs were selected to bolster variation in institutional mission, size, and selectivity, consisting of three flagship research universities (> 30 K students), one non-flagship research university (> 30 K), a medium-sized (< 15 K) private university, and a small (< 5 K) private liberal arts college.[2] While the institutions are not representative of all PWIs in the United States, the range of institutional types offered the capacity to examine STEM instructors' interpretive frames of persistence across a variety of organizational and geographic settings.

The case study from which this analysis was drawn included interviews and surveys with students as well as classroom observations to identify factors that led students to switch out of STEM majors. The present analysis draws on data from semi-structured interviews with 73 undergraduate instructors of introductory STEM courses across each of the six participating institutions. The instructors in the sample were predominantly male (66%), White (77%), and distributed across the disciplinary spectrum within STEM (see Table 1). Approximately half (49%) of the instructors were non-tenure

Table 1. Instructor characteristics.

	N (%)
Sex:	
Male	48 (66)
Female	25 (34)
Racial/Ethnic Identity:	
White	56 (77)
Asian or Pacific Islander	5 (07)
Latin@ or Hispanic	2 (3)
Black or African American	0 (0)
American Indian or Alaska Native	1 (1)
Multi-racial	0 (0)
Not reported	9 (12)
Discipline:	
Biology	9 (12)
Chemistry	19 (26)
Computer Science	7 (10)
Engineering	11 (15)
Mathematics	14 (19)
Physics	13 (18)
Job Title:	
Teaching Assistant	2 (03)
Lecturer or Instructor	26 (36)
Senior Lecturer or Senior Instructor	5 (7)
Visiting Professor	2 (3)
Assistant Professor	6 (8)
Associate Professor	16 (24)
Professor	14 (19)
Other	2 (3)

track faculty, which was consistent with the population of instructors teaching introductory STEM courses at these institutions.

The recruitment of participants began by identifying the instructors of record for all introductory courses that serve as gateways to STEM majors at each participating institution. Courses most likely to be gateway courses were initially chosen based on a review of the literature (e.g., Alexander, Chen, & Grumbach, 2009; Gasiewski et al., 2012; Malcom & Feder, 2016; Seymour & Hewitt, 1997; Suresh, 2007) and by examining course requirements for entry into STEM majors at the participating sites. At each institution, these courses typically included: General Biology, General Physics (calculus and algebra based), General Chemistry, Organic Chemistry, Calculus 1– 3, Differential Equations, Intro to Programming, and Data Structures. This initial list was then circulated to academic advisors, instructors, and other informants at each institution to ensure that all introductory courses were included and to add any unique to each site.

The instructor of record for each course was contacted via email solicitation. The total sampling frame across all six sites consisted of 278 instructors. From this list, the objective was to solicit participation from 10–15 instructors per site, with representation from each of the disciplinary areas described above. In the end, 26.3% (N = 73) of the instructors from the sampling frame agreed to participate in the interview. Upon consent, instructors were scheduled for a 90-minute interview that was held in their office during site visits. The interviews were conducted between 2012 and 2014 by a team of four social scientists with extensive training in field-based methods of data collection, especially around undergraduate STEM education. Nevertheless, some participants may have been drawn to socially desirable responses about undergraduate education given the interviewers' academic backgrounds. In addition, the racial and gender makeup of the interviewer team was similar to those of the participants−-all were White, and three of the four were men. This may have allowed some participants to feel more at ease in discussing issues of inequality in STEM, but it is also possible that the positionality of the interviewers led to bias in the types of cues and follow-up questions that were asked.

The interviews covered topics related to student persistence and teaching practices in introductory STEM courses. The current analysis focuses on a series of questions about how instructors explain student persistence and departure from STEM fields. This portion of the interview[3] began with the following questions:

(1) In general, when a student persists to degree completion in your field, what factors do you think contribute to this outcome?
(2) Conversely, when a student switches from your field to a non-STEM major, what do you see as contributing to this outcome?

The interviewers were trained to clarify with phrases such as, "In general, how do you explain these outcomes?" or "What seems to really drive student persistence and departure in these areas of study?" These questions were meant to elicit an initial, top-of-mind explanation. However, the semi-structured design of the interviews gave interviewers flexibility to probe instructors' thinking on these general questions. For example, participants were prompted to address whether they thought instructors or higher education institutions in general have any influence over student persistence. Once participants offered their initial explanations, the interviewers asked questions about persistence among underrepresented students. Such questions included:

(1) Do you think there are any particular challenges or opportunities for women and/or for students of color who are pursuing a degree in your field?
(2) Do you think any of these identities shape students' sense of belonging and/or their emerging identity as a scientist?
(3) What about financial concerns – such as the need to work or concerns over financial aid?

Analysis

All interviews were audio recorded, transcribed into Word documents, and imported into NVivo for coding. We pursued an open coding of these data to identify recurring concepts, paying close attention to participants' causal explanations about persistence in STEM, the contexts in which instructors situated these explanations, and the implications these assumptions might have for practice (e.g., instruction or advising). To begin, the two authors simultaneously worked through a sample of randomly selected transcripts to develop an initial set of concept codes (Saldaña, 2013). Following multiple revisions to ensure consistent granularity of the concepts, we then independently applied the codes to another random set of transcripts from each site and discussed discrepancies to reach mutual understanding and revise ambiguous concept codes (MacQueen, Mclellan-Lemal, Bartholow, & Milstein, 2008). Once the final set of concept codes was established, the second author applied the codes to the entire dataset following the principles of the constant comparative method (Corbin & Strauss, 2008). A total of 41 codes were constructed from the instructor transcripts.[4]

The objective of the second stage of coding was to identify the interpretive frames about persistence underlying the concept codes. We proceeded with this step in multiple ways. First, we created a participant-by-concept code matrix indicating whether or not (i.e., 1/0, respectively) a given participant was associated with each concept code. We then utilized matrix coding practices to identify frequent and infrequent co-occurrences between concept codes. Next, we used cluster analysis and correspondence analysis to further analyze the underlying patterns of concept codes through which participants made sense of persistence (for applications of these techniques using qualitative data, see Namey, Guest, Thairu, & Johnson, 2008). Through this process, we classified instructors into six mutually exclusive groups. We then re-examined the transcripts within each cluster to better understand the specific combination of codes that distinguished one cluster of participants from another, and to explore both the commonalities and conflicting ways that participants made sense of persistence. The resulting configuration of codes represented the interpretive frames of persistence constructed by the participants.

Finally, we again used matrix coding to explore how the interpretive frames of persistence were distributed across the gender and racial identities of instructors, as well as the disciplinary contexts in which they were embedded. While our sample of instructors contained enough gender diversity to meaningfully explore differences, the sample was overwhelmingly White given the context of STEM at PWIs (see Table 1). As such, we resisted making statements about "non-White" instructors in the aggregate due to the risk of essentializing the experiences of our participants. However, we did explore instances in which White faculty were under- or overrepresented among the difference interpretive frames. This was an important task since, by definition, PWIs have an embedded White institutional presence that often creates a cultural climate of color-blind race relations (Bonilla-Silva & Forman, 2000).

Findings

Overall, the instructors made sense of persistence through six unique interpretive frames differentiated by an emphasis on either micro-level attributes of individual students (e.g., the "individual ability" frame) or constraints associated with meso- and macro-level institutions. Table 2 summarizes these frames along this conceptual principle of differentiation. At the poles (i.e., "individual ability" and "societal constraints"), instructors espoused frames that offered singular explanations of persistence (e.g., persistence is based on individual ability alone). Others espoused components from multiple frames that, at times, contained contradictory elements. This can be seen in the correspondence plot in Figure 1. While the "individual ability" and "societal constraints" frames are separated by great distance in the plot–-indicating that they shared relatively few codes in common–-other frames occupy more similar positions since they tended to share certain codes in common. For example, the "hybrid" and "social networks" frames occupy relatively close positions in the CA plot, suggesting that these two frames tended to share concept codes in common. In fact, the position of the "hybrid" frame at the origin of this plot is indicative that it is comprised of

Table 2. Summary of instructors' interpretive frames of persistence.

Interpretive Frame	*N* (%)	Description
Individual ability	16 (22)	Individual student ability is the main driver of success in a context of objectivity with little to no mention of external constraints on students along lines of identity.
Social networks	17 (23)	Ties and relationships that students have with other students and with faculty drive persistence. STEM is demanding but also identity-blind; anyone can succeed if they struggle together.
Preparation	7 (10)	The success or failure of students is driven by the preparation they received in the K-12 system. It is very difficult for instructors to overcome these deficits that students bring with them to college.
Postsecondary instructional practices	18 (25)	The local institutional context, specifically how instructional factors impact student success, is most important in determining persistence. While identity used to affect persistence, there have been great strides on this front, and STEM success is no longer predicated on these constraints.
Societal constraints	5 (7)	STEM success remains stratified by race, class, and gender due to factors that reach beyond the STEM context and into multiple institutions of society. STEM culture perpetuates inequality through unequally distributed cultural capital or contexts that are inhospitable to underrepresented students.
Hybrid frame	10 (14)	Multiple (often conflicted) factors explain patterns of persistence in STEM. Ability and effort drive persistence, but a variety of exogenous constraints for certain students shape how ability is exercised.

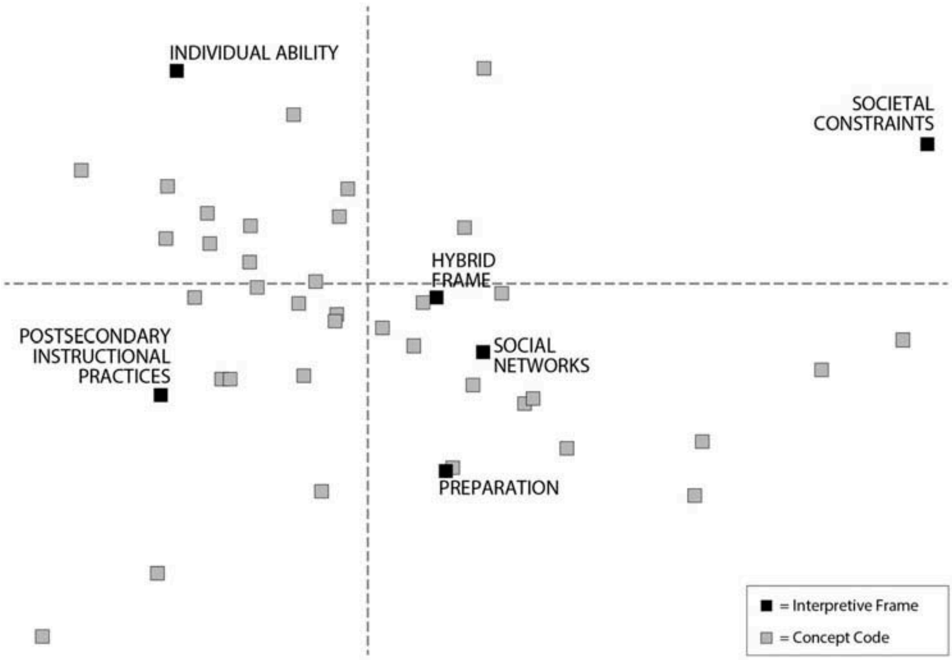

Figure 1. Two-dimensional correspondence plot of instructors' interpretive frames (blacksquares) and concept codes (gray squares). Some concept codes and all concept code labels have been suppressed to reduce clutter in the plot. The distances between interpretive frames can be interpreted as an expression of the relative degree of dissimilarity based on shared concept codes.

a set of concept codes that cut across the other five frames. However, despite some overlap in the frames, instructors overwhelmingly emphasized a (singular) core frame to make sense of student persistence in STEM. We now turn to unpacking each of the core frames and discuss specific instances of overlap where appropriate.

Individual ability

Numerous instructors in our sample (22%) made sense of persistence patterns through a frame that emphasized individual student qualities. These instructors held a strong belief that student persistence in STEM was rooted in ability, perseverance, and passion for the content. This sentiment was equally pervasive across gender and racial groups in the sample. The foundation of this form of sense-making was situated in the perceived objectivity of STEM disciplines, a perception held widely among instructors regardless of their espoused frame. These participants argued that the content in STEM was particularly difficult, and thus only those with the requisite ability and perseverance will persist toward degree completion. Student passion or external incentives may serve as motivation, but these qualities alone could not overcome the demands of STEM. An engineering instructor summed this up well, as follows:

> Instructor: [I]t isn't preparation that's the issue as far as content. I said this semester there's one [student] I think isn't gonna make it. I don't think he has the reasoning engine and I don't know where you would have to start to start where he is. I mean I can use plain English with logic, and he doesn't know which direction to go based on a logic sequence. So if he can't do that…
>
> Interviewer: So it's critical thinking.
>
> Instructor: Yeah it's critical thinking and I'm, this is probably heresy in your field, but I don't think every student should be an engineer. But I think there is a chunk that are in the C- area, who could be B students with certain factors coming together for them, but I don't know if I can solve it in my class. (white female, senior lecturer, computer engineering, medium-sized private university)

This interpretive frame–-that "students either have it or they don't"–-informed instructors' perceptions of the options available to help struggling students. Many instructors expressed a willingness to work with such students, but as the quote above illustrates, the key constraint was identified as the students themselves.

The frame of individual ability also informed assumptions about historically underrepresented students. On the one hand, instructors used this frame to inoculate themselves from the perception of responsibility. For instance, the instructor quoted above further noted as follows:

> I can't handle it. I can't take responsibility if people have upbringing issues, psychological issues, self-esteem issues, cultural issues. I can't solve that. I can be as helpful as I can and offer as many opportunities as I can, but I'm not gonna give them a C when they earned an F.

On the other hand, since the "individual ability" frame assumed persistence in STEM was driven by student aptitude within the context of objective knowledge, many of these instructors perceived that underrepresented students had certain advantages given current efforts to bolster rates of persistence among students from disadvantaged backgrounds (e.g., based on affirmative action policies). All things being equal, in other words, they believed that an under-represented student may have the upper hand over their peers.

The "individual ability" interpretive frame was most commonly espoused by math and chemistry instructors, but was equally represented across all types of institutions in the sample. One-quarter (26%) of chemistry instructors and over one-third (36%) of math instructors espoused this interpretive frame, accounting for 63% of all "individual ability" instructors despite only comprising 45% of the total sample. Nearly all the remaining instructors using this frame were from engineering and computer science. In contrast, none of the biology instructors and only one physics instructor made sense of student persistence through this frame. However, given that degree programs in physics and biology require at least general courses in chemistry and math, students in the former fields would have been likely to encounter instructors who assumed persistence to work in this way.

Social networks

The "social networks" frame was another frequently (23%) articulated explanation of persistence by the instructors we interviewed. This interpretive frame highlighted the importance of social relationships that students have with other students and faculty in the processes of persistence. The network focus was elaborated under a characterization of STEM as a highly demanding endeavor that required students to make full use of the resources accessible through interpersonal relationships with their peers and instructors.

Many instructors, including 40% of the engineering instructors, discussed the need to form strong study groups through which students could challenge one another and gain access to multiple ways of understanding the material. The disciplinary context was seen as important here, as engineers often discussed the team-based context of the profession. In fact, some instructors believed that failure to establish ties to a study group directly resulted in attrition from the field:

> Yeah, I think having that social support is important at this level, too. One of my students, one of our strongest year-long calc students was thinking of transferring to another school, and when I talked to her as to why, she said, "well I haven't formed a study group for the class." She's not in an engineering dorm; she's in another dorm. And she says she likes her dorm but the people she knows, the friends she knows aren't STEM majors so she hasn't found people to study with and do homework with and I said well maybe you need to switch dorms. (Asian female lecturer, calculus, flagship research university)

These instructors also perceived weak ties between students and TAs to be crucial, especially for those students doubting whether they can succeed in such a demanding major. In the latter instances, encouragement, not necessarily content, was identified as the essential resource transferred through the social tie.

While the "social networks" frame emphasized establishing social ties along pathways to persistence, these instructors also frequently conceptualized the establishment of network ties as an important instrumental strategy for success. In this sense, social networks were viewed as an individual-level strategy through which students can maximize their own abilities to rise to the demands of STEM coursework. In addition, many of the same instructors articulated this frame through a "post-identity" perspective that rejected the notion that race and gender constituted barriers for advancement, implying that anyone could succeed if they could made the right connections–-regardless of race, class, or gender. Like those who utilized the "individual ability" frame, these instructors generally did not perceive overt discrimination in STEM disciplines or within their respective institutions. "Maybe there's some biases and prejudices, whatever, I'm not even aware of, but I don't think so," one instructor explained. "[M]aybe non-verbal or I don't know … but I try to treat everyone the same, you know? You're here to learn; I'm here to teach you, and … if you have problems come and see me" (White male, associate professor, engineering, flagship research university).

Although instructors who made sense of persistence through a network-based frame saw little evidence of gender or racial disadvantage, this was the only interpretive frame that was disproportionately espoused across the gender identities of instructors. In fact, over one-third (36%) of the women in our sample espoused a network-based frame compared to 17% of the men. Thus, while women only represented 34% of the sample, they constituted 53% of the instructors who primarily made sense of persistence through a network lens. This is consistent with prior literature on social networks that finds women tend to have a stronger perception of networks and the role they play in facilitating attainment (Brands & Mehra, 2018).

Preparation

The aforementioned interpretive frames have centered on the actions or attributes of individual students and their relations to others. Yet, a number of instructors focused on educational institutions. For example, through the "preparation" frame of persistence (10% of participants), instructors pointed to students' experiences in the K-12 system as the most crucial factor separating those who persisted in STEM from those who did not. While this frame was not entirely disconnected from the "individual ability" frame, it was distinct in instructors' assignment of causal attribution to a failure of secondary schools. In most cases, this narrative was framed negatively to express how ill-prepared many students were in mathematics and other forms of problem solving necessary for STEM success. These instructors–-who were disproportionately White men in our sample–-indicted the secondary education system and the need for systemic reform to better prepare students for the demands of college work.

The preparation frame was also utilized to make sense of what some instructors perceived as a racial attainment gap in STEM majors. One instructor explained as follows:

> I'd say, like inner-city schools a lot of times … you don't have as good teachers. So then if the students aren't getting a good education to begin with, sadly a lot of

> those minority students struggle I think a lot more. And so I think it's far more before they get to college. I don't think it's, "Oh, in college you only see these certain types of groups." I think it's far before then. (White female, lecturer, general chemistry, flagship research university)

In addition, there was a strong belief that the cultural contexts underrepresented students experienced in high school were a key component of their preparation for college. Female instructors, for instance, often pointed to their own experiences in having a female role model in high school who encouraged them to pursue a career in the sciences.

In making these arguments, the university context was typically exonerated from contributing to these inequities, leaving instructors with a constrained perception of the available practices to remediate the disadvantages poorly prepared students faced. Indeed, this frame was expressed in equal proportions across the public research and private institutions. When strategies and practices in the postsecondary context were discussed, it typically related to the role of social networks in supporting students with poor preparation. For example, some instructors believed it was possible for poorly prepared students to make up ground by integrating into study groups or developing relationships with faculty. Nevertheless, the central causal orientation among these instructors was the experiences students accumulated before arriving on campus, and thus the primary levers of change were located in the K-12 system.

Postsecondary instructional practices

While some identified prior educational experiences as the most important factor influencing persistence, far more instructors (25%) focused on students' postsecondary education experiences. This was especially true among math instructors, as 6 of the 14 (43%) in the sample emphasized this frame in explaining persistence in STEM. Notably, instructors used this postsecondary-focused frame to identify themselves as the key drivers of student persistence, a sentiment shared equally across the racial and gender identities of instructors and across all types of institutions. For example, a lecturer in computer science discussed how he altered the syllabus to help retain students, "So I actually changed the course in the third year and incorporated [content on] graphics right away … and my retention was 90% maybe."

Some instructors who believed in college educators' influence on persistence outcomes also perceived curriculum and pedagogy as key practices that could retain women in areas of STEM where they remained underrepresented (i.e., computer science and engineering). However, others associated this frame with a view of gender and race relations that privileged the pursuit and dissemination of knowledge:

> [E]verybody can be an engineer … And as a matter of fact there should be no barrier … I think engineers have a deep respect for dissemination of knowledge as a whole. That's all they care about. I don't care about race or religion, if an engineer has a problem with somebody's race or religion, that is their prerogative. People are people. But I think on a whole, the community of engineering as a whole is very tolerant of these things because what they care about is saving people's lives, making things better and making them sustainable, do you know what I mean? We care about making the world a better place and that means creating a community where everybody is the same. (White male, lecturer, mechanics, flagship research university)

This exacting focus on the content and practice of STEM was a prevalent cultural context that cut across nearly all instructors, institutions, and disciplines in the sample.

The privileging of knowledge was typically seen as a progressive, "come as you are" mentality. Instructors saw themselves and the university at large as a space of optimism in which exogenous inequalities could be overcome through progressive instructional practices. Many who espoused this frame championed efforts to bring diversity and equality to STEM fields and perceived the transformation of instructional practices as a key to these ends.

Societal constraints

A fifth interpretive frame used by a small percentage (7%) of instructors emphasized factors beyond the education system. Racial, gender, and social class barriers were said to pervade nearly all institutions in society, and those obstacles were perceived to be replicated in the high-status domains of STEM. Like those who utilized the "preparation" frame, these instructors recognized inequities in the K-12 system as creating future disparities in persistence and degree completion in STEM. However, a key difference was that those working within the "societal constraints" frame saw inequity as more pervasive, extending into higher education and other societal institutions.

Importantly, these instructors did not share the optimism about higher education as their counterparts who espoused the "postsecondary instructional practices" frame, and instead perceived that STEM culture perpetuated inequality through unequally distributed cultural capital or through contexts that were inhospitable to underrepresented students. In many ways, we observed the "societal constraints" frame as a sense-making tool in direct conflict with the "individual ability" frame. As one instructor noted, "We think that we are rewarding merit, and everybody buys into it. You know, hook, line, and sinker. Students, teachers, everybody." His indictment of the system continued as follows:

> Instructor: [W]e have … a system that is extremely misogynistic. That is not respectful of diversity … [L]et's not even talk about sexual minorities, right?
>
> Interviewer: Right.

> Instructor: And then we ask … why aren't students … [thriving]? We're not respecting the students … How can we expect them to thrive? … I think the idea of why are they leaving … why shouldn't they be leaving? (South Asian male, research professor, engineering, flagship research university)

Not all instructors were as critical of the system, but most who utilized this frame shared a similar pessimism about STEM programs and professions. Speaking of a cultural mismatch embedded in STEM fields, a White male professor of physics (small private liberal arts college) noted that, "a Black kid or a Native American kid has lived with being regarded by middle class White students mostly as being something less than a full *bona fide* student. Getting past that shell or whatever protective carapace they elect to live with that is harder to do."

Hybrid frame

Finally, a sizeable portion (14%) of the instructors in our sample articulated "hybrid" frames, simultaneously pointing to individual abilities and exogenous constraints beyond the control of students. These instructors shared much in common with those espousing a strict "individual ability" interpretive frame. However, unique to their frame was the recognition that factors connected to historical under-representation (e.g., women, students of color) sometimes challenged the ideal of success being based on ability and effort alone. The men, women, and White instructors in the sample generally espoused this hybrid frame in proportions reflective of the overall sample.

The tension of multiple explanatory factors in this frame was frequently observed in the way instructors oscillated between individual and institutional factors. This tension emerged more frequently in the private universities. Take, for example, the following professor of chemistry at the private liberal arts college. When asked about potential barriers based on identity, she initially wavered on the idea that such constraints existed any longer, "So, that seems … but I don't think … I guess it doesn't seem just in general that there are huge [racial or gender] barriers anymore." Further, while she acknowledged that the need to work may constrain some students, she also suggested that some students could overcome that barrier through hard work, She stated as follows:

> Instructor: I think [financial constraints are] a big thing, but then on the other side it's not, like a lot of our international students work two and three on-campus jobs. I mean, I've known several who are sending money back to their families. But then at the same time they seem to be the students who do the best because they're so driven to work hard and they see that short-term need to work now but also a long-term success … So I don't think it has to be a barrier but I think for a lot of students they don't pick the right job. I had a student who didn't pass one of my Gen Chems who … was working like every

> Thursday night from three to midnight or something. And our test … is on Friday. (White female, professor, general chemistry, liberal arts college)

Note, though, that even when the need to work was acknowledged as a constraint, the instructor assigned agency to the student in failing to pick a job with the right schedule. These types of internal contradictions typified instructors who explained persistence through this "hybrid" interpretive frame.

Discussion and conclusion

The interpretive frames that instructors used to make sense of persistence ranged from explanations based on individual qualities (e.g., ability)–-in which students possess supreme agency and instructors had minimal power to influence inequality in persistence outcomes–-to those that pointed to a variety of overlapping institutions (family, education, economy, etc.) in society as the principal determinants of persistence and attainment. In describing the frames through which instructors made sense of persistence, we saw that their frames shape what they believed to be viable solutions to problems of persistence in STEM fields. Although a limitation of the present study is that we focused exclusively on instructors' subjective explanations, the findings are consistent with previous research that has linked these tacit assumptions to instructors' decision-making about pedagogical practices (Ferrare & Hora, 2014; Hora, 2014; Marbach-Ad et al., 2014; Prosser et al., 1994; Sunal et al., 2001). The present study extends this area of the literature by describing instructors' broader interpretive frames of student success and advancement in these fields.

The results suggest that efforts to change the ways instructors support student persistence will be shaped by their subjectively held beliefs about how such student outcomes are influenced. This may prove complex given the commonsense status of instructors' interpretive frames (Bourdieu, 1990; Swidler, 1986). For example, instructors who make sense of persistence through a frame of "individual ability" or "preparation" are unlikely to perceive themselves as significantly influential in students' persistence and attainment trajectories. Such a conjecture resonates with research showing that fixed beliefs about ability are associated with departure from biology majors (Dai & Cromley, 2014). In fact, the vast majority of instructors in our sample explained student success in STEM as primarily influenced by factors outside the control of postsecondary institutions. This implies that, at least tacitly, most instructors of introductory STEM courses across a broad sample of PWIs embodied relatively low levels of self-efficacy when it comes to impacting student outcomes. Prior research suggests that teacher self-efficacy is linked to student achievement (Ashton & Webb, 1986) and the likelihood of taking on new pedagogical challenges (Colbeck, Cabrera, & Marine, 2002; Gibson & Dembo, 1984). Future research should examine the link between STEM instructors' interpretive frames about student success and their self-efficacy for engaging in practices known to bolster student persistence.

We also found that numerous frames were articulated through color-blind and gender-blind narratives, which has important implications for how these instructors may be expected to support underrepresented students in these fields. Indeed, efforts to transform cultural narratives of success in STEM at PWIs will have to contend with a pervasive disposition of identity-blind attainment among instructors, one that conceptualizes the objectivity of STEM content as separate from the social relations of its production (Bourdieu, 2004; Latour, 1988). The perception that STEM fields are equally hospitable to all students willing to put in the necessary work was a prevalent sense-making tool among the introductory instructors in our sample–-regardless of the frame through which they explained patterns of persistence. Indeed, we found little evidence of variation in the distribution of interpretive frames across the different types of PWIs in the sample. This is to be expected given that these instructors likely received their training from similar types of institutions, thus being socialized into a similar space of institutional logics (Bastedo, 2009; Friedland & Alford, 1991; Upton & Warshaw). Future research should examine whether this identity-blind disposition is as pervasive at institutions that pri-
Q3 marily serve minority populations (e.g., HBCUs, HSIs< Please spell out "HBCU" and "HIS.">). While these institutional contexts have received substantial attention in the literature (e.g., Crisp et al., 2009; Eagan, Hurtado, & Chang, 2010), much of this work to date has focused on students rather than faculty.

Although many instructors espoused interpretive frames about persistence that placed much of the burden of success on factors beyond the control of universities, a quarter of those interviewed saw students' persistence trajectories as anything but fixed. Rather, instructors who interpreted processes of persistence through the "postsecondary instructional practices" frame expressed substantial optimism about how they can transform student outcomes through curricular and pedagogic changes. Despite the tendency to conceptualize such efforts in identity-blind ways, this finding suggests that the instructional reforms attempting to bolster retention in STEM (see, e.g., PCAST, 2012) are already part of many instructors' common sense understandings of persistence. Future research should explore how these interpretive frames shape policy implementation and instructional reform efforts at the institutional and local levels (Bastedo, 2009; Coburn, 2001).

In the aggregate, the introductory STEM instructors in our sample espoused interpretive frames that are entirely consistent with prior research on the determinants of persistence in these fields (Gayles & Ampaw, 2014; Maltese & Tai, 2011). As we saw, however, the distribution of the frames was uneven across individuals and disciplines. In this way, student persistence can be thought of as a broad puzzle, with individual instructors each holding pieces of that puzzle in the form of their interpretive frames. Which "piece" they picked up throughout their career reflected the practical embodiments of their experiences and positions in a given social space – a finding anticipated by theories attentive to both the cognitive and social contexts of organizational life (Bourdieu, 1990; Swidler, 1988).

This insight does not imply that the instructors' interpretive frames of persistence were "incorrect." To the contrary, it is to acknowledge that their sense-making about success in STEM reflects their situated experiences in these settings. Viewing sense-making in this way points to the capacity for growth in the interpretive frames through which actors understand their social environments. With this in mind, our findings suggest that rather than working to falsify instructors' explanations of persistence, it would be more effective to build directly from the commonsense frames through which they already interpret student persistence and success in STEM fields. We know that qualities such as individual ability, high school preparation, and networking capacity are highly significant to success in STEM (and undergraduate education more generally), but these explanations are incomplete when they stand alone. Therefore, all of these frames could potentially be motivated by recognizing the underlying individual or interpersonal assumptions at work alongside those that are absent.

Based on an understanding of each frame as partial or fractured, a program designer's response to an instructor's frame need not be "No, that's wrong because …" but instead "Yes, that's correct and also …" In addition, researchers and practitioners alike can reframe their roles in these spheres as co-creators of more complete frames rather than introducing practices that may entirely contradict instructors' taken-for-granted assumptions. Just as instructors use interpretive frames as sense-making tools, then, program designers and policymakers can utilize these frames to motivate programmatic changes such as instructional reforms or formal mentoring and research relationships that have been shown to bolster student outcomes in STEM (Laursen, Hunter, Seymour, Thiry, & Melton, 2010). Motivating programs through an explicit appeal to interpretive frames is an important component because, by definition, these frames will already be persuasive to instructors who interpret their environment through similar assumptions about the world (Holland & Quinn, 1987).

Notes

1. For the sake of consistency and clarity, we use the term "interpretive frame" to refer to the tacit theories that instructors construct to make sense of student persistence. This concept could be used interchangeably with "cultural models" (Holland & Quinn, 1987) or "logics of action" (DiMaggio, 1997), both of which emphasize individual sense-making.

2. The selection of sites was also intended to maintain continuity with a prior study of student persistence in STEM fields that took place at the same six institutions.
3. The responses to our questions averaged 2,564 words per instructor. As a coverage of the total interview, the responses ranged from 4.6% to as much as 45.5%. The overall distribution of coverage had a mean of 22.9% (median = 21.2%) with a standard deviation of 7.98%.
4. A list of all concept codes and definitions is available upon request.

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