# Students with High-Incidence Disabilities in STEM: Barriers Encountered in Postsecondary Learning Environments

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**Abstract**

Students with non-apparent, high-incidence disabilities encounter barriers in postsecondary STEM learning environments. These barriers negatively influence their success therein. Using Fishkin's (2014) theory of bottlenecks within opportunity structures, data from 16 qualitative interviews show how barriers encountered serve to constrain the success of students with disabilities. These barriers exist during the transition to postsecondary STEM learning environments, and arise from peer and faculty behavior, organizational structures, and the alignment of STEM and disability identity. Major implications relate to the redesign of STEM learning environments and the use of bottlenecks as analytic lens for studying the experiences of students with disabilities

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More empirical literature focused on the postsecondary experiences of students with disabilities is being produced than ever before (e.g., Carroll et al., 2016; Cox et al., 2017; Fleming et al., 2017; Vaccaro et al., 2015), but they remain an under-researched population (Kimball et al., 2016; Peña, 2014). A particularly noteworthy gap in this literature base concerns the experience of students with disabilities in science, technology, engineering, and mathematics (STEM) fields. Although STEM degrees provide access to lucrative professional pathways (Joint Economic Committee of the U.S. Congress, 2014), and students with disabilities express an interest in STEM careers (Newman et al., 2019), fewer students with disabilities earn STEM degrees compared to their peers without disabilities (National Science Foundation [NSF], 2017). The limited literature available suggests that environmental barriers may contribute to a "leaky pipeline" in STEM for students with disabilities: students often do not encounter disability-inclusive pedagogy in STEM classes (e.g., Bettencourt et al., 2018; Moriarty, 2007; Street et al., 2012), and STEM instructors have been shown to be resistant to providing needed accommodations (e.g., Lee, 2011; Love et al., 2014; Rao & Gartin, 2003).

However, disability is a multivalent identity that interacts with postsecondary STEM learning environments in complex ways (c.f., Friedensen & Kimball, 2017; Vaccaro et al., 2018). The way that the same disability manifests can vary considerably from person-to-person based on how the environment influences the salience of impairments, the presence or absence of activity limitations, and the extent of participation restriction (Braddock & Parish, 2001; Jones, 1996). Thus far, however, most major studies of postsecondary STEM education for students with disabilities have focused on either a specific disability type or explaining a relatively narrow portion of their experience (e.g., Jenson et al., 2011; Wei et al., 2014). As a result, too little attention has been paid to the experiences of students with varied disabilities in heterogenous STEM learning environments. Work incorporating this broader perspective has the potential to reveal common barriers to STEM success that can be addressed through modifications to environments, which are more easily scalable and replicable than individualized accommodations.

To address the need for research examining a wide variety of STEM experiences across disability-types,

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this study explores barriers experienced by students with non-apparent, high-incidence disabilities (e.g., learning disabilities, attention deficit-hyperactivity disorder [ADHD]) in STEM fields at a public research university in the northeastern United States. In this interview study, students with disabilities describe their perceptions and experiences of barriers, challenges, or successes in STEM learning environments. The research question addressed was, "how do students with non-apparent, high-incidence disabilities describe their experiences of factors that contribute to or inhibit their success within STEM learning environments?"

## Conceptual Framework

Fishkin (2014) defines opportunity bottlenecks as artificially narrow spaces within opportunity structures through which people must pass to reach desirable opportunities. This conceptualization both recognizes that individuals make choices about their futures and also offers a reminder that those choices are not always fairly or freely made. Instead, as Fishkin (2014) noted, opportunities and opportunity bottlenecks arise from systems of power, privilege, and oppression that that make accessing them easy for some people and nearly impossible for others. This approach to conceptualizing access and opportunity emphasizes the societal, cultural, and institutional structures that can lead to suppressed achievement for a specific population—the pursuit and fulfillment of STEM aspirations for students with disabilities.

Using Fishkin's (2014) conceptualization of bottlenecks to frame STEM learning environments as a form of opportunity structure that students with disabilities must navigate, this study examines potential barriers, or bottlenecks, that might prove difficult for some or all students with disabilities to navigate regardless of their aptitude. Notably, this conceptualization emphasizes that barriers and bottlenecks are not qualities inherent in the students themselves or their disabilities; rather, they are located within the postsecondary STEM learning environments, which means they can be addressed by changes to policy and practice. Thus, using the idea of the bottleneck to interpret the experiences of students with non-apparent, high-incidence disabilities as they pursue STEM majors aids in developing an understanding of where possible bottlenecks in STEM opportunity structures may lie.

## Literature Review

This paper highlights barriers to participation experienced by students with non-apparent, high-incidence disabilities in STEM fields by exploring bottlenecks in the postsecondary opportunity structure. While much scholarly attention and public awareness has focused on relatively low-incidence disabilities such as d/Deafness, blindness, and mobility restrictions, the recent growth in postsecondary enrollment among students with disabilities has been driven by those with relatively high-incidence diagnoses such as dyslexia, attention deficit-hyperactivity disorder (ADHD), and emotional/behavioral disorders (Gage et al., 2012; Lovett et al., 2015).

Many high-incidence disabilities are also hidden or non-apparent, meaning that they cannot be readily discerned from visual cues alone and instead must often be self-disclosed by the student (Lovett et al., 2015; Tinklin et al., 2004). While they cannot easily be detected in daily life, non-apparent, high-incidence disabilities create participation restrictions for students—for example, limiting social and co-curricular engagement due to the need to spend more time on academic tasks (Markoulakis & Kirsh, 2013; Tinklin et al., 2004). They can also be the source of self-stigmatizing behaviors—such as not disclosing a disability to an instructor or not accessing support services—due to fears of being negatively judged by faculty and peers (May & Stone, 2010; Tinklin et al., 2004). Therefore, this study focuses on this population in order to more fully understand the participation restrictions experienced by students with disabilities pursuing STEM degrees. To help establish the context for this investigation of postsecondary opportunity structure bottlenecks for students with high-incidence and non-apparent disabilities, reviewing literature both about students with disabilities in higher education broadly and STEM fields specifically was essential.

### Students with Disabilities in Higher Education

Many factors contribute to the college academic experiences of students with disabilities. Prior studies emphasize the importance of belonging for students with disabilities (Vaccaro et al., 2015; Vaccaro & Newman, 2016). However, studies have shown that students with disabilities face academic, social, and communication challenges that can inhibit the development of a sense of belonging and contribute to lower persistence rates (Carroll et al., 2016; Cox et al., 2017). Ready access to high quality support services can improve the inclusiveness of postsecondary environments for students with disabilities (Kimball et al., 2016); however, the extent to which (a) students know these services are available and how to access them, (b) students are willing to access them and disclose their disability, and (c) faculty are willing to provide these services varies considerably (e.g., Barnard-Brak et al., 2009; Bourke et al., 2000; Sharpe & Johnson, 2001). Additionally, erroneous instructor beliefs about students with disabilities can contribute to non-inclusive pedagogy (e.g., Baker et al., 2012; Schelly et al., 2011). For example, one such belief concerns the very definition of disability—with faculty sometimes overly focused on low-incidence visible disabilities and unaware of the importance of addressing higher-incidence, non-apparent ones (Bettencourt et al., 2018).

Likely as a result of these challenges, many studies show that students with disabilities are less likely to persist within or complete postsecondary education than students without disabilities (DaDeppo, 2009; National Center for Education Statistics, 2016). However, other studies have shown that students with disabilities can succeed within postsecondary education at rates similar to their peers (Wessel et al., 2009). Attempting to reconcile these two sets of findings, scholars have found that academic and social engagement plays a significant role in retention and completion for students with disabilities (Fleming et al., 2017; Kimball et al., 2017; Mamiseishvili & Koch, 2011, 2012; Wessel et al., 2009). Other contributing factors include type of disability, financial status, other demographic statuses such as race and gender, and support utilization (Dong & Lucas, 2013; Mamiseishvili & Koch, 2012; Troiano et al., 2010; Wei et al., 2014). What this previous literature shows is that students with disabilities experience challenges and obstacles during their postsecondary education. The current study situates these challenges and obstacles within both a narrower STEM context and a broader understanding of the way that environment can impact opportunity structures.

### Students with Disabilities in STEM Fields

Compared to their peers, students with disabilities enroll in similar numbers in STEM courses (Lee, 2011; NSF, 2017). However, fewer complete college with a STEM degree (Dunn et al., 2012). For example, the NSF (2017) reported that 24.7% of students without disabilities and 23.3% of students with disabilities claimed STEM as their major field of study in 2012. However, people with disabilities make up just 6.8% of STEM doctoral recipients and, among the total 25 million employed scientists and engineers, less than 10% of them are people with disabilities (NSF, 2017). These rates are further suppressed when students hold intersecting marginalized identities, such as underrepresented races/ethnicities (Lee, 2014).

Students with disabilities may stop out of STEM majors due to various barriers. These barriers include a lack of STEM role models, a lack of encouragement to pursue STEM, a lack of instructor understanding of disability, and technical barriers such as inaccessible labs or safety equipment (Dunn et al., 2012). Other studies about students with disabilities in STEM have found that faculty in STEM often do not employ inclusive pedagogies and resist providing reasonable accommodations (Moriarty, 2007; Rao & Gartin, 2003). These issues are exacerbated by the fact that fewer students with disabilities receive accommodations in STEM fields than in other majors, perhaps leading to a longer time-to-degree or stopping out completely (Lee, 2011). Racial/ethnic minority students with disabilities rely on social support from peers, family, and the university as well as on the proper handling of accommodations to succeed in STEM (da Silva et al., 2016).

While researchers have been steadily filling out the contours of the college experience for students with disabilities, they have not focused as strongly on their experiences within STEM (Kimball et al., 2016). Understanding the experience of students with disabilities within STEM is important given that STEM is a growing and lucrative sector of the work force (Joint Economic Committee of the U.S. Congress, 2014). Additionally, external stakeholders, such as the NSF, have identified students with disabilities as a population whose participation in STEM has been suppressed (NSF, 2017). In other words, STEM represents an opportunity structure that leads to fulfilling and lucrative careers, if one completes their postsecondary STEM education (Areheart & Stein, 2015; Fishkin, 2014). The obstacles discussed above limit the full STEM participation for students with disabilities, potentially causing a “bottleneck.” This study explores the experiences of students with non-apparent, high-incidence disabilities in STEM to understand their perceptions of challenges and obstacles, as well as successes and accomplishments, at a large research university.

## Methods

Our study utilized a cross-case comparative design (Stake, 2013). This design allowed us to examine variation in student experience based on both their disability diagnosis and also their STEM learning environment. This paper focuses only those barriers seen broadly across varied disability types and learning environments. This focus is consistent with Fishkin’s (2014) conceptualization of bottlenecks, which arise from the overall configuration of opportunity structures rather than variation in individual experience.

### Participants

This study took place at a large, public flagship land-grant research university in the northeast, categorized as Research 1. Given the difficulty of reaching students with disabilities in a college setting, the exploratory nature of our research, and the role that the accommodations process could play in alleviating or exacerbating bottlenecks, we recruited a broad sample via email sent through the institution's disability services office. As we did not specify a disability type in our recruitment, we received interest from students with a wide array of disabilities. Overall, eighteen students were interviewed, five of whom were men. Sixteen of the participants grew up in the northeastern United States; one grew up in the southern U.S. and one was an international student from Mexico. After aggregating disability type, we discerned that our participant pool was made up almost entirely of students with high-incidence and non-apparent disabilities (n = 16). We therefore limited our discussion to this population in order to maximize the transferability of our findings. Doing so meant that we excluded two participant accounts from our analysis. Table 1 describes the participants in our study in greater detail.

## Procedure

Given that our interests were in gaining an in-depth understanding of these STEM experiences and extended case method's qualitative nature, we decided that interviews were a suitable method of data collection. Therefore, our study employed a semi-structured interview protocol to gather information about the climate experiences of students with disabilities. Consistent with the goals of an extended case analysis, the interviews that we conducted were structured to provide data to test the applicability of Fishkin's (2014) bottleneck theory. Thus, we needed to understand the social, institutional, and academic dimensions of their experiences. The interview protocol was designed to prompt the student participants to reflect on these dimensions. The research team included researchers with extensive experience in qualitative methodology and interviewing. Furthermore, two members of the researcher team had specific experience developing interview protocols for individuals with disabilities and had recently written a review of research on disability in higher education (Kimball et al., 2016). These varied experiences helped guide the development of the protocol. Some questions queried their experiences with disabilities: Do you identify as having a disability? How does it impact your daily life? Other questions asked about their general college experiences, while still others focused on their STEM experiences. For example, we asked participants to describe their experiences in science and math courses, describe the organization of STEM majors, and what kinds of support they received in their STEM studies. We also asked how they assessed the impact that their disability had on their overall STEM experience. Given the semi-structured nature of the protocol, the precise phrasing and sequencing of the questions varied from interview-to-interview.

Since our data collection was theory-laden, our analysis was as well: we began with a collection of *a priori* coding categories, which we augmented with emergent themes (Saldaña, 2015). *A priori* codes sought to capture the larger structures of the participants' experiences, including curricular and co-curricular, organizational, and psychological dimensions. We then subjected our data to a multi-state coding process. In our first order coding process, we began by generating open codes and applying *a priori* codes based on a careful review of interview transcripts. In our second order coding process, we then created categorical codes by linking topically similar first order codes. Finally, in our third order coding process, we sought to connect first and second order codes based on how they described participants' experiences of barriers in postsecondary STEM learning environments. As noted above, throughout our coding process we also engaged in cross-case analysis by dividing and reanalyzing our dataset based on latent characteristics of our study population (Yin, 2008)—specifically disability type and major.

## Enhancing Research Quality

In order to enhance the credibility and trustworthiness of our research, we used peer debriefing at all stages of our study design to ensure that our methodological, analytical, and interpretive decision-making had face credibility. We also sought consistency and rigor in our analytic process by having each transcript coded by one researcher and reviewed by another. Where issues arose, we negotiated them as a larger group to achieve consensus. We consciously constructed our research team to include scholar-practitioners who identify as persons with disabilities, who have worked with people with disabilities, and who have family members with disabilities to enhance reflexivity. Finally, we utilize thick descriptions wherever possible to ensure that the reader can clearly see the connections between a participant's experience, our interpretations of that experience, and the broader conclusions that we reach. A key part of this development of thick description is also the presentation of negative cases or discrepant information, which allows the reader to more fully assess the quality of evidence we present.

## Limitations

We recognize that neither STEM nor disability are singular phenomena. Due to the exploratory nature of this research inquiry, we chose to select a sample reflecting a wide-range of STEM fields and disabilities but acknowledge that there is also an inherent limitation in aggregating STEM fields as well as disabilities within this study. Additionally, we limited our study to students with non-apparent, high-incidence disabilities who were registered with disability services; thus, we are able to report on the experiences of only a subset of the broader population of students with disabilities, including those who have not yet gone to the disability services office. Indeed, even within the category "high-incidence," there is remarkable variation of experience. As a result, it is important not to over-generalize to all students with disabilities from our interpretation of data. However, the bottleneck framework does allow us to comment on larger systemic issues in STEM for students with non-apparent, high-incidence disabilities through individual experiences, rather than comment on the experiences themselves.

## Findings

Findings from this study demonstrate that the idea of a bottleneck is useful in understanding the experiences of student with disabilities in STEM fields. However, data show that the bottleneck process is not linear—in other words, there are multiple narrow places in the STEM opportunity structure that can become bottlenecks. The first bottleneck comes quite early: the transition to postsecondary STEM learning environments—either from high school or another postsecondary institution. After that, the behaviors of peers and faculty members could serve to narrow or widen bottlenecks in STEM opportunity structures. These individual behaviors also served to either reduce or enhance the impact of organizational challenges that also created barriers to STEM participation. Finally, perceived disconnects between one's identity and STEM also contributes to a narrowing of the opportunity structure. Ultimately, at the time of data collection, the students interviewed had not yet stopped out of STEM; however, their experiential accounts highlighted the various times and ways the STEM opportunity structure can narrow for students with disabilities.

### Bottlenecks in the Transition to Postsecondary STEM Learning Environments

Bottlenecks are places where broader social forces come to bear on a person and slow their progress through an opportunity structure. One of the first instances where broader social forces, such as preparation for college, intersects with disability to form a bottleneck is the transition to college. Christine, a transfer student, demonstrated that issue clearly—noting that: "It was a terrible transition coming here. Not only just being like a transfer student but also having a disability, which made it twice as bad." In large measure, Christine attributed that difficulty to being unused to the campus environment and a lack of intentional orientation to the environment. Notably, even participants who did not encounter this transition in problematic ways anticipated barriers. Abigail, for example, provided a typical example of a student transitioning well: "I thought it would be too big and overwhelming. I didn't think that big classes would be good for my learning style. I haven't found that to be an issue." Within these environments, the experience of barriers was so pervasive that it was seen as normal, and when they did not appear, participants expressed surprise.

Unfortunately, these smooth transitions were comparatively rare. Stanley's experience in this regard was far more typical. Commenting on the problematic interface between high school, community college, and college STEM courses, Stanley noted that he had attended a community college with strong support for students with disabilities for two years before transferring to the a much larger institution. Even though he took STEM courses in both high school and community college, he noted that, "I didn't have a lot of the courses in high school that kids out of high school are coming in with, so I'm doing that now." While he learned skills to ease navigating college while also having dyslexia, Stanley had less exposure to technical content. He also noted that the need to take additional coursework in the electrical engineering major would likely delay his graduation, and, due to the restrictive nature of the major, may push him out altogether if he had to repeat courses. For other students, the barriers that they encountered were far more tangible. Christine described her reaction to a new form of simulation lab: "There was no explanation on how to take lab, what a lab was. On how to take a practical. So that was a punch in the face first of all." Additionally, the lab was not set up in a way that could accommodate Christine should she have a seizure, which was possible due to her disability. However, Christine felt that, at that time, she did not have the tools necessary to broach that issue with the lab instructor and to have her needs met.

### Barriers Arising from Peer and Faculty Behavior in STEM Learning Environments

The next bottleneck in the STEM opportunity structure was created by the social environments in academic settings. In a very real way, the behavior of others—peers, faculty, and teaching assistants—in academic settings determined whether someone could participate fully in STEM learning environments as well as whether they felt at home within the institution. Not surprisingly, participants' peers provided the most important behavioral influence on their experiences. For example, Francesca described the very different behavioral climates in different STEM fields, noting that she preferred her major's less competitive atmosphere:

> Definitely like other majors, I've heard, are a lot more competitive. I'm taking a Kinesiology class, like Anatomy, Physiology, even in their labs they're like weirdly competitive about really dumb things. Where I'm like why would you even brag about that, it's not even that cool. Definitely a way different atmosphere than Biochem where everyone is like: "I don't know either; this is hard."

For Francesca, this less competitive atmosphere made it easier for her to process information about biochemistry without worrying about her performance or the increased amount of time she took to complete her work due to her dyslexia. Many participants had disabilities that manifested themselves primarily in group settings—for instance, attention deficit disorder or auditory processing issues that could be made worse by noise. Caroline, for example, described the dual-edged nature of peer interactions: "Socially most everybody's been very nice. Academically I like sitting by students in class who are quiet and don't distract me and stuff." Consistent with this quote, many participants viewed the presence or absence of barriers as arising from their peers, and noted that this behavior had to be carefully calibrated to both promote feelings of inclusion and also to create a distraction-free environment.

The impact of students' perceptions of their instructors' actions in the classroom and other academic settings was also important. Caroline described the positive impact a professor could have just by performing relatively common pedagogical practices, such as providing "handouts to help and practice problems and answer keys." For Caroline and others, however, the experience was not always positive. Caroline described attending a large university, finding:

> It's hard to really get a feel for them [faculty members] because they have so many students. I don't want to say that they don't care, but the turnover rate kind of makes it impossible for them to develop a relationship with everybody.

Others were less generous in their interpretation of instructor behavior. Casey suggested that there were widely disparate faculty attitudes toward students:

> Some of them, I'm shocked they're professors. Others, I'm like, "Wow, this guy is just here for research." Other ones you can tell that they really care about teaching the kids. Most of the STEM classes, they actually cared about teaching and making sure you understood the material.

For many participants, their expectations of faculty behavior had been set in secondary school contexts where they perceived teachers to be more focused on their instruction and more helpful when a student's needs varied from the majority of students in a class. However, when describing postsecondary STEM learning environments, they frequently noted that some instructors seemed to be more focused on other matters or that their instructors were basically strangers due to large class sizes.

While some of these descriptions of instructor behavior did not focus on disability specifically, many did. For example, Christine noted that: "I think that there are some really great professors . . .but there are some that need to be brought up to standard as far as how to deal with people with disabilities." Christine's experience also highlighted the key role that faculty play in the creation of STEM opportunity structures and bottlenecks. Simply put, most of the accommodations available at the university in this study relied on faculty members to implement them, and not all did so effectively.

Positive responses from faculty helped these students build confidence in their academic abilities and continue through the opportunity structure, while negative responses represented an obstacle to learning and, perhaps, a contribution to a bottleneck. As Abigail shared:

> In statistics, yes, because I go for a good amount of extra help. They've been very available. It's been super-helpful that I've been able to learn to kind of do more on my own throughout the semester. It's been a really good semester in stats. Oceanography I only have seen him [the instructor] about taking extended time or something like that. I haven't really seen him a lot.

The responses were contextual, rooted in Abigail's need for support, and highlighted how individual needs change from person to person and from course to course. Given the difficult subject matter, all students are likely to struggle at some point in STEM courses; for students with non-apparent, high-incidence disabilities who may learn differently than their peers, their perceptions of instructor awareness of and response to these struggles is particularly important. These students perceived faculty awareness as either a help or a hindrance, especially regarding disability issues.

In this regard, participants perceived a wide range of awareness levels from faculty and instructors. Several participants recounted interactions with faculty members which were not overtly hostile, but conveyed a disregard for the role disability may play in the classroom. For example, Francesca told a story wherein her biochemistry advisor told her that her grades were not good enough to find work after college. When she objected that she had dyslexia and had a hard time with her coursework, he said, "yeah, well, they don't really care about that, they just look at GPAs." While this faculty member may have been trying to prepare Francesca for STEM climates outside her college classroom, she felt that he lacked compassion and understanding of her disability. Particularly, this was a moment where the faculty member could have provided tools or advice on how to squeeze through this particular bottleneck; however, he instead disregarded the impact of her disability and consider Francesca's work solely through the lens of GPA. Additionally, some participants indicated that they felt that faculty members and teaching assistants were not prepared to handle the full array of possible disabilities in their classrooms. Although these instructors may have been prepared, they did not convey that sentiment to their students, who felt under-supported as a result.

**Barriers Arising from Organizational Structures in STEM Learning Environments**

Several institutional features also contribute to narrowing the STEM opportunity structure. Some of these organizational structures, discussed briefly below, are relatively common features of STEM curricula, which means that they may present bottlenecks for all students. Others, especially the accommodations process, are unique to students with disabilities. Notably, the fact that a barrier exists for all students does not mitigate its impact for students with disabilities; instead, it highlights the way that overlapping barriers for bottlenecks that may be more or less pronounced for some students than for others.

As general organizational features, the complexity of STEM enrollment could also be compounded by the fields' interdisciplinary natures. Francesca described it thusly:

> You have to take kind of like all [College of Physical Sciences]. Physics, Math, Bio and Chem and then Orgo and Orgo lab, which I took…I knew it was going to be hard for me so I took it over the summer…I took a summer program there. Otherwise there are a genetics course you have to take. I forget. There's another 200 levelish class that you have to take then a biochemistry lab. Two 500 levels, physical chemistry which was like the death of me.

While STEM faculty members, academic advisors, and published descriptions of major curriculum seemed to assume that the connections among these courses would be clear to those taking them, it was not always the case. For example, when asked to explain which of the science courses she had taken were required, Jennifer stated:

> So, this is the thing that really sucks. So, I was going to go pre-vet, and pre-vet requires physics. But because now I'm going to stay in animal science, I don't need physics, and I missed the withdrawal date too. Or calculus, for that matter, so I'm taking two classes that I don't need, and I'm really frustrated because I can't seem to understand…the material.

For Jennifer, the rationale for the difference in requirements was radically unclear and poorly explained. Jennifer's memory disorder—compounded by a lack of institutional clarity—made it hard for her to succeed in these courses, compounding the frustration and cost of taking unnecessary courses.

Francesca shared a similar frustration reporting that she could not actually get into some of the courses that she needed because they were offered by a different but related program:

> Then eight credits of upper level sciences [are required], which is like very broad but frustrating because all the upper level science classes are majors only…You go to the professor, she's like no you can't get in because it's only for [majors].

These problems worsened when the curriculum proceeded in lockstep. William, for example, reported that "there's a lot of electives" but also that "pretty much everything" had to be within his major. According to participants, STEM fields required so many courses that there was little room to do something that simply interested them. That problem was worse for those participants who had commitments—for example, athletic participation and part-time jobs—that restricted scheduling choices.

Some organizational features, however, intersected with these students' disabilities to impact the way they navigated STEM opportunity structures. Several participants chafed at the perceived gatekeeping nature of the introductory courses, noting that these were the courses that triggered their disabilities the most and yet had the most power to keep them from pursuing their major. Lucy shared a story in which she had to petition her major (microbiology) for readmittance after having been kicked out for failing organic chemistry twice even though she had good grades in other upper-level courses in the major: "I went and took the class at another college, and I just came here and pretty much forced them to take me back."

The interviews also suggested that the way that a student decides to access or not access disability support services also impacts the STEM opportunity structure. Many participants suggested that they frequently tried to complete their coursework without utilizing disability support services or using them as minimally as possible. For others, support services were simply a needed modification so that they could engage fully in the environment. Some students ultimately opted not to disclose to the institution, citing that they no longer felt that the accommodations were useful to them—even though the disabling environments continue unmodified. Accommodations mentioned included extended time and/or separate locations for exams, extended time for assignments, and note-takers. Very few, if any, participants reported feelings that their accommodations were tailored to their individual needs, indicating that the accommodations system at this institution relies on neutral and generic processes.

Notably, however, almost all students who described using support services described their experience as mixed. Noting her academic struggles earlier in her career, Christine stated:

> So, it was just better that I start over another semester with that class and then get some systems in place because it is going to be disaster if this continues. And that is why I say if I have had professors say to me they don't like disability services. And I have professors say to me they are willing to take the extra time with me in class. So, it depends on the professor, you know... whatever happens is in their hands.

Importantly, Christine's brief recollection highlighted both the role individual agency—"I start over…and get some systems in place"—and the institutional restriction of individual agency—"whatever happens is in their hands." That tension perhaps helps to explain students' profound ambiguity regarding the value of disability support services: they simply did not know what to expect to receive, and for those students who did not readily identify with their disability, the threat of resistance from faculty was a sufficient incentive not to seek services.

In addition to faculty behaviors, participants reported frustrations with the loosely-coupled nature of the accommodations system at their institution. This system relied on students to self-disclose their diagnoses to the disability services office and then self-disclose again to faculty members to receive accommodations after the institution had confirmed their diagnosis. There are many points at which this system could break down, thus depriving students of legally mandated accommodations. For example, Jennifer related her frustration during an episode when communication between her accommodations manager and one of her faculty members broke down about exam format. Due to her disability, Jennifer found open response questions quite challenging and wondered if she could have had a different format. When she broached the issue with her accommodation manager, she was dissuaded from asking for an alternative test format on the assumption that the instructor would feel that they were changing the course just for her.

The loosely-coupled accommodations system affected the ways that students with disabilities experienced instructional processes and physical learning environments. Christine mentioned that her labs were especially stressful, due in part to her instructor's insensitivity to her accommodations due to her disability. She also mentioned issues with the note-taking system in her anatomy course:

> I didn't get notes for all of the entire first month… until after the first exam. So I took the first exam without notes. The note-taker kept telling me she was going to load them. She never did. She never would.

Overall, the students in this study reported that, at best, accommodations made little impact on their progress and, at worst, could depress their participation. As Stanley said: "Accommodations do not make a 300-person lecture 25 people, it doesn't change the way that the professor presents the information."

### Disability Identity as a Bottleneck in STEM Learning Environments

The final bottleneck identified emerged from the interplay between students' sense of self, including the way they perceive disability, and STEM environments and expectations. Participants sometimes reported feeling as though it was hard to find space for their own senses of self within the sciences. Lucy stated:

> Everybody just sees science of just one way, but there's so many kinds. I just know every day, for example, I have that lab, and genetics is a very formal type of science, the type of science that has always been more structure, the more stereotypical way a scientist should be. Within that stereotype I am not comfortable.

For Lucy, the lack of fit she felt in that lab had a very real psychological consequence. She stated later:

> Sometimes I even come in crying after lab or after a day in which I have so many things to do and just fighting. It feels like a complete battle everyday just to prove that I'm one of the club, that I'm part of the club…It's been rough for my self-esteem.

As a result of her experience in STEM courses, Lucy was led to question whether she really wished to be a part of the field.

For other students, the psychological dimensions of climate were equally real but manifested themselves differently. Many participants described the postsecondary environment as more chaotic than high school and suggested that they found it bewildering. Sally was typical in that regard and also connected this perception to her experiences with ADHD: “being in those big classes it kind of discouraged me because they were so big and I was like, ‘What am I doing here? Do I actually belong here? I can’t concentrate.’” While Sally eventually adapted, the limited support provided an initial message that she might not belong.

Social identity and its intersection with larger social forces is at the center of the bottleneck approach. For the students in this study, disability existed as a facet of identity separate from, and sometimes inconsistent with, their other social identities and understanding of self. However, STEM learning environments could—and often did—cause students with disabilities to feel “disabled” within particular courses or spaces. In one example, Mike responded to a question about whether he identified as a person with a disability by stating:

> Well, yes and no. I mean, I don't see myself as a person with a disability, but technically I am. I have ADD, so I mean, I definitely struggle with that at some points, but for the most part, I've learned pretty well to deal with it at this point. I got diagnosed when I was in third grade and started taking medications right off the bat. I didn't even know. My parents kept it a secret from me. They'd tell me I was taking vitamins, but I've been pretty comfortable with it. I don't see it as a big thing.

In this exchange, Mike demonstrated the inherent complexity encountered by students as they process their disability status. Unlike most other social identities, disability is not only defined by intra- and inter-personal processes but also by legal regulations and medical diagnosis. Consequently, students frequently describe disability both as something that is a part of them and something that exists external to their sense of self. However, in the bottleneck approach, their choices are still impacted by ways that society structures opportunity—usually by privileging those without disabilities over those with them.

## Discussion

The findings demonstrate how barriers encountered in the transition to postsecondary STEM learning environments interact with additional barriers arising within the STEM learning environment create a bottleneck in structure of STEM opportunities for students with disabilities. Specifically, peer and faculty behavioral, organizational structures, and lack of alignment with disability identity are barriers the students in this study encountered. The imagery of bottlenecks and opportunity structures (Fishkin, 2014) is a way of conceptualizing access and outcomes while taking both individual agency and structure into account. In other words, it accounts for the choices that individuals make (e.g., to major or not major in a STEM field) and the social and organizational pressures that impact that choice. Rather than having large bottlenecks in key places, there were multiple small bottlenecks throughout the STEM opportunity structures for these students with non-apparent, high-incidence disabilities. Starting at the very beginning of their college career—their transition to college—students with disabilities encountered several places where they found their ability to continuing choosing STEM constrained or impacted somehow. Some of these bottlenecks were products of the academic environment or faculty responses to disability, some were products of organizational features, and some were products of how STEM fields present themselves and where students with disabilities saw themselves.

One of the strengths in the bottleneck framework is the acknowledgement of the complex social and academic forces at play in individual decisions to persist in STEM or change major. Such forces include faculty understanding of and empathy towards disability; instructional practices used by faculty not entirely trained to be good pedagogues; curricular rigidity; and the loosely-coupled nature of the accommodations system. These findings suggest that student perceptions about the level of disability awareness that their instructors display impacts the STEM experiences of students with non-apparent, high-incidence disabilities. The extent to which students perceived that faculty were supportive of—or even open to—accommodations and supporting students with disabilities influenced their decisions about which STEM courses to take and how to pursue their STEM goals (May & Stone, 2010; Tinklin et al., 2004). Very few of the students interviewed identified an instructor who indicated that they not only understood the particular challenges for students with non-apparent, high-incidence disabilities, but also that they were willing to help these students. While it is important that students with all kinds of disabilities are able to see people with all kinds of disabilities in positions of power on campus, disability awareness highlights both the capacity of any institutional stakeholder to be an ally (Rankin & Reason, 2005) and the extent to which an instructor's lack of disability awareness may prevent a student with a non-apparent disability from even participating in the classroom in the first place (Baker et al., 2012; Schelly et al., 2011).

The students with high-incidence, non-apparent disabilities in this study indicated that faculty instructional practices and curricular rigidity impacted their progress through the institution's STEM opportunity structure. Faculty reliance on traditional teacher-centered methods such as lectures, summative assessments, and other passive learning activities intersected with non-apparent, high-incidence disabilities such as dyslexia and ADHD to make it difficult for these students to sufficiently learn and understand the materials. Furthermore, participants perceived a lack of empathy on the part of faculty members in both their teaching styles and their perceived sensitivity to issues particular to students with non-apparent disabilities (Moriarty, 2007). Taken together with past findings that STEM faculty are less receptive to granting accommodations (Bettencourt et al., 2018), these findings suggest that students with non-apparent disabilities in STEM are less likely to request accommodations than their peers in non-STEM fields (Lee, 2011) due to expectations of rejection or negative opinion. Additionally, the lockstep nature of the curriculum created a frustrating environment for the students in this study, especially in concert with non-inclusive pedagogies (Moriarty, 2007). These experiences indicate that STEM departments at this particular institution need to reconsider aspects of their academic plans. Lattuca and Stark (2009) advised that universities, colleges, and departments remember to consider learner characteristics, goals, and abilities when crafting their academic plans and curricula. Indeed, these academic forces can impact the progress of all students, not just students with disabilities, suggesting the need for STEM departments to seriously reconsider the ways that instructors are trained to teach and the ways that they construct curricula and pathways through STEM majors.

The obstacles and difficulties—sometimes small, sometimes major, but always cumulative—experienced by these students all represent ways that these individuals with high-incidence disabilities may feel limited or restricted from full STEM participation. In other words, the perception that instructors are unsympathetic or uninterested in a student's disability status, students' disinterest in utilizing potentially useful accommodations, and challenges presented by lock-step curricula can act as bottlenecks, or part of a larger bottleneck, in the STEM opportunity structure (Areheart & Stein, 2015; Fishkin, 2014). These experiences thus reveal the ways that students with disabilities can be slowly discouraged or turned away from their STEM aspirations. This gradual wearing away of a student's STEM aspirations can also have profound implications for their self-understanding: as demonstrated in the discussion of "Self vs. STEM"—students with disabilities may struggle to understand themselves as fully agentic beings within learning environments that seem highly structured and beyond their control. The high degree of paradigm consensus and rigid curricula in STEM fields would certainly appear to enable this possibility. This finding aligns with prior work that has shown the importance of an affirmative disability identity to the postsecondary success of students with disabilities (e.g., Cox et al., 2017; Vaccaro et al., 2015).

## Implications for Research and Practice

Future research should further explore the bottleneck approach (Fishkin, 2014) as a useful tool for understanding the experiences and challenges faced by students with disabilities. Specifically, this research should explore how disability identity of students, disability services and accommodations processes, and instructor awareness of disability may expand understandings of access, opportunity, and success. The findings also highlight the way in which disability connects with other social identities. Future research should treat disability in an intersectional fashion and explore variations in the experience of students with disabilities based on factors such as gender identity, race/ethnicity, socioeconomic status, and diagnosis. This analysis should compare the experiences of students with high-incidence disabilities, students with low-incidence disabilities, and students without disabilities to determine whether these additions are useful generally or only for specific groups.

In terms of practice, the findings suggest not only that onerous requirements and rigid curricular structures could pose particular challenges to students with disabilities in STEM fields but also that many students with non-apparent, high incidence disabilities experience these obstacles in similar ways. Notably, many of these challenges are not easily addressed by the highly siloed approach adopted on many college and university campuses of simply allowing disability services to be solely responsible for supporting students with disabilities. As such, the qualitative data offered by this study suggests several broad strategies that STEM majors, departments, and programs should consider deploying to increase both the numbers and persistence of students with the most common kinds of disabilities. First, study findings highlight the need for periodic assessments of the academic plans (Lattuca & Stark, 2009) utilized within postsecondary STEM learning environments. Doing so would help STEM majors, departments, and programs to ensure that the goals, structure, and learner experience in their curricula are in alignment and also inclusive of the needs of all learners. These findings also highlight the singular importance of first-year courses to postsecondary STEM trajectories, which would make them a particularly important place for time-pressed academic units to begin their work. Second, STEM majors, departments, and programs should enhance opportunities for faculty teaching development. Participants in this study were especially sensitive to perceptions that faculty were uninterested in their teaching or in the success of students with disabilities. Thus, efforts should be made to create and maintain teaching interest among STEM faculty and to increase awareness and understanding of learner-centered pedagogy and practices. Given the lack of substantive expertise many faculty have in pedagogy or in disability support, drawing on the collective expertise of disability services personnel would be critical to the success of this undertaking.

Taken as a whole, this study provides badly needed empirical information about students with disabilities—an understudied, minoritized population—in STEM fields—an increasingly important pathway to economic opportunity and societal impact. It also extends prior empirical work by demonstrating how Fishkin's (2014) work on bottlenecks can reveal shared experiences among students with non-apparent, high-incidence disabilities. In so doing, this study offers implications both for practice and future research that can contribute meaningfully to improving STEM outcomes for postsecondary students with disabilities.

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**Table 1**

*Participant Major and Disclosed Disability*

| Participant | Major | Disclosed Disability |
|---|---|---|
| Abigail | Psychology* | ADHD |
| Diane | Public Health (Science Track) | ADD |
| Adrienne | Biology/Italian Studies | ADHD |
| Scoti | Physics/Astronomy | Dyslexia |
| Caroline | Chemistry | ADD/ADHD |
| Casey | Biology/Chemistry | ADHD |
| Christine | Biology | Seizure / Learning Disability |
| Colin | Engineering | Dyslexia |
| Guillaume | Undeclared (Engineering) | Autism Spectrum Disorder |
| Lucy | Microbiology | ADHD |
| Mike | Kinesiology | ADD |
| Sally | Psychology* | ADHD |
| Sarah | Undeclared (Business)** | Auditory Processing Disability |
| Stanley | Engineering | Dyslexia |
| Francesca | Biochemistry | Dyslexia |
| Jennifer | Animal Science | Anxiety/Memory Disorder |

*Note.* *Students majoring in psychology in the sample were included due to the program's emphasis on cognitive neuroscience and NSF's inclusion of psychology in the definition of STEM fields. **Although presently undeclared and in an exploratory program related to business, Sarah was included in the sample because she originally pursued a degree related to forensic science before deciding " science was not an option" due to her STEM experiences.