A Review of Inclusive Practices and Language to Advance Scientific Identity of Marginalized Undergraduate Biology Students

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Abstract

This paper had a goal to do a thing and it achieved that thing with relative success.

Contents

1 Introduction

This review was developed in order to promote diversity, equity, and inclusion (DEI) within the undergraduate biology and/or science, technology, engineering, and mathematics (STEM) settings. Specifically, this review aims to provide literature and recommendations to advance marginalized students' scientific identity (Sci-ID). Moreover, this review proposes an extension of the definition of Sci-ID drawing from the principles of computational identity (CI).

1.1 Scientific identity

Scientific identity (Sci-ID) is broadly defined as an identity model of one's inner sense of their alignment with science: whether or not they are a "science person".[1] Oseguera et al. 2019 found that Black students had significantly lower Sci-ID than their white counterparts and identified that Sci-ID is a strong predictor of persistnce in science. Moreover, the study found that intervention targeted towards improving Black students' Sci-ID is successful in raising Sci-ID to levels comparable to their white counterparts.[2]

Sci-ID development, therefore, is important to understand. Salehjee 2018 establishes a seven-domain conjugated model of Sci-ID development. Sci-ID is influenced by: (1) global forces, such as one's identity, (2) social agencies and agents, such as educational institutes, teachers, and parents, (3) transformational learning experiences, including accidental and planned events that shapes one's perception of science, (4) one's openness to new information, (5) personal preference that selects for favored learning experiences, (6) individual internal agency, or one's internal drive to develop their Sci-ID, and (7) their core identity, which can be stable or fluid. Domains 1-3 direct information through domains 4-6, which filter what information acts on and develops domain 7, the core Sci-ID.[1]

Sci-ID's development is well-defined, however, Sci-ID itself varies in definition across literature. Thus, this review proposes a three-part definition drawing upon an analog from computer science: computational identity (CI). Brousseau and Sherman 2019 defines CI as a key factor in students' persistence in the pursuit of computing comprising of three components: (1) the perception that computing is useful, (2) self-efficacy in computing, and (3) a sense of belonging in computing.[3] Using this definition, this paper proposes a generalization of CI to Sci-ID, defining Sci-ID by three analogous components: (1) the perception that science is useful, (2) self-efficacy in science, and (3) a sense of belonging in science.[3] This definition is summarized in figure 1.

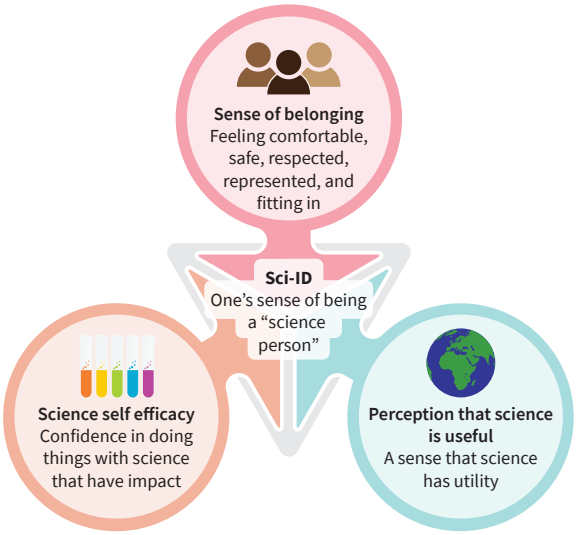

Figure 1: **Defining scientific identity (Sci-ID): a three-component system.** This diagram summarizes the definition of Sci-ID and its three components: (1) the perception that science is useful, (2) science self efficacy, and (3) a sense of belonging in science.

Perception that science is useful

An integral aspect of one's Sci-ID is one's perception that science is useful, in other words, they must have a sense that science is "worth doing". Moreover, one must feel that science is functional and applicable to their life. This is important as, per Eccles' expectancy-value theory[4], the higher a student's subjective task value for science (their perception of the value and utility of learning and doing science), the more motivated they are to persist in science.[3] This perception that science is useful is critical to one's Sci-ID as it directly impacts their motivation and persistence in science.

Science self efficacy

Science self-efficacy is one's own confidence in their ability to do science.[5] To elaborate, it is one's sense that not only can they do science, but in combination with their perception that science is useful, the things they can do with science have utility and impact.[3] Bandura

[1] Salehjee 2018.
[2] Oseguera et al. 2019.
[3] Brousseau and Sherman 2019.
[4] Wigfield and Eccles 2000.
[5] Ballen et al. 2017.

1993 found that one's self efficacy is a strong indicator of one's anxiety, motivation, and performance in a given domain; high self-efficacy conflates with strong performance and motivation with minimized anxiety whereas low self-efficacy is accompanied by high anxiety, a lack of motivation, and poor performance.[6] Thus, it becomes apparent that science self efficacy is critical to one's Sci-ID; their confidence in science directly impacts their motivation to persist and their performance.

Sense of belonging in science

A student's sense of belonging consists of two major components: comfortability and fitting in; these components manifest across three domains: environment, relationships, and involvement. Students feel as though they belong when they feel comfort with others and in their surroundings and that they fit in with others and their surroundings on their campus.[7]

Developing a sense of belonging differs between marginalized and privileged students. It is important to understand how to support a sense of belonging for both types of students.[7] Figure 2 summarizes the key elements of the development of the sense of belonging and how it differs between privileged and marginalized students across the three domains. Vaccaro and Newman 2016 found key differences emerge when analyzing the sense of belonging for marginalized students. In addition to feeling comfortable and fitting in, marginalized students value safety and respect where they feel physically safe in their settings, welcomed, accepted, and that both themself and their culture are respected.[7]

Students' environment impacts their sense of belonging; this impact varies greatly between marginalized and privileged students. Privileged students feel a sense of belonging in environments in which they describe as friendly, fun, and comfortable; these students typically attribute a sense of belonging exclusively to positive descriptors regarding their environment. Marginalized students, however, typically feel a lack of belonging in their environment as a result of feeling like the "only one" due to a lack of campus diversity and a restriction of authenticity in their expression due to judgement from peers and unfair treatment. Thus, marginalized students require support in their authentic expression and diverse representation to feel belonging in their environment.[7]

Relationships are critical to students' sense of belonging. Privileged students seek a sense of familiarity with others, having fun, and receiving support in tasks in order to feel a sense of belonging. Marginalized students, rather, require deep connection and the ability to be comfortably authentic in their relationships in order to have a sense of belonging. Moreover, marginalized students may actively reject relationships that do not embrace their authentic expression.[7]

Involvement, too, is crucial to students' sense of belonging. Again, privileged and marginalized students value different aspects of belonging in involvement. Privileged students value fun and enjoyable involvement and when their involvement has a perceivable impact. Marginalized students, on the other hand, require involvement that allows and encourages authentic expression. Further, marginalized students value involvement that fosters authentic conversations and connections. This sense of authenticity is critical for marginalized students; involvement that did not nurture this authenticity did not foster belonging for these students and often led to these students discontinuing their involvement.[7]

Therefore, a marginalized students' sense of belonging is critical to their development and maintenance of Sci-ID, and thus, their performance and persistence in science. Their sense of belonging must be prioritized and nurtured, along with the other aspects of their Sci-ID.

1.2 Nurturing scientific identities of marginalized students

Given the dependence of marginalized students' perserverance and performance in science on scientific identity (Sci-ID), it becomes increasingly apparent that educational institutions must nurture marginalized students' Sci-IDs. For the undergraduate sciences, this paper presents a glossary of diversity, equity, and inclusion (DEI)-oriented terms sourced from recent academic journal articles, domain-specific recommendations, and an index of diverse and accurately-represented scientists to be used by undergraduate professors to nurture the Sci-ID of marginalized students and proposed studies to evaluate the efficacy of these recommendations and resources.

2 Methodology

The resources provided in this paper — the glossary, recommendations, and index of diverse and accurately-represented scientists — are suggested for use to develop the scientific identity based upon reviewed literature. They, however, have not been validated. Thus, this paper provides a proposed study design accompanied by survey instruments to collect student identities, measure scientific identity of students, quantify instructor adherence to guidelines, and calculate a coefficient of relevance representative of the degree to which these guidelines should apply to the course. These materi-

[6] Bandura 1993.
[7] Vaccaro and Newman 2016.

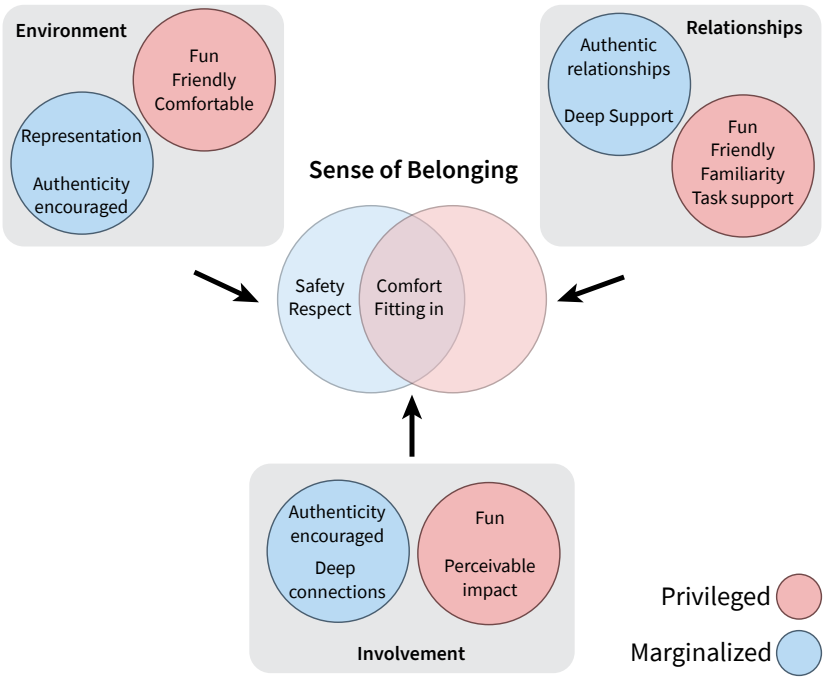

Figure 2: **Model of belonging differs for privileged and marginalized students and is dictated by involvement, relationships, and environment.** This diagram, sourced from Vaccaro and Newman 2016, summarizes key components of a sense of belonging and how those differ between privileged and marginalized students across environment, relationships, and involvement. Privileged students are represented in red and marginalized students are represented in blue.

als are to be used to evaluate the utility these resources have in and assess the role of student identities in the development of student Sci-ID.

3 The Glossary

The glossary was constructed from a review of literature. The glossary lists:

▶ inclusive terms
that are suggested for use by individuals that are not part of the community and/or identity being discussed which are denoted with a ▶ and highlighting them in blue.

◀ exclusive terms
that are not suggested for use by individuals that are not part of the community and/or identity being discussedthat do not identify with the identity in reference which are denoted with a ◀ and highlighting them in gray.

It should be noted that these classifications are based on their use by individuals who are not a part of the community and/or identity being discussed; Ultimately, individuals who identify with the identity and/or community being discussed should be listened to and their self-identified labels and chosen terminology should be used. Self-labelling and chosen terminology is, typically, a result of personal context, intersectionality, self-agency, and, in some cases, a form of resistance.[8] It should be the right of individuals who identify with the identity and/or community to make these choices as it empowers them and centers their needs and autonomy in discussions regarding them. [9]

Additionally, these classifications make no indication on the moral good or bad of the term they are describing, rather they indicate the general acceptability of using that term to describe the phenomenon.

[8] Wagaman 2016.
[9] Botha, Hanlon, and Williams 2021.

Finally, it should be noted that, in this paper, these definitions are categorized under the category of which they are most related to. This method of categorization, however, is not representative of intersectionality of identities. Thus, readers are encouraged to visit the digital glossary at github.com/ec-belonging-in-biology/sci-id-development where each definition is tagged with each of its relevant categories and can be filtered, which better represents the intersectional nature of the terms defined herein.

3.1 General

▶ equality
the ideal that every individual receives the same amount of resources and opportunities.[10]

▶ equity
the ideal that every individual is allocated a variable amount of resources and opportunities to (1) counterbalance any disadvantage not resulting from an individual's choice and (2) to reward or punish in proportion to an individual's contribution to an impact or outcome.[10]

▶ diversity
the heterogeneity, in otherwords, the sense of individual uniqueness, of people as a result of each person's individual ideologies, identities and lived experiences.[11]

▶ marginalization
the act of a society deplatforming and pushing people away from economic, sociopolitical, and cultural participation on the basis of identity, lived experience, and/or ideology that ultimately results in a maintained power imbalance between the dominating and marginalized identities and leads to deterioration of marginalized persons.

▶ accountability
in the social justice context, an individual and/or group's sense of responsibility as a result of their identity both privileging them at the expense of the marginalization of a group and providing them agency to use their privilege to align with and support the marginalized group.[12]

▶ personal accountability
the actions taken by an individual to hold themselves accountable in advancing a collective approach towards tansforming higher oppressive systems. While this is important, personal accountability should not be the focus of accountability as it undermines accountability's emphasis of collective action.[12]

▶ collective accountability
the collective action taken by a privileged group to hold themselves accountable in dismantling large-scale oppressive systems.[12]

▶ ally
an advocate or supporter of margianalized groups who jabe a reasonable understanding of the inequities and discrimination margianalized groups face and recognize their part in perpetuating the status quo that ultimately opresses these groups. [13]

▶ culture
a learned and dynamic social and individual construct that is a descriptive part of one's identity that manifests at several different depths, affects one's social and biological behavior and interpretations and perceptions of others' behaviors, ranges in applicability from individual to global used to associate with a social group. Individuals who identify as a part of a culture may vary in their degree of association and which aspects of a culture they specifically associate with.[14]

▶ cultural appropriation
the act of individuals who do not identify as part of a culture stealing expressions, artifacts, intellectual property, history, and ways of knowledge from said culture without permission. [15] This can manifest itself in one of at least three forms: subject, content, and tangible object appropriation.[16]

▶ cultural subject appropriation
the representation of a culture by someone who is not part of that culture, such as a non-Indigenous person making a documentary on Indigenous peoples. [16]

▶ cultural content appropriation
the use of a culture's property as a part of a cultural outsider's work, such as a white Internet influencer's use of African American Vernacular English in their content. [16]

▶ cultural tangible object appropriation
the stealing of culturally-significant artifacts, human remains, and/or destruction of culturally-significant landmarks,[16] such as the desecration of the Black Hills, sacred to the Lakota Sioux, into Mount Rushmore.[17]

Acknowledgements

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[10] Frønes et al. 2020.
[11] Kvam, Considine, and Palmeri 2018.
[12] Wooldridge 2019.
[13] Nash et al. 2021.
[14] Spencer-Oatey 2012.
[15] Howard 2020.
[16] Lalonde 2021.
[17] Cottrell 2020.

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A Instruments

Instrument 1: **Quantification of Sci-ID (QOS)** This survey instrument consists of several questions to measure a student's Sci-ID over its three domains — self-efficacy, sense of belonging, and perception that science is useful — and their cumulative effect.

Science Self-Efficacy			
Question	**Options**	**Purpose**	**Format**
To what degree do you agree with the following statements: - Science is hard - Science is something I can do - I can become good at science - I can do useful things with Science	- Disagree - Somewhat disagree - Neither agree nor disagree - Somewhat agree - Agree	Assess the student's perceived science self-efficacy	Matrix 5-point likert
Complete the following statement: When I'm stuck on something in science,	- I can usually figure it out right away - It takes some time, but I can usually work it out - I often can't figure out the problem - I don't even know where to start - Other (please elaborate)	Assess the student's science self-efficacy	Select one with "other"
Perception of Science Utility Based in Expectancy-Value Theory			
To what degree do you agree with the following statements: - Science can be used to solve "real-world" problems - Science is useful for everyday life - Science is worth doing - I need to keep studying science for it to be useful	- Disagree - Somewhat disagree - Neither agree nor disagree - Somewhat agree - Agree	Assess the student's perception of science's utility based upon expectancy-value theory	Matrix 5-point likert
Complete the following statement: I want to learn science because,	- I think it's interesting - I think it's useful - It will help me accomplish professional goals (e.g. career, graduate school) - It will help me accomplish personal goals (e.g. creative or meaningful projects) - Other (please elaborate)	Assess the student's value of science's utility based upon the expectancy-value theory	Select all that apply with "other"
Sense of Belonging in Science			
To what degree do you agree with the following statements: - Science is something people like me do - I belong using science, in other words, science is for me - I want to learn science because I think I could be good at it	- Disagree - Somewhat disagree - Neither agree nor disagree - Somewhat agree - Agree	Assess the student's sense of belonging in science	Matrix 5-point likert

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Question	Options	Purpose	Format
Complete the following statement: When I see others who are better than me at science, I	- am inspired - feel discouraged - don't care - Other (please elaborate)	Assess the impact of the student's sense of belonging	Select all that apply with "other"
Effective/Cumulative Sci-ID			
To what degree do you agree with the following statements: - Science is an empowering skill - I can use science to make powerful/meaningful change in my life - I can use science to make powerful/meaningful change in my community - I prefer getting an assignment from a textbook over choosing my own topic - Learning about science make me see opportunities to apply it in everyday life	- Disagree - Somewhat disagree - Neither agree nor disagree - Somewhat agree - Agree	Assess the student's perceived effective Sci-ID	Matrix 5-point likert
To what degree do you agree with the following statement: I can do real things with science	- Disagree - Somewhat disagree - Neither agree nor disagree - Somewhat agree - Agree	Assess the student's perceived cumulative Sci-ID	Matrix 5-point likert

Instrument 2: **Qualitative Identity Inventory (QII)** This survey instrument asks participants several questions to obtain a comprehensive and accurate representation of their identity and determine which underrepresented identities they may possess including ability, race, ethnicity, sexuality, religion, socioeconomic status, gender, reproductive ability, body size, campus involvement, parental status, place of birth, on-campus housing status, immigrant status, language, and prior education.

Activity			
Question	**Options**	**Purpose**	**Format**
How many hours per week do you do unpaid organizational activities (e.g. clubs, organizations, volunteer work, internships, etc …)?	Any integer greater than or equal to 0	Assess the amount of the student's available time dedicated to involving themselves in their communities	Integer
How many hours per week do you do unpaid organizational activities (e.g. clubs, organizations, volunteer work, internships, etc …)?	Any integer greater than or equal to 0	Assess the amount of the student's available time dedicated to involving themselves in their communities	Integer
How many hours per day do you have lectures?	Any integer greater than or equal to 0	Assess the amount of the student's available time dedicated to academic studies	Integer

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Question	Options	Purpose	Format
How many hours per day do you have labs and studios?	Any integer greater than or equal to 0	Assess the amount of the student's available time dedicated to academic studies	Integer
How many hours per day do dedicate for studying?	Any integer greater than or equal to 0	Assess the amount of the student's available time dedicated to academic studies	Integer
How many hours per day do you have unstructured/unscheduled for daily tasks and self-care?	Any integer greater than or equal to 0	Assess the amount of the student's available unstructured time	Integer
How many hours per night do you sleep?	Any integer greater than or equal to 0	Assess the sleep the student is getting	Integer
Disability & Neurodivergence			
How difficult are the following tasks, 0 being no more difficult being no more difficult than the average person, 10 being impossible? - Personal care (e.g. washing, dressing) - Lifting 25 lbs - Walking - Sitting - Standing - Sleeping - Maintaining a sex life - Travelling - Eating	Any integer greater than or equal to 0 but not more than 10	Assess the impact any condition(s) a student may have on their physical abilities	0 - 10 point integer scale matrix
How difficult are the following tasks, 0 being no more difficult being no more difficult than the average person, 10 being impossible? - Maintaining a social life - Maintaining attention - Reading - Managing worries and anxiety - Managing feelings of anger - Managing feelings of sadness or disappointment - Meeting social expectations - Meeting deadlines - Communicating adequately	Any integer greater than or equal to 0 but not more than 10	Assess the impact any condition(s) a student may have on their mental health	0 - 10 point integer scale matrix
On an average day, when at rest, what is your pain on a scale from 0 - 10, 0 being no pain, 10 being the worst pain you've ever felt?	Any integer greater than or equal to 0 but not more than 10	Assess the magnitude of the student's baseline chronic pain (if any)	0-10 point integer scale

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Question	Options	Purpose	Format
How do you feel about the size of your body?	- I think I should be a lot bigger - I think I should be a bit bigger - I think I should be the size that I am now - I think that I should be a bit smaller - I think I should be a lot smaller	Assess the student's perception of their body size	Select one
Origin & Language			
What country were you born in?	Any name of a country; see options appendix for full list	Assess the student's degree of displacement from family and native culture and social and systemic barriers they may have encountered	Select one
How many of your guardians are immigrants?	Any integer greater than or equal to 0	Assess the student's nuclear family's degree of displacement from family and native culture and social and systemic barriers they may have encountered	Integer
How long, in years, has it been since you lived in your country of origin? (If you currently live in your country of origin, enter 0)	An integer greater than or equal to 0	Assess the student's degree of displacement from family and native culture	Integer
What languages can you use with a proficiency of conversational or greater?	Any language(s); see options appendix for full list	Assess the multilingual competency of the student	Select all that apply with search helper
How fluent are you in the language in which your classes are taught?	- Native speaker - Fluent - Proficient - Conversation - Beginning - Not at all	Assess the degree to which language may impose a barrier in the student's education	Select one
How many languages did you learn before learning the language in which your classes are taught?	Any integer greater than or equal to 0	Assess the degree to which language may impose a barrier in the student's education	Integer
How long, in years, have you known the language in which your classes are taught?	Any integer greater than or equal to 0	Assess the degree to which language may impose a barrier in the student's education	Integer
Prior Education & Support			

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Question	Options	Purpose	Format
Are you a first generation college student?	Yes or No	Assess the support from guardian experience available to a student	Select one
How much effective support did your family provide to you in k-12 education on a scale from -5 to 5, -5 being strong antagonism, 0 being no antagonism nor support, 5 being strong support	Any integer greater than or equal to -5, but not more than 5	Assess the support from guardians provided to a student	-5 to 5 integer scale
How much effective support does your family provide to you in undergraduate education on a scale from -5 to 5, -5 being strong antagonism, 0 being no antagonism nor support, 5 being strong support	Any integer greater than or equal to -5, but not more than 5	Assess the support from guardians that continues to be provided to a student	-5 to 5 integer scale
In high school, how many courses were offered that could get you college credit?	Any integer greater than or equal to 0	Assess the resources available to the student in their high school	Integer
In high school, how many courses did you take that could get you college credit?	Any integer greater than or equal to 0	Assess the resources utilized by the student in their high school	Integer
In high school, how many hours did you work per week during the school year at a job out of necessity?	Any integer greater than or equal to 0	Assess the degree to which financials imposed a barrier to the student.	Integer
In high school, how many hours did you work per week during the summer at a job out of necessity?	Any integer greater than or equal to 0	Assess the degree to which financials imposed a barrier to the student.	Integer
Race & Ethnicity			
What is your race?	- Asian - Alaskan Native - Pacific Islander - Native Hawaiian - Black - Latina/o/e/x - Hispanic - Middle Eastern - White	Assess the magnitude of potential social and systemic barriers posed to the student	Select one
What is your ethnicity?	Any ethnicity(ies); see options appendix for full list	Assess the magnitude of potential social and systemic barriers posed to the student	Select all that apply with search helper
Religion			

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Question	Options	Purpose	Format
What is your religion?	Any religion(s)	Assess the magnitude of potential social and systemic barriers posed to the student	Select all that apply with helper search
On a scale from 0 to 5, 0 being not at all, 5 being most important, how important is religion to you?	Any integer greater than or equal to 0, but not greater than 5	Assess the magnitude of potential social and systemic barriers posed to the student and degree to which their religion influences their life	Select all that apply with search helper
Sex & Gender			
What pronouns do you use?	- Any set of pronouns; see options appendix for full list	To use to discuss particular cases while respecting the student's pronouns.	Select all that apply with helper search
To which degree do you align with the following genders, 0 being the least, 5 being the most? - Nonbinary - Female - Male - Bigender - Trigender - Gender fluid - Agender - Questioning	Any integer greater than or equal to 0, but not greater than 5	Assess the magnitude of potential social and systemic barriers posed to the student	0 to 5 integer scale matrix
Are you transgender?	- Yes - No - Unsure	Assess the magnitude of potential social and systemic barriers posed to the student	Select one
To what magnitude do you align with the following gender expressions, 0 being not at all, 5 being the most? - Androgynous - Feminine -Masculine	Any integer greater than or equal to 0, but not greater than 5	Assess the magnitude of potential social and systemic barriers posed to the student	0 to 5 integer scale matrix
Do you or have you ever had a uterus	- Yes - No	Assess the magnitude of potential social and systemic barriers posed to the student	Select one
Sexuality			
What is your sexuality	Any sexualty(ies); see options for appendix for full list	Assess the magnitude of potential social and systemic barriers posed to the student	Select all that apply
Socioeconomic Status			

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Question	Options	Purpose	Format
How much of your expenses relating to your attendance to college (e.g. tuition, living, food, etc …) paid for using loans?	- $0 - $1 – $5,000 - $5,001 – $10,000 - $10,001 – $20,000 - $20,001 – $50,000 - Greater than $50,001	Assess the magnitude of potential financial barriers posed to the student	Select all that apply
How much money do you have available per semester for non-essential purchases?	- $0 - $1 – $2,000 - $2,001 – $5,000 - $5,001 – $10,000 - Greater than $10,001	Assess the magnitude of potential financial barriers posed to the student	Select all that apply
How much money is made available to you by your guardians per semester?	- $0 - $1 – $5,000 - $5,001 – $10,000 - $10,001 – $20,000 - $20,001 – $50,000 - Greater than $50,001	Assess the magnitude of potential financial barriers posed to the student	Select all that apply
How many hours per week do you do paid work for your institution?	Any integer greater than or equal to 0	Assess the magnitude of potential time constraints and financial barriers posed to the student	Integer
How many hours per week do you do paid work for an entity outside your institution?	Any integer greater than or equal to 0	Assess the magnitude of potential time constraints and financial barriers posed to the student	Integer