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Research Article

Sense of Belonging Among College Students with Disabilities in STEM Fields: A Large-Scale Survey Analysis

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Abstract: Sense of belonging is a key to educational success for all students, though much less is known about this topic among students with disabilities majoring in science, technology, engineering, and mathematics (STEM) fields at four-year colleges and universities. To address this gap in the literature, we analyzed large-scale survey data from 4,518 undergraduate STEM majors with disabilities to explore the frequency and nature of their on- and off-campus experiences, paying close attention to the relationship between disabled STEM students' perceived sense of belonging and a battery of on- and off-campus experiences. Hierarchical linear regression identified 11 significant predictors of belonging (e.g., quality of interactions with peers, commute time to campus), which together explain 36% of the variance in scores. Results affirm the importance of on- and off-campus experiences (e.g., peer interactions, undergraduate research, working off-campus), yielding significant implications for future policy, practice, and research.

***Keywords*:** STEM, disabled, sense of belonging, engagement

1. Introduction

The Chronicle of Higher Education (hereafter, "The Chronicle") recently published an article titled, "Everybody's Talking about Belonging", noting the meteoric rise in media- and scholarly attention to sense of belonging in higher education (Lu, 2023). It's seemingly everywhere. For example, it's an eye-catching oversized poster adorning an administrative building at Kent State University. It's boldly proclaimed on a t-shirt at the University of Tennessee, Knoxville, a blue and white notebook at University of Kentucky, a website at Amherst College, and campus signage at Washington State University, Western Michigan University, and LeMoyne-Owen College, to name a few. Over 60 jobs posted at The Chronicle have 'belonging' in their title and just as many were posted at HigherEdJobs on the time of this writing including cabinet-level positions at Belmont University, University of Massachusetts Boston, Colorado College, and Harvard University. The Chronicle writer points out, however, that "for all the progress in research and resources… no one has perfected a blueprint for belonging". Yet and still, a consistent line of studies show that sense of belonging facilitates educational success for college students (e.g., Gopalan & Brady, 2020; Strayhorn, 2019).

Sense of belonging is operationally defined as perceptions of feeling accepted, cared about, and important to others on campus such as faculty and staff within one's major (Strayhorn, 2019). It refers to a feeling, a shared faith

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that one's needs-whether academic, social, psychological, or otherwise-will be met by a commitment to being together in a supportive, trusting community with other members who share common experiences, interests, and values. "College students stress the importance of social acceptance, support, community, connections, and [mutual] respect to their own identity, development, mental health, well-being, and academic success" (Strayhorn, 2019, p. 6). Previous studies have examined the role that belonging plays in improving academic achievement and adjustment for college student populations, including first-year collegians (Means & Pyne, 2017), summer bridge students at minority-serving institutions ((MSIs) Barth et al., 2021), and even women majoring in STEM (Johnson, 2012). Leading scholars posit that sense of belonging matters for all students-as a basic need and human right-but takes on heightened importance at certain times and in particular settings for our most vulnerable populations (Strayhorn, 2019), including "new majority" students such as adult learners (Inoue et al., 2020), racial/ethnic minorities (Museus & Chang, 2021), college students with disabilities, and those who live at the intersection of these identity categories, namely adult learners with learning disabilities (e.g., Strayhorn & Johnson, 2024). Note that "although person-first language is commonly used in many professional settings, this practice has received criticism from self-advocates and scholars who believe that identity-defining features, such as autism, cannot be separated from the individual" (Taboas, 2023, p. 565). In light of this and some evidence showing that members of the disabled community prefer identity-first over person-first terms, we intentionally use these interchangeably throughout this manuscript.

According to recent data, approximately 21% of college students report at least one disability (National Center for Education Statistics, 2023). The most prevalent disabilities among college students in the U.S. include attention deficit-/hyperactivity disorder (ADHD), learning disability, and deaf or hard of hearing (American College Health Association, 2024), to name just a few. Less than 2% of college students report a speech impairment, and only 4% are legally blind. Francis et al. (2019) conducted in-depth one-on-one interviews with eight disabled college students, using a semi-structured protocol. Through a form of open coding analysis, they found that some disabled college students feel disempowered due to educators' lack of knowledge about disabilities and insecure when comparing themselves to their abled-bodied peers. Furthermore, participants expressed feeling isolated, at times, from staff and students due to their disability and/or being labeled as different. It's important to note that language throughout this paper reflects our commitment to challenging ableist terminology. For instance, we avoid the term 'able-bodied' as it seems to incorrectly assume that disability is equivalent with inability-that disability anywhere defies or denies ability everywhere. Our research, to date, indicates that nothing could be further from the truth (Strayhorn & Johnson, 2024). Furthermore, participants expressed feeling isolated, at times, from staff and students due to their disability and/or being labeled as different.

Previous studies have examined the prevalence of disabilities among college student populations (e.g., ACHA). Disabled college student studies cover a range of topics including key educational outcomes, such as sense of belonging (e.g., Vaccaro et al., 2015). Belonging studies involving disabled college students have examined their experiences within STEM fields (Friedensen et al., 2021). Yet, comparatively few published studies were found that focus on what disabled students do (i.e., engagement)-rather than what they cannot do-and, additionally, how on- and off-campus engagement influences their perceptions of belonging, noting any variability by academic major. In fact, Holloway (2001) noted: "...the lived experience of disabled students has been missing from previous studies and that what is needed is research which treats seriously the perspectives of disabled students" using diverse, larger samples (p. 598). This is the gap addressed by the present study.

1.1 *Purpose and research questions*

The purpose of this quantitative study is to cast much needed attention on the experiences of college students with disabilities majoring in STEM fields and their sense of belonging at 4-year institutions in the United States (U.S.). Although scholars have shown that people are "more than [just] their disability" (Monaco et al., 2024, p. 20) and "identity-defining features (e.g. autism) cannot be separated from the individual" (Taboas et al., 2023, p. 566), comparatively few large-scale, survey-based studies examine the frequency and nature of on- and off-campus experiences among differently abled college students majoring in STEM, with notable exceptions (e.g., Gormley et al., 2016; Lambert & Tan, 2020). We use the term "differently abled" at times to acknowledge that abilities exists on a spectrum rather than in binary categories of abled or disabled. Our intentional use seeks to shift focus from deficits to the unique assets and capacities each individual brings, aligning with our unapologetic belief that ability is fluid and

shaped by context, opportunity, and support(s), among others. In this empirical project, we analyze secondary data from a national cross-sectional survey to explore a single research question:

1. What is the relationship between sense of belonging and on- and off-campus experiences among college students with disabilities majoring in STEM?

Before detailing the methods of our study, we provide a detailed explanation of the conceptual framework then pivot to a substantive review of the existing literature that informs the focus, design, and interpretations presented in sections that follow.

1.2 *Conceptual framework*

Given the importance of engagement to community and community to success, sense of belonging made a logical choice as the conceptual framework for this study. A conceptual framework organizes and synthesizes existing knowledge to provide a coherent interpretive structure, offering a lens through which to analyze data and derive meaningful conclusions (Imenda, 2014). Conclusions drawn from the framework build upon a comprehensive understanding of student engagement and its relationship with belonging. This framework explores the interplay between academic and non-academic engagement, modality of participation (formal vs. informal), and locus of affiliation (campus vs. unaffiliated). Collectively, these core elements inform how sense of belonging is cultivated and its positive impact on student outcomes. Figure 1 operationalizes these constructs therein to guide this study.

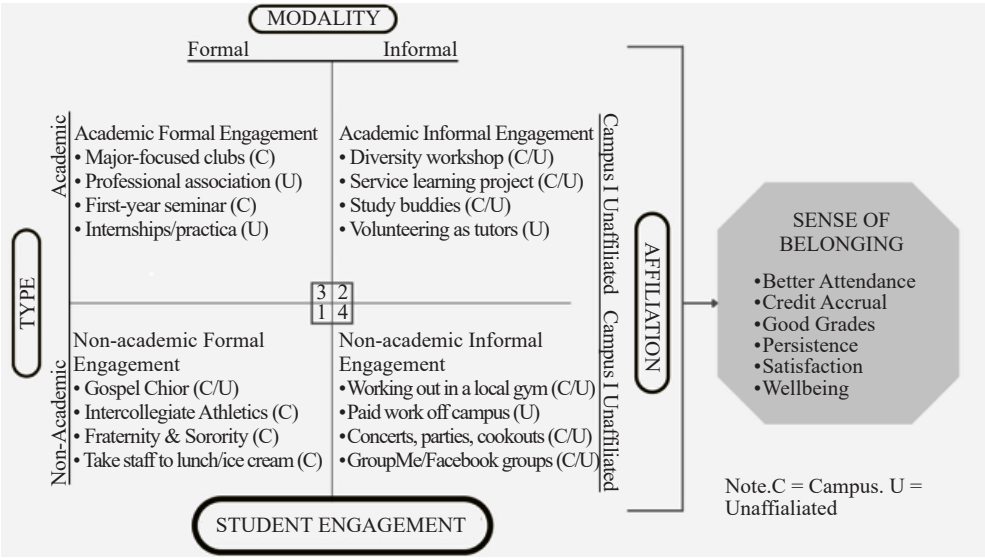

Figure 1. Conceptual framework of student engagement and sense of belonging

According to the model, student engagement is categorized along two primary axes: type (academic vs. non-academic) and modality (formal vs. informal), with affiliation as a secondary dimension. Dimensions of affiliations range from structured, academic-centered initiatives such as major-focused clubs and professional associations to non-structured, unaffiliated experiences such as working out at a local gym or attending off-campus social gatherings. Each quadrant represents a distinct engagement pathway, reflecting diverse ways students connect with their environment and peers to nurture their sense of belonging.

Sense of belonging-the central outcome of these engagements-is conceptualized as the degree to which students feel accepted, connected, and valued within their community, whether on- or off-campus. Empirical studies emphasize belonging as a predictor of key success metrics, including academic performance (i.e., grades), retention, persistence, and well-being (Gopalan & Brady, 2020; Strayhorn, 2019).

By situating engagement within the broader context, this framework highlights the dynamic nature of belonging

as an adaptive and intersectional process. Some activities crossover lines of the framework that separate academic from non-academic domains and/or campus-affiliated from unaffiliated spaces. For example, student diversity workshops can be academic in nature, but hosted by unaffiliated faith- or nonprofit groups off-campus, exemplifying the complex interplay involved in fostering belonging.

The study's conceptual framework, developed by the lead author, underscores the importance of intentionally designing programs, practices, and policies that acknowledge diverse student experiences and myriad forms of engagement to facilitate sense of belonging. Before reviewing the study's methods, a review of the existing literature is presented in the next section.

2. Literature review

Prior research on topics related to our study can be organized into several major categories. The largest category comprises national reports, health updates, and bulletins tracking the general characteristics and prevalence of disabilities in society generally and higher education specifically (Zablotsky et al., 2019). Some STEM scholars have explored the academic and social experiences of disabled students in these highly specialized disciplines. Disability scholars tend to advance existing knowledge, exploring how students' disability(-ies) affect their experiences in college. Lastly, belonging scholars acknowledge that identity matters and conduct studies examining experiences of disabled students in college. Our review is organized around these bins of knowledge.

2.1 *Disabled college students characteristics*

Dozens of published studies and reports describe the general characteristics and traits of college students with disabilities. For example, the most common disabilities among college students are learning impairments and mental health issues, as previously noted. Beyond this, the American College Health Association's (2024) annual report draws on responses from 79,246 undergraduates at 154 institutions, revealing relatively high rates of anxiety (36%), depression (27%), and ADHD (14%), to name a few.

Other studies examine the central tendencies and characteristics of disabled college students (e.g., Fleming et al., 2017; Francis et al., 2019). For example, Fleming et al. studied 325 disabled students from three large public universities to explore the relationship between personal characteristics, perceptions of campus climate, and academic performance. Results indicate that age and self-advocacy behaviors significantly predict disabled students' academic success. Self-advocacy skills are strongly correlated to grades, although, as we've said elsewhere (Strayhorn & Johnson, 2024), expecting disabled students to advocate for themselves places an undue burden on them to trust the intentions of others, defy ableist structures, and confront university personnel despite unequal power dynamics, which seems risky and only likely to reinforce existing inequities.

2.2 *Experiences of disabled college students in STEM*

Contrary to popular belief, research evidence consistently shows that a fair number of college students with disabilities enter college with interest in STEM fields who, later, go on to declare a major in these demanding subjects. For instance, Hedrick et al. (2010) investigated the relationship between five benchmarks of institutional performance (i.e., academic challenge, supportive campus) and student engagement, comparing STEM and non-STEM students with and without disabilities using data from 4,467 undergraduate students in the National Survey of Student Engagement (NSSE). They found that STEM students report significantly higher levels of academic challenge and more enriching educational experiences compared to non-STEM students. Additionally, students with disabilities in STEM fields perceive interactions with faculty as generally more positive than their non-disabled STEM peers. However, students with disabilities and STEM students report less favorable perceptions of the campus environment compared to their counterparts, respectively.

Other relevant studies exist that employ qualitative methods. For example, Cardoso et al. (2016) explored the experiences of six racial and ethnic minorities majoring in STEM using semi-structured interviews. They found that participants placed the greatest emphasis on interpersonal support from faculty, staff, and peers in terms of their STEM

success. Beyond mere provision of services, results indicate that faculty and peer attitudes toward accommodations shaped the likelihood that disabled STEM students request academic support. Although some participants spoke positively about the benefits of joining campus clubs and organizations, others report difficulty forming relationships, due, in part, to excessively competitive classroom environments where one's success is all-too-often framed at the expense of others.

Although undergraduate research experience (URE) is praised as a high-impact practice that produces a wide array of learning outcomes such as understanding of the scientific method, critical thinking and problem solving (Lanning & Brown, 2019), less is known about UREs and disabled STEM college students. To this end, Gin et al. (2022) presented data from two studies to examine the challenges and opportunities that students with disabilities face in UREs. In the first study based on survey data from 1,200 undergraduate students at 87 institutions, they found that 12% of those engaged in undergraduate research have at least one disability, concluding that such students are underrepresented in UREs in life sciences. Respondents reported various types of disabilities with learning disabilities and mental health being most common. Time devoted to research projects and topics varied, but most were supervised by a faculty member or graduate student and received course credit for their work. Using semi-structured interviews (Study #2, n = 20), they identified unique challenges disabled students' face in UREs. For example, those with learning disabilities had trouble reading dense scientific material, keeping up with deadlines, and completing tedious tasks such as counting models or balancing formulas, to name a few.

2.3 *STEM experiences by disability type*

Recent studies have analyzed the experiences of disabled college students in STEM, categorizing them by disability type. These investigations reveal significant variations in student experiences across different disability categories. For example, Wei et al. (2013) investigated college enrollment and STEM participation using a large, nationally representative U.S. sample of young adults with disabilities. Analyzing data from 660 young adults with autism spectrum disorder (ASD) and/or their parents revealed that, compared to individuals with other disabilities, ASD students are more likely to be male, come from wealthy backgrounds, enroll in 2-year community colleges, and experience difficulties with everyday conversation. Furthermore, individuals with ASD demonstrated the highest STEM participation rates among all disability groups, especially among science and computer science majors. Several factors positively influence college enrollment and STEM participation for students with ASD, with higher rates observed in those who are older, have higher SES, and possess greater mental health skills.

Other studies use qualitative approaches to study disabled STEM students' experiences. For example, Majocha et al. (2018) explored five deaf students' UREs in STEM and relationships with hearing mentors using semi-structured interviews. They identified four themes related to deaf interns' success, two of which are deaf awareness and mentor advocacy. Specifically, mentors enact their advocacy by respecting and supporting interns through regular check-ins, being available to explain tasks, and including them in team meetings and consultations. Participants reported that these positive interactions made them feel seen, supported, and valued by mentors and other interns.

2.4 *Disabled college students' sense of belonging*

The weight of empirical evidence clearly affirms that college students' sense of belonging predicts academic success (Strayhorn, 2019), with a growing line of inquiry assessing sense of belonging among disabled college students. For example, Vaccaro et al. (2015) used semi-structured one-on-one interviews with eight disabled college students to explore how they develop a sense of belonging during their first year on campus. Sampling from a midsized, public research university located in the eastern region of the country, results suggest that sense of belonging in the first-year depends, in part, on students' successfully mastering the demanding roles and responsibilities of being a college student while also developing supportive relationships with faculty, staff, and peers. Participants talked at length about the interconnections between these three factors and how they seemed to reinforce and reify one another.

In a quantitative study, Strayhorn and Johnson (2024) examined on- and off-campus experiences that influence sense of belonging among older Black college students with learning disabilities. Analysis of 874 NSSE responses suggests two major findings. First, belonging scores differ, with higher scores among Black peers without disabilities. Second, engagement in fraternity/sorority life, UREs, and service-learning activities is associated with higher belonging

scores. As another example, Barnes et al. (2021) analyzed survey data from 445 college students at two different institutions, one highly-selective university and an urban campus. Using a blend of non-parametric statistics, they found that academic self-confidence and peer belonging are lower for disabled collegians compared to their peers without disabilities. They conclude that educational experiences are likely "influenced by the nature of [one's] disability, whether it is visible or not, and the levels of stigma and acceptance experienced by students" (p. 7). Attending college can expose students to a wide range of social networks, which contributes to a sense of belonging. However, some disabilities may reduce students' opportunity to participate in social activities, make friends, work on teams, or collaborate with faculty in specialized, technical fields like STEM where such interactions are common.

A small handful of studies explore sense of belonging among disabled college students in STEM fields. Friedensen et al. (2021) conducted 16 semi-structured interviews to explore the barriers faced by students with hidden disabilities in STEM fields at a public research university in the northeastern region of the United States. Using a cross-case comparative design, they found that faculty and peer behaviors, as well as perceptions of the STEM environment, created significant obstacles for disabled students' success. For example, the competitive nature of STEM learning environments make it difficult to process information due to feeling rushed to respond quickly or outperform peers. Faculty play crucial roles, yet most respondents explained that some instructors fail to offer adequate accommodations to support their learning. Consequently, participants describe feeling out of place and unsupported, as though they did not belong in STEM.

Previous research has examined disabled students' experiences in STEM laboratories by specific disability categories. For instance, Leigh et al. (2023) presented seven case studies that outlined barriers to practical strategies that enhance accessibility, inclusion, and belonging in STEM laboratories for students with chronic illnesses and neurodivergence at the University of York. Various challenges were reported, including physical inaccessibility of laboratories, limited digital accessibility, and a lack of inclusive teaching practices. These barriers contributed to feelings of alienation, inadequate support, and social exclusion among disabled students in STEM fields.

To ensure full coverage of the existing literature on sense of belonging among disabled college students majoring in STEM, we conducted an extensive search of relevant databases such as EBSCO, JSTOR, and Project Muse using keywords like sense of belonging, college students with disabilities, and STEM. Our search yielded 7,391 academic publications including 27 reports, 273 chapters, and 679 peer-viewed journal articles. Of that latter group, we were able to access the full-text version for 220 articles and less than 50% were quantitative in design, revealing a significant gap in the literature that the present study was designed to fill.

2.5 *Restate purpose*

Recall the purpose of this quantitative study is to cast much needed attention on the experiences of college students with disabilities majoring in STEM fields at 4-year institutions in the U.S.

3. Methods

This project is part of a larger mixed methods research program investigating sense of belonging for diverse samples of college students with disabilities (e.g., Strayhorn & Johnson, 2023) that consists of qualitative (i.e., interviews) and quantitative (e.g., surveys, interventions) data. In keeping with our research questions, however, this manuscript is based on multivariate secondary analysis of cross-sectional survey data only.

3.1 *Sample*

The sample consisted of 4,518 undergraduate disabled students in STEM at four-year colleges and universities in the U.S. In this paper, STEM was defined using a dichotomous, composite variable (STEM major = 1; non-STEM major = 0); STEM fields included: biological sciences, agriculture, natural resources, physical sciences, math and mathematical fields, computer science and technology, and engineering (all subdisciplines), at four-year colleges and universities in the U.S. The majority were women (63%) and 35% were men, 2% another gender or other. About half identified as White, 14% Hispanic, 8% Black, two or more races (6%), just to name a few. The average age is 23.39

(*SD* = 7.97), 40% were 19 or younger, 34% were 20 to 23 years old, and the balance were 24 or older. Over half (65%) identified as straight/heterosexual, whereas 5% were another/prefer not to say, 7% bisexual, 3% queer/questioning, to name a few. A significant proportion (38%) were first in their family to go to college (hereafter, first-generation), though only 2% attended historically Black colleges and universities (HBCUs). In terms of ambitions, 26% aspired to attain a bachelor's degree, 32% a master's, and 34% a doctorate. While 41% of the sample live on campus, 17% live within walking distance, and 37% live farther than walking distance. Less than 10% are current or former members of the military.

Sample participants' disability status varied. Similar to the broader population (American College Health Association, 2024), 30% had a learning disability, 24% a mental health disorder, and 9% a sensory impairment. Almost one quarter (20%) had "more than one disability or impairment", whereas 12% had a "disability/impairment not listed". Three percent had a mobility impairment (See Table 1).

Table 1. Description of study sample: college STEM majors with disabilities (*N* = 4,518)

Characteristic/Experience	%
Demographics	
Women	63
LGBTQIA+	35
First-generation	38
Black/African American	8
Live on-campus	41
Disability: Learning impairment	30
Disability: Mental health issue	24

Note. Percentages reflect proportions or the summation of the highest two response options on item scales (e.g., % = "very often" + "often")

3.2 *Data collection*

Data were collected as part of a national administration of the National Survey of Student Engagement (NSSE) headquartered in the center for postsecondary research (CPR) at Indiana University. NSSE is an annual survey that measures the degree to which college students are engaged in educationally purposeful activities that nurture learning and development (Kuh, 2003). Typically distributed in the spring semester, the survey has been administered to over 500 U.S. postsecondary institutions and yielded more than 3 million total responses to date. For more detailed information about NSSE, its population size, methodology, and extraction criteria, see Kuh (2011). All respondents gave their informed consent to participate in the study, in keeping with ethical standards and institutional review board regulations.

3.2.1 *Instrumentation*

NSSE is a 191-item questionnaire designed to measure the extent to which students participate in high-impact practices (HIPs) associated with greater levels of development and learning. The instrument addresses students' educational journeys, including active and collaborative learning, student-faculty interactions, and supportive campus environments, to mention a few (Kuh, 2011).

In this analysis, items related to one's subjective evaluation of their on- and off-campus experiences were selected as proxies for students' sense of belonging. For instance, one question asked: "I feel valued by my institution?" Response options ranged from 1 (strongly disagree) to 4 (strongly agree), using a Likert-type scale found effective for assessing students' perceptions. Other questions related to specific engagement activities were included. One asked:

"About how many of your courses have included a service-learning project?" Response options ranged from 1 (none) to 4 (all). For a full list of variables, see the survey manual (Indiana University Center for Postsecondary Research, 2025).

NSSE has been widely validated in higher education research and demonstrates strong psychometric properties, including high interval consistency and reliability across various student populations (Pike, 2013). Its design allows for detailed analysis of engagement patterns and their relationship to outcomes such as academic success, persistence, and sense of belonging, even among STEM college students (e.g., Hedrick et al., 2010).

3.3 *Data analysis*

Data analysis was conducted using Statistical Package for the Social Sciences (SPSS), version 30 and proceeded in three stages. First, we computed means and standard deviations for all variables included in this analysis. Second, we calculated the frequency of on- and off-campus experiences among college students with disabilities majoring in STEM. Third, we conducted hierarchical linear regression (HLR) tests to explore the relationship between sense of belonging and on- and off-campus experiences among disabled college students in STEM. HLR refers to a statistical technique used to evaluate the relationship between one or more predictor variables and an outcome variable, where predictors are systematically added to the model in a step-by-step manner. The approach allows researchers to assess the incremental contribution of each set of predictors to the model's overall explanatory power (Moran, 2024) (See Table 2).

Table 2. Experiences of college STEM majors with disabilities (N = 4,518)

Characteristic/Experience	%
Off-Campus Experiences	
Worked off-campus for pay (1 to 15 hrs/week)	16
Worked off-campus for pay (30+ hrs/week)	9
Relaxed with friends (30+ hrs/week)	5
Took care of children, family, or parents (up to 30+ hrs/week)	28
Commuted to campus (e.g., driving, walking) (1 to 15 hrs/week)	66
On-Campus Academic	
Provided feedback on a draft or work in progress	55
Conducted research with a faculty member	22
Never taken a service-learning course (for credit)	46
Interacted positively with academic advisor	48
Interacted positively with faculty member(s)	51
Interacted positively with peers	52
Interacted positively with student services staff	38
On-Campus Non-Academic	
Participated in co-curricular activities (1 to 10 hrs/week)	48
Participated in co-curricular activities (30+ hrs/week)	1.5
Member of a social fraternity or sorority	11
Member of sports team sponsored by institution	6
Worked on-campus for pay (6 to 15 hrs/week)	14

Note. Percentages reflect proportions or the summation of the highest two response options on item scales (e.g., % = "very often" + "often")

3.3.1 *Positionality*

Researcher positionality refers to "the participants' identities, social and structural contexts, beliefs, and values that influence their practices and processes" of inquiry (Peters, 2023, p. 950). Like Corlett and Mavin (2017), we believe sharing one's positionality is important for helping readers understand "the conditions of knowledge production"-that is, the constellation of decisions, thoughts, beliefs, experiences, and "aha's" that undeniably shape why we chose this topic, how questions were framed, when/how analysis was conducted, how variables were operationalized, and so much more. Indeed, precedent has been set elsewhere for including positionality statements in quantitative studies (Tran et al., 2024).

While the study is quantitative, several aspects of this investigation could be influenced by our perspectives. For instance, authors in this study are equity-minded researchers. The first author is a tenured professor and social science researcher at a university who approaches this work from an identity-conscious, racially-affirming, strengths-based lens. The second author of this paper has lived experience championing the needs of his younger brother who has a disability, which knowingly shapes his commitment to disability awareness and advocacy. These points likely influenced our view of the topic, the words we chose, and the conclusions we drew in known and unknown ways.

Our positionalities may have influenced the study in other ways. For example, as collaborators, we seek to produce scholarship that helps to cultivate sense of belonging for all students, particularly those who have been historically excluded or overlooked in higher education. This critical quantitative stance (Stage, 2007) stoked our intellectual curiosity to know more about the relationship between sense of belonging and disabled students' on- and off-campus experiences within the sample, as a way of using such information to create conditions for students with disabilities in similar contexts.

4. Results

RQ: What is the relationship between sense of belonging and on- and off-campus experiences among college students with disabilities majoring in STEM?

A hierarchical linear regression analysis evaluated the relationship between sense of belonging and on- and off-campus experiences among college students with disabilities majoring in STEM. Results suggest the linear combination of measures accounted for a significant proportion of the variability in sense of belonging scores within the sample, $F(22, 4{,}517) = 117.64$, $p < 0.001$, $R = 0.604$, $adj.R^2 = 0.362$, indicating that disabled college students majoring in STEM who had short(-er) commutes to campus and generally positive interactions with faculty, staff, and peers tended to feel a stronger sense of belonging in college. Statistically significant predictors of sense of belonging among STEM majors with disabilities include: instructors provide test feedback, instructors explain course goals, instructors teach in organized ways, instructors provide draft feedback, service learning courses, quality of interactions (QI) with academic advisors, QI with faculty, QI with peers, QI with student services staff, work off-campus for pay, and hours commuting to campus.

Interestingly, the sequential design of the regression model enabled us to evaluate whether certain off-campus experiences (formal or informal) predict sense of belonging scores over and above forms of on-campus experiences (formal or informal) among STEM majors with disabilities, in keeping with our conceptual framework. The six off-campus measures accounted for a significant proportion of variance in sense of belonging scores, after controlling for the effects of 16 on-campus experience measures, $\Delta R^2 = 0.009$, $\Delta F(5, 4{,}495) = 12.379$, $p < 0.001$. Results suggest that STEM majors with disabilities who have similar on-campus experiences feel a stronger sense of belonging if (and when) they live on-campus, stay within walking distance, or work on-campus for pay. Table 3 presents a summary of the hierarchical linear regression results.

Table 3. Regression results: Predicting sense of belonging from on- and off-campus experiences among disabled college students in STEM (Model 4)

Variables	Unstd. B	SE	B
Constant	0.816	0.07	-
Attended an art exhibit, play or performance	0.017	0.01	0.020
Asked questions, contributed to class discussions	0.008	0.01	0.009
Instructors provided feedback on tests and assignments	0.041**	0.01	0.050
Instructors clearly explained course goals	0.083**	0.02	0.086
Instructors taught courses in organized ways	0.081**	0.02	0.086
Instructors provided feedback on drafts	0.032**	0.01	0.041
# service-learning courses	0.060**	0.01	0.056
QI: advisors	0.043**	0.01	0.101
QI: faculty	0.100**	0.01	0.186
QI: students	0.112**	0.01	0.206
QI: student services	0.053**	0.01	0.113
Discussions with people of different race	-0.010	0.01	-0.012
Working on-campus for pay (hours/week)	-0.006	0.01	-0.011
Co-curricular activities (hours/week)	-0.001	0.01	-0.002
Fraternity/sorority member	0.014	0.03	0.006
Student-athlete	-0.052	0.04	-0.016
Preparing for class (hours/week)	0.007	0.01	0.016
Socializing with friends (hours/week)	-0.001	0.01	-0.002
Volunteer work (hours/week)	0.009	0.01	0.014
Working off-campus for pay (hours/week)	-0.017**	0.004	-0.051
Providing care for dependents (hours/week)	-0.004	0.01	-0.011
Commuting to campus (hours/week)	-0.042**	0.01	-0.070

** $p < 0.001$

5. Limitations

As with all studies, this project is not without limitations. One limitation relates to the self-reported nature of NSSE data. Self-reports are subject to social desirability bias and recall errors. While self-report surveys are a standard methodology in educational research (e.g., Anaya, 1999), they provide subjective, rather than objective, accounts of engagement and outcomes.

Another limitation is related to secondary analysis of pre-existing data. In such studies, analysis can be constrained by measurement choices made by previous researchers such as the way in which scales and items have been operationalized; this, of course, may place limits on the psychometric properties of indicators (Koljatic, 1999). To the

extent this occurred, generalizability of results may be reduced.

Despite these limitations, this study is important, timely, and represents a worthy contribution to the growing body of research on college students with disabilities in STEM fields and highlights the transformative role that on- and off-campus experiences can play in fostering their sense of belonging.

6. Discussion

Recall that the purpose of this quantitative study was to cast much needed attention on the experiences of college students with disabilities majoring in STEM fields at 4-year institutions in the United States (U.S.). Using a conceptual framework that differentiates on- and off-campus experiences that are more academic/faculty-focused from those that are social/peer-focused or more general in nature, we analyzed survey data from over 4,000 STEM majors with disabilities using a blend of descriptive and multivariate statistics. Results are useful for painting a statistical portrait of college students with disabilities majoring in STEM fields, highlighting who they are and what they do on- and off-campus.

First, results from the present study help paint the broad contours of a statistical portrait of STEM majors with disabilities. Sample demographics suggest that most are white, women, living off-campus, nearly a quarter work for pay on-campus, and 28% spent over 30 hours per week caring for dependents. Approximately one-third report having a learning disability, where about one-quarter report mental health issues.

Whereas demographic data give us a sense of who STEM majors with disabilities are, other results reveal what they do, both on- and off-campus. Almost a quarter conducted research with a faculty member; nearly half had never taken a service-learning course. Yet, research and service-learning have been identified as HIPs given their ability to produce robust learning outcomes in students (Kilgo et al., 2015). Recall Gin et al. (2022) reported that 12% of undergraduate disabled students engage in research, which is much lower than results based on our analytic sample. Our sample numbers are likely higher due to the fact that many NSSE institutions are research universities or that all of our participants are STEM majors-studying in scientific/technical fields where UREs are common, prevalent, and, in some cases, required at certain institutions. It may also be the case that STEM faculty at comprehensive or liberal arts NSSE institutions took proactive steps to market research opportunities in ways that attract students with various disabilities. For instance, effective marketing materials incorporate accessibility features such as alternative (ALT) text, screen readers, and high-contrast settings to recruit STEM majors with sensory (e.g., visual) or learning disabilities. Results suggest that STEM faculty at other institutions would do well to collaborate with disability services specialists to develop inclusive marketing campaigns, connect with disabled student networks, and sustain the support that ensures students' success as undergraduate researchers.

Another HIP is study abroad (Kilgo et al., 2015). Yet our results, like others (Heirweg et al., 2019), indicate that very few STEM majors with disabilities have done so. This is consistent with general findings about study abroad-Wanger et al. (2020) noted: "...while campuses within the [U.S.] collectively enroll a growing number of international students, the number of American students studying abroad during an undergraduate degree program remains consistently low" (p. 1). Causes for underparticipation in study abroad are likely many. For instance, a sizeable proportion of our sample identified as students of color or international students studying in the U.S. Some international (and domestic) students are reluctant, if not unwilling, to study abroad due to restrictive immigration laws, border control issues, and current political actions denying re-entry for student VISA holders (Bound et al., 2021). Additionally, studying abroad is not for the faint of heart (Heirweg et al., 2019). It may involve transferring credits, securing lodging, and learning a foreign language (Vossensteyn et al., 2010), which can disadvantage disabled students without necessary support. Other aspects of studying abroad can be difficult for students with disabilities-moving briskly through big airports, standing in long customs lines, dealing with impatient airport/transportation security administration (TSA) staff, managing anxiety on planes amid take-off, landing, and turbulence, as well as paying exorbitant costs for passports, VISAs, plane tickets, and the like (Kasravi, 2018). To increase participation among STEM majors with disabilities, study abroad coordinators might partner with disability services to identify and address potential barriers early in the planning process, develop relationships with international institutions to narrow lodging options or other accommodations, and establish peer mentoring programs that connect disabled STEM students with students who

have successfully studied abroad. All staff-whether academic or airport-should be trained on disability rights, anti-discrimination laws, customer service, universal design for learning (UDL) principles, and unconscious bias.

Study results provide evidence that sense of belonging is related to the frequency and nature of disabled STEM students' on- and off-campus experiences. STEM majors with disabilities who get more feedback from instructors on tests (or assignments) tend to feel a stronger sense of belonging, compared to their peers who receive little to no feedback. Furthermore, STEM majors with disabilities whose instructors clearly communicate course goals, teach in organized ways, and provide more feedback on drafts tend to have a higher sense of belonging than their peers whose instructors fail to communicate, teach without structure, and provide little to no feedback on drafts. Findings from the present study are consistent with other studies (Kirby & Thomas, 2022). Applied to practice, faculty development programs might prioritize training that helps instructors, particularly in STEM fields, understand the importance of growth-minded feedback and how to provide it to students frequently through assignments, tests, and early drafts. Academic deans and department chairs might adopt standards that ensure all instructors clearly articulate course objectives in syllabi and discuss them with students in-class. Aligning course objectives with program outcomes can be helpful for differently-abled students who need consistency, predictability, and routine to thrive. Structure helps them feel safe, secure, and reduces anxiety and stress (Breitenbach et al., 2012), which, in turn, may facilitate a sense of belonging, according to our study results.

In addition to instructor practices, service-learning courses can also play a vital role in cultivating a sense of belonging among marginalized populations (Soria et al., 2019). Our results suggest that taking more service-learning courses boosts sense of belonging among STEM majors with disabilities. Coordinators of service learning and faculty members should prioritize integrating service-learning opportunities into STEM curricula and ensure these courses are accessible for differently-abled students. Academic advisors can also play a role, encouraging disabled STEM students to take more service-learning courses, especially if/when advising students who feel alienated, isolated, or lonely.

Our study shows that STEM students work on- and off-campus for pay, consistent with previous studies (e.g., Cardoso et al., 2016). It's likely true, but unfortunate, that STEM majors with disabilities may encounter significant challenges finding suitable on-campus employment that fits their specific needs (Marr, 2015). As a result, they may have to look off-campus for work that's more flexible, even if it means working longer hours. Working long hours off-campus for pay negatively impacts their sense of belonging, according to our study. Student employment staff should take steps to circulate broadly information about on-campus, paid work opportunities; use appropriate hashtags and listservs to connect with disabled student networks. Hiring staff should ensure job postings are accessible to all students, using plain language that describes job responsibilities, duties, and time requirements. Requirements should be communicated reasonably to help students assess their fit for the roles, in light of other school- and family commitments. Roles should comply with fair labor standards that prevent supervisors from overworking student employees. Overworking student employees, especially those employed off-campus, is not only stressful, it can reduce their sense of belonging, which, theoretically, undermines achievement, compromises retention, and threatens degree completion.

Much that has been written focuses on legal requirements for reasonable accommodations (Krebs, 2019) without noting practical strategies that prove useful for students with disabilities, particularly in STEM fields. Results from our study highlight several promising pedagogical practices and classroom cultures that help facilitate sense of belonging among STEM majors with disabilities. For instance, study results affirm the importance of STEM environments where students feel safe asking questions and can expect constructive feedback from instructors who teach in organized ways. Extending advice from others (Black et al., 2015), we recommend implementing UDL principles in classrooms as a way of enhancing student participation, engagement, and academic success among disabled STEM majors. For example, STEM faculty should incorporate clear, accessible language in labs and lectures, while providing ongoing feedback to accommodate diverse learning styles using simple explanations of complex concepts such as quantum mechanics or JAVA computer programming and adjusting instructional pacing based on students' comprehension and mastery of the material.

Not only do STEM majors with disabilities engage with faculty, but they also spend time with peers and student services staff. In the present study, just over a third of students in our sample interacted positively with student services staff, while others reported much better relationships with faculty and peers. Our findings add to the literature on disabled students' relationships with campus personnel (Moriña, 2019) by assessing the favorability of their interactions with career services, student activities, and housing staff, to name a few. It may be the case that traditional campus

activities are not designed with these students in mind, according to our results. To improve the nature of relationships between student services staff and STEM majors with disabilities, we recommend more inclusive programs and practices. For instance, staff can modify activities such as intramural sports to make them more accessible, vis-a-vis wheelchair basketball or sitting volleyball. Staff might also regularly evaluate sports equipment by conducting accessibility audits, seeking feedback from disabled students, or collaborating with disability support teams to ensure they meet the needs of students with varying levels of (dis)ability.

To this end, we make several recommendations. STEM faculty should normalize help-seeking and intentionally offer a variety of non-intrusive ways for all students, like our participants, to ask questions in class using live polls, short message service (SMS) text messaging, whiteboards, and written notes. Keep in mind, talking is only one way to communicate and some students talk with their hands (e.g., ASL) not their mouths. Academic program coordinators would do well to ensure all STEM classes follow UDL principles and best practices for disability inclusion by granting students advance access to lecture notes when possible, recorded class sessions, multimedia materials (with captions), text-to-speech technologies, and alternative assessments (e.g., writing a paper, making a video); providing feedback on such assignments positively influences sample students' sense of belonging. Teaching assistants, on the other hand, might respond to questions posed in the learning management system (LMS) to offer ongoing support and can make themselves available during office hours to provide feedback on drafts for students who need help making sense of abstract STEM concepts like carbonation, programming languages (e.g., C+), mitosis, mathematical proofs, or entropy. Let's be clear, STEM subjects are generally difficult and students are going to have questions in some form or fashion. But asking questions shouldn't make them feel inadequate, incompetent, or invisible; it should empower them to deepen their understanding, build STEM self-efficacy, and fully engage in their learning, which results in greater sense of belonging.

Sense of belonging matters for all students' educational success, even in STEM fields (Hedrick et al., 2010; Strayhorn, 2019). Results from the present study indicate that a variety of factors contributes to belonging for STEM majors with disabilities, some on- and some off-campus, some academic and some non-academic in nature. Importantly, findings affirm the usefulness of the study's conceptual framework. All in all, measures included in the last and final model explained nearly 40% of the variability in the sample's belonging scores, which is notable as it's generally higher than what most social science regression-based studies can account for (Von Eye & Schuster, 1998) and well above the 5% typically explained by ecologists and biologists for instance (Møller & Jennions, 2002).

Findings from the present study have significant implications for policy and future research. For instance, results support the use and effectiveness of UDL practices (e.g., giving advance feedback on assignments) in STEM learning environments. But typically, use of such designs is left to chance with individual faculty members. Deans and academic program coordinators might consider these results when formulating new or revising existing policies that govern teaching excellence, standardizing incorporation of UDL principles in all STEM courses.

The study has other implications for policy. We uncovered statistical differences across disability types; thus, institutions should prioritize collecting disaggregated data on students, including STEM disabled students. Datasets might include information about their on- and off-campus, academic- and social experiences in internships, co-op programs, and student teaching placement. Storing this data in student information systems can be facilitated by linking students' academic records with medical history and their campus ID card that tracks their involvement and use of student services and supports. Such data would offer insights into how specific disabilities influence experiential learning, guiding efforts to create more accessible and inclusive support systems in STEM fields.

The present study also has significance for future research. To date, studies have primarily focused on disability experiences with little attention to on- and off-campus experiences of STEM students with disability (Fox et al., 2021). Data from the present study might be used to extend previous findings by conducting longitudinal investigations that track STEM disabled students throughout college, well into graduate school and beyond. While the present study provides valuable insights into STEM-specific experiences (e.g., internships, UREs), longitudinal data would highlight how support needs and barriers may evolve over time. Additionally, comparative analyses across multiple institutions could help identify best practices for supporting diverse disability populations in STEM fields at predominantly white institutions (PWIs) and HBCUs, potentially leading to more targeted and effective interventions.

7. Conclusion

This large-scale quantitative investigation sought to measure differences in the on- and off-campus experiences of STEM majors with disabilities, paying close attention to factors related to their sense of belonging in college. The weight of evidence presented in this article documents that on- and off-campus experiences shape sense of belonging among STEM majors with disabilities. Similarly, instructor feedback on assessments, well-organized course designs, and high-quality interactions with others on- and off-campus nurture feelings of connectedness and support that boost belonging. Findings underscore the need for institutions to create high-touch, inclusive environments that consider the unique needs of STEM students with varying levels of (dis)ability. Addressing these nuanced experiences through tailored academic support and accessible learning environments could improve overall engagement and sense of belonging among STEM students with disabilities. Insights from this study can act as a playbook of sorts, helping to pave the way forward.

Conflict of interest

The authors declare no conflict of interest.

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