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Science Identity in Undergraduates: A Comparison of First-Year Biology Majors, Senior Biology Majors, and Non-STEM Majors

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Abstract: We argue it is important for everyone to possess basic scientific literacy for multiple reasons. Viewing oneself as a science person or not can impact one's confidence and willingness to engage with science content thereby improving science literacy. Identifying as a science person may develop early but is not fixed and may shift through science identity work. We investigated science identity views between STEM (science, technology, engineering, and mathematics) and non-STEM majors and assessed whether these views may be influenced by science identity work. Our questions were as follows: (1) How does science identity perception differ between non-STEM and STEM majors? (2) How do non-STEM and STEM students' perceptions of their science identity change over time? (3) How do non-STEM majors describe a science person compared to STEM majors? We surveyed first-year biology majors, senior biology majors, and non-STEM majors to address our research questions. We found significant shifts in science identity in non-STEM majors taking a general education lab science class pre-course and post-course, differences in agreement regarding science identity between groups, and differences in how a science person is defined among the groups. Our data suggest that instructors can scaffold and support students' science identity work to increase confidence, STEM retention, and ultimately can improve overall scientific literacy.

Keywords: science identity; self-perception; undergraduates

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1. Introduction

In the United States, all students graduating from high school have completed basic science coursework, generally between two and four classes [1]. Of college-bound students, some go on to major in STEM (science, technology, engineering, and mathematics), but many choose majors outside of STEM fields. In college, students who are non-STEM majors are a large portion of the undergraduate population—approximately 75% of the 2.1 million bachelor's degrees awarded in 2020–2021 [2]. Students who choose a major outside of STEM typically report that they do not identify as 'science people,' or have high anxiety toward STEM subjects [3], but this does not mean that they cannot begin to identify as science people through positive and applicable experiences with science [4]. Confidence and willingness to participate in scientific thinking and socioscientific issues are important for multiple reasons, from effective civic engagement [5], for promoting environmental literacy [6], to comprehending impacts on public health [7]. Science identity and scientific identity development have commonalities, such as recognition by an expert, practice using scientific knowledge and language, and confidence in engaging with scientific material [8–10].

Generally, a 'science person' is one who views science as a part of themselves [11], and this identity is the result of a composite of behaviors and experiences in science [12]. While STEM identity development is often in the context of improving interest or retention in STEM, it is also important for undergraduate non-STEM major students to undertake identity work in this area to improve social and personal engagement with science as an educated citizen [13,14].

While there is not a consensus on the definition of science identity, there are common aspects that arise in the literature. The first aspect is self-recognition of being a science person and having a high science self-efficacy, including knowledge and the ability to participate in science [15,16]. The second aspect is a strong sense of belonging and encouragement in science [17–19] with outside affirmation by others, particularly peers, educators, mentors, or other respected individuals that one is a science person [14,20,21]. Science identity is not fixed, but rather may change based on students' personal circumstances, other identities, relationships, or experiences [21]. Emergence of a science identity is related to and important in developing career aspirations and for effective learning in science [22]. However, identifying as a science person is complex and is juxtaposed by many other identities including gender, race, and ethnicity [9]. Certain stereotypes of science and scientists can negatively affect science identity, belonging, and career interests for female students particularly when they view science as nerdy or masculine [14,23]. Additionally, minoritized students are less likely to identify as science people which may affect science career aspirations [11].

One means of improving science identity in students is through 'science identity work'. This occurs when a student is engaged in scientific action or practice, when they are affirmed as being a science person by an expert such as a professor or working scientist, or by developing a personal sense of themselves as being able to understand and carry out science [8–10]. Leveraging students' other interests to engage them in science course content is an important factor in identity work [24,25]. All of these processes can positively influence development of a science identity and can be consciously implemented throughout an undergraduate curriculum. In prior research, non-STEM majors engaged with science topics and communicated science as experts in a topic of their choice, leading to higher self-perceptions as science people [8]. These early results support the concept that an appropriate curriculum for both STEM and non-STEM students to improve science identity can include traditional classroom and laboratory work designed to improve engagement with and understanding of science through authentic experience where content is connected to action and the practice of science [8]. A curriculum supporting identity work should also include assistance with content knowledge acquisition through tutoring or office hours to enhance feelings of belonging in science [26]. Consistent informal recognition of students' improvement or successes in a STEM course by faculty provides supportive outside affirmation of one's science identity [13]. Together these strategies may improve learning and career aspirations because students who identify themselves as science people more frequently access faculty mentoring, research opportunities, and enrichment programs [26]. For those who have career aspirations in science, identity development is important for belonging and ultimate success [27].

Because college and university faculty teach students majoring in STEM in multiple science courses, and often non-STEM majors in a single course as their only (and likely final) formal science education, these faculty are uniquely situated to help students build both a science identity and increase scientific literacy. Science identity is important in building scientific literacy because it instills confidence in interacting with scientific material, including investigation of information within a specific context and the ability to identify misinformation [28]. We have seen the importance of public engagement and understanding of science in recent public health matters, from responses to measles outbreaks [29], COVID-19 [30], and understanding anthropogenic climate change [31].

We were particularly interested in how college students from a STEM major (biology) may differ in their identity as a science person relative to college students from non-STEM majors taking a biology non-major course. We also were interested in whether science identity work within a single course (for non-STEM majors) or a curriculum (biology majors) may influence students' science identities. We addressed the following specific research questions: (1) How does science identity perception differ between non-STEM and STEM majors? (2) How do non-STEM and STEM students' perceptions of their science

identity change over time following science identity work? (3) How do non-STEM majors describe a science person compared to first-year and senior biology majors?

2. Materials and Methods

2.1. Research Context

This study occurred at a private, medium-sized, faith-based university (Arroyo University, a pseudonym) in the western United States. In fall 2021, the university had approximately 3600 undergraduate students, with 59% identifying as female and 41% identifying as male. In the 2020–2021 academic year, Arroyo University conferred 820 bachelor's degrees, of which 19% were in STEM disciplines, and 40% of those were in biology. Following Institutional Review Board [IRB] approval, participants were recruited through two cohorts in each of three specific undergraduate courses across a two-year period. The three courses included general education biology semester-long courses, a spring semester first-year colloquium course for biology majors, and a spring semester senior capstone course for biology majors. Participants, having provided informed consent, then voluntarily completed surveys containing questions dealing with self-perception and experience in science that included five-point Likert scale items and open-ended response questions. All survey data were anonymized and analyses performed after submission of final course grades.

The non-STEM major subjects came from either a general non-major biology course with topics ranging from cells and genetics to ecology and evolution, or a non-major introductory environmental science course with topics ranging from climate change to biodiversity and conservation. Both non-STEM major courses fulfilled the university's general education lab science graduation requirement. The university program learning outcomes for general education lab science require students (1) to understand the methods used by scientists to investigate and answer questions about the natural world, and (2) to demonstrate the ability to assess the reliability and limitations of those methods. The biology major first-year colloquium course is designed to orient new students to the major, connect them with a senior mentor, and introduce them to primary scientific research literature and critical analysis of scientific results. The senior biology major capstone course is designed to measure student competence of program learning goals by demonstration of scientific writing and analysis skills in a case study, by leading peer discussions on current scientific topics, and by participating in a service-learning education outreach project. For both biology majors courses, the full program learning outcomes require students (1) to display an understanding of biological systems and evolutionary processes spanning all ranges of biological complexity, (2) to be proficient at applying principles of the scientific method to problems in biology, and (3) to demonstrate preparedness for service and leadership in science-related issues affecting society, at introductory (first-year) or mastery (senior) levels of achievement.

Surveys were collected from 171 first-year biology majors, 61 senior biology majors, and 89 non-STEM majors who consented to participate over the two years of data collection. For non-STEM majors and first-year biology majors, we asked identity questions in pre-course and post-course surveys, to assess whether their science identity had shifted during the course of the semester. For seniors completing their program of study, we only asked the science identity question at the end of the semester, as we were most curious about how they identified following four years of science study rather than making a comparison from the beginning to the end of their final semester. We removed responses that were missing either the pre-course or post-course survey and removed responses from participants who had not provided consent but who still completed the survey.

All surveys included identical Likert response identity items adapted from [12] and an open-ended question asking participants to define what it means to be a science person. The purpose of these items was to learn to what extent students identified as science people, identify common ideas on what attributes are ascribed to a 'science person', and determine to what degree respondents felt others (current/former educators) viewed them as science

people. Also included in the survey were items to assess various criteria of self-identified scientific literacy, but are not included in these analyses.

2.2. Data Analysis—Quantitative

To compare the Likert scale response distribution among our groups for the "I see myself as a science person" question, we used the Bayesian modeling approach proposed by [32] to infer relationships among these ordinal variables tested against four possible distribution models. The four models are an unconstrained model, a dominance model, a constant shift model, and a null model. This approach was chosen because our Likert responses are on a discrete ordered scale (1–5; strongly disagree, disagree, neutral, agree, strongly agree), but lack defined intervals. These data characteristics, common in Likert-type responses, have led many researchers to question the validity of metric models for analysis and suggest that those approaches are greatly prone to error [32–34], leading to the proposed use of better modeling approaches.

We entered response frequencies for each experimental test group into a user-friendly web-applet [32,35]. The approach allows for specifying two prior standard deviations (b_α and b_θ) to provide limits for model testing. These values may vary and can affect the model outcomes but are selected based on best estimation of data structure and distribution. We chose values of 0.8 and 0.25 for b_α and b_θ, respectively, for the analysis comparing first-year biology major to senior biology major responses. These values were chosen because in these groups there was a tendency for student responses to be at the extreme of the range rather than the center and we did not expect a large difference in the distribution values in this scenario as both cohorts were STEM students; see [32] for discussion of parameter selection. We chose values of 2.0 and 0.33 for b_α and b_θ, respectively, for the analysis comparing non-STEM major responses to first-year biology major responses. These values were chosen because in these groups there was a tendency for student responses to be across the range but somewhat clustered in the center and we expected a slightly larger difference in the distribution values because of students' differences in interest in science when entering their undergraduate program. For both sets of comparisons, we allowed for two-way stochastic dominance and used the default values for the Markov Chain Monte Carlo (MCMC) algorithm. The web-applet outputs values for Bayes Factors (BF) that provide a measure of how well each of the models predicted the data distribution [36]. The Bayes Factor values then allowed us to infer how the groups varied in distribution or not. We varied both b_α (0.8 to 2) and b_θ (0.2 to 0.33) to determine the effects on BF. Increasing b_α values tended to improve the BF values but did not change model preference. Altering the b_θ value tended to decrease the BF values but did not change model preference.

For the classes with paired data (non-STEM majors and first-year biology majors), we performed descriptive statistics and Wilcoxon Signed Rank tests using SPSS [37] to determine whether or not there was a significant difference among groups from the pre-course to post-course survey for specific response items or whether the response level for items changed from the beginning of the semester to the end of the semester. Of particular interest was the level to which they described themselves as science people and to what degree they perceived mentors believed they were science people. For the senior biology majors' surveys, we analyzed the items using descriptive statistics, because we were interested in knowing the students' perceptions of themselves as science people and how they felt others perceived them in their final semester in the biology major rather than how their feelings changed from the beginning to end of the term.

2.3. Data Analysis—Qualitative

All three groups of participants (non-STEM majors, first-year biology majors, and senior biology majors) were asked their definition of a science person with non-STEM majors and first-year students responding to this question at the beginning of the semester, and seniors responding at the end. Initially, we analyzed these definition responses for common word count, but recognized quickly that word count did not capture the essence

of the definitions. Rather, we discovered theme commonalities throughout the responses as follows: (1) discussion of a science person being connected to an emotion or feeling, (2) identifying a science person as part of an intrinsic identity, or (3) describing a science person as being connected to an activity or action (see Table 1 for descriptions of definitions, and related references). These themes allowed the authors to code for the science person definition survey responses in a categorical manner in which responses may exhibit zero, one, two, or all three of the codes. Across the two years of data collection in six courses, only two student responses out of 305 were not able to be coded into at least one of the three themes.

To totally blind respondent personal and group identity from raters, participant responses were placed in a spreadsheet, then assigned random numbers between 1 and 1000 [38]. The new list was copied, all class and identity affiliation removed, and then the list was re-sorted in numerical order. Two raters independently coded the blinded responses according to the three themes (see Table 1) of a data subset and came to 86% agreement over 20% of the data, exceeding the recommended threshold for inter-coder reliability [39]. However, because we wanted to have a consensus on all responses, both raters independently coded all remaining responses, with a final rater agreement rate of 95%. Raters examined and discussed disagreement to come to a consensus rating on the remaining 5% of responses. Following blind coding, the individual response and coded data were reassigned back to their original class categories only (non-STEM major, first-year biology major, or senior biology major) allowing us to make comparisons within and between groups. We performed pairwise Chi-square tests using R [40] on the percentages of responses that fell into each code to determine whether statistical differences existed between the groups.

Table 1. Themes used to code science identity descriptive responses along with definitions for each theme and an example response illustrating the theme.

Theme/Code	Definition	Example	References
Feeling/emotion	Description of a science person is based on feelings (i.e., love, like, passionate)	"Someone who enjoys learning about science outside the classroom and on their free time." (Student 769)	[22,41]
Identity/intrinsic	Description of a science person is based on the identity of the person or intrinsic nature of the person (i.e., is good at, skilled, has knowledge)	"I prefer or excel in science related material and classes." (Student 140)	[42]
Activity/action	Description of a science person is based on actions or activity (i.e., does/doing, performs, studies, asks)	"Studying the physical and natural world through the scientific process." (Student 454)	[10,25,42]

3. Results

We are presenting the results first by the Likert scale identity questions from the survey, then the qualitative definitions of a science person by code.

3.1. Are You a Science Person?

In the survey, we first asked students to what degree they identified as a science person, followed by a request to describe what it means to them to be a science person. Next, the survey asked participants to answer a variety of Likert scale questions related to science identity perception from family (not analyzed) and mentors. We present results of student participant responses to the survey questions related to their science identities and across groups (research question 1), followed by an analysis of shifts that may have occurred between pre-course and post-course survey responses within a group (research question 2) and then address student participant descriptions of a science person (research question 3).

3.1.1. Are You a Science Person?—Group Comparisons

We were interested in investigating how students in the three groups viewed their own science identity and determining if there were differences in the distribution of responses among groups. Table 2 shows the relative frequency of responses to each scale for the science identity self-perception question for four group surveys along with results of the Bayesian model testing of our distributions for two meaningful comparisons. In both group comparisons (non-STEM majors to first-year biology majors, post-course; and first-year biology major pre-course survey to senior biology majors survey), the best model to fit the distribution of the data was the constant shift model [32]. The distribution difference in the favored model was roughly 15 to 1 (see Table 2) for the non-STEM to first-year biology major comparison, but was supported to a lesser degree (~1.5 fold) for the first-year biology to senior biology major comparison. To put the models in context, the unconstrained model allows any type of distribution including non-ordered distributions; this model was not favored for our data. The constant shift model infers that there is a constant shift in the central tendencies across values between groups, and was the favored model for our data. The dominance model infers a cumulative distribution effect across values in one direction, but again, this model was not favored in our analyses. The null model simply indicates that there is no difference in distribution of values across groups, and was not a supported model.

Table 2. Frequency (%) of response within each scale for the question "I see myself as a science person" by group and survey. Two relevant comparisons (gray and white rows) were analyzed using the Bayesian model test for inferring distribution differences among groups [32]. To the right are the results of the best supported model for each comparison.

Group	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Best Model Fit
Non-Stem Major post- survey	6	20	27	30	17	Constant Shift Model (BF = 17.58 relative to unconstrained model = 1)
First-Year Major post-survey	0	3	3	53	41	
First-year Major pre-survey	0	1	11	53	35	Constant Shift Model (BF = 1.459 relative to unconstrained model = 1)
Senior Major survey	1	0	7	38	54	

These analyses indicate that there is a distribution difference between both sets of groups and that the trend is a shift in distribution in one direction in one group relative to the other. Given the relative frequency values, this can be interpreted as a significant directional shift to higher levels of agreement to the statement for first-year biology students relative to the non-STEM major students. Likewise, there is a supported directional shift to higher levels of agreement for senior major students relative to first-year biology students. Both outcomes make sense relative to these students' college career choices, probable experiences, and factors that lead to individual science identity within each group. These factors are discussed in more detail in subsequent sections.

3.1.2. Are You a Science Person?—Pre-Course to Post-Course Shifts

We were interested in determining if there were significant shifts in science identity from the beginning to the end of the term in our non-STEM majors and first-year biology majors as possible evidence for the effects of science identity work occurring within the respective courses. Table 3 shows the median and mode responses to the three identity questions from our Likert scale survey questions comparing pre-course to post-course results. Below, we describe the context of each group and also provide insight into curricular attributes that may have influenced science identity shift outcomes.

Table 3. Student median and mode responses by group to three science identity Likert scale survey questions. Likert scale values were assigned as follows: 1 = strongly disagree, 2 = disagree, 3 = unsure or neutral, 4 = agree, and 5 = strongly agree. Median or mode values marked as n/a indicate that a question was not included in a survey or that the survey was not administered.

Response Item	Group	Median (Beginning of Course)	Median (End of Course)	Mode (Beginning of Course)	Mode (End of Course)
I see myself as a science person	Non-STEM Major	3	3	2 *	3 *
	First-Year Biology	4	4	4	4
	Senior Biology Major	n/a	5	n/a	5
In the past, my teachers have seen me as a science person	Non-STEM Major	3	n/a	4	n/a
	First-Year Biology	4	n/a	4	n/a
	Senior Biology Major	n/a	n/a	n/a	n/a
Currently, my biology professor(s) see me as a science person	Non-STEM Major	3	4	3 **	4/5 **
	First-Year Biology	4	4	3	4
	Senior Biology Major	n/a	4	n/a	4

*, ** Statistically significant using Wilcoxon signed rank test ($p < 0.01$).

3.1.3. Non-STEM Majors in a General Education Science Class

Arroyo University has a single-semester general education science course requirement, meaning that this course for non-STEM majors represents their last formal science experience. Typically, students enter excited but nervous about the course, because they usually hear that college-level science is hard or they often do not feel like they are science people.

The non-STEM major student pre-course responses (Table 3 and Figures 1 and 2) indicated that they were generally unsure of their own science identity (median score = 3) as well as being unsure of how their teachers viewed them in terms of being a science person (median score = 3), although most students agreed (median score = 4) that past teachers had viewed them as science people. The most frequent choice regarding their perception of themselves as science people before their science course at Arroyo University was that they disagreed that they identified as science people (mode score = 2). These data are consistent with the idea that non-STEM major students entering a college-level science course generally do not have a strong sense of science identity [43] and are not confident in their current professor's perception of them as science people [8,44].

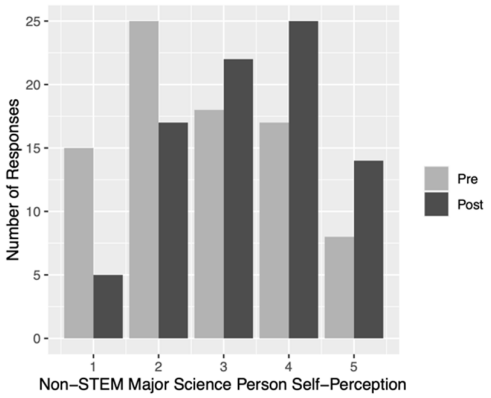


Figure 1. Frequency of pre-course and post-course responses (n = 83) from non-STEM major students about their science identity self-perception. Median and mode data are shown in Table 3. Likert scale values were assigned as follows: 1 = strongly disagree, 2 = disagree, 3 = unsure or neutral, 4 = agree, and 5 = strongly agree.

Following their biology course experience, non-STEM students' median responses did not change, but the most frequent responses (mode value) showed a significant shift (Wilcoxon signed rank test, $p < 0.01$) toward positive identity images for themselves and also for how their professors view them as science people. The data shift in mentor perception of students as science people aligns with the research showing that external recognition

is an important contributor to individual science identity [14,20,21]. While we cannot determine if the significant shift in personal science identity is directly the result of their shift in professor perceptions of them, the two shifts are parallel.

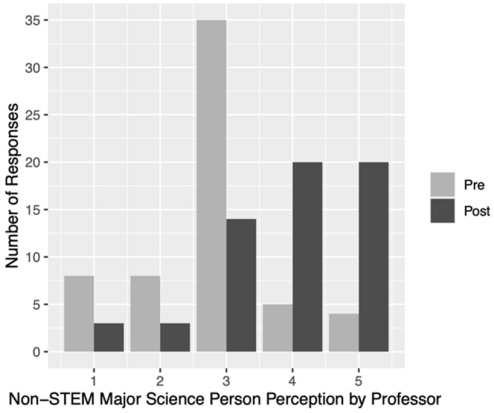


Figure 2. Frequency of pre-course and post-course responses (n = 61) from non-STEM major students about whether they perceive past and current professors (questions 2 and 3 combined) view them in terms of being a science person. Median and mode data are shown in Table 3. Likert scale values were assigned as follows: 1 = strongly disagree, 2 = disagree, 3 = unsure or neutral, 4 = agree, and 5 = strongly agree.

3.1.4. First-Year Biology Majors Colloquium Course

First-year biology majors at Arroyo University are required to enroll in a colloquium during the second semester of their biology major. Generally at this point in their curriculum, these students have completed one semester of major level chemistry or one major level biology course, and in many cases both. The results of the pre-course and post-course survey identity questions are shown in Table 3 and Figures 3 and 4.

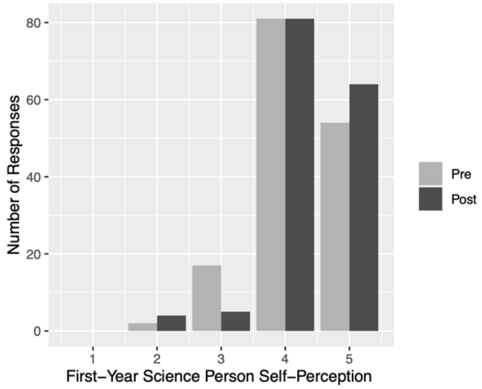


Figure 3. Frequency of pre-course and post-course responses (n = 154) from first-year biology major students about their science identity self-perception. Median and mode data are shown in Table 3. Likert scale values were assigned as follows: 1 = strongly disagree, 2 = disagree, 3 = unsure or neutral, 4 = agree, and 5 = strongly agree.

The first-year biology students agreed or strongly agreed that they were science people (Figure 3), and we saw the same frequency in the agreement category from pre-course to post-course survey, but with a small shift from the neutral to strongly agree categories at the course end. However, there was no statistically significant difference in these data between pre-course and post-course surveys (Wilcoxon signed rank test, $p = 0.065$). First-year biology students likely already have a stronger sense of belonging in science with a good science identity (median/mode scores = 4) and therefore are less likely to be shifted in their identity perceptions [17–19,45]. Additionally, these students would have likely had

other experiences prior to college that had shaped or strengthened their science identity in a way not found for many non-STEM major students [43].

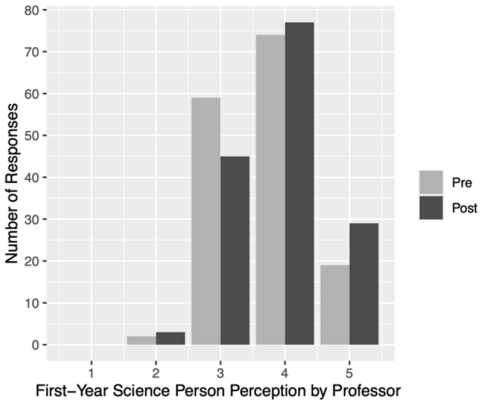


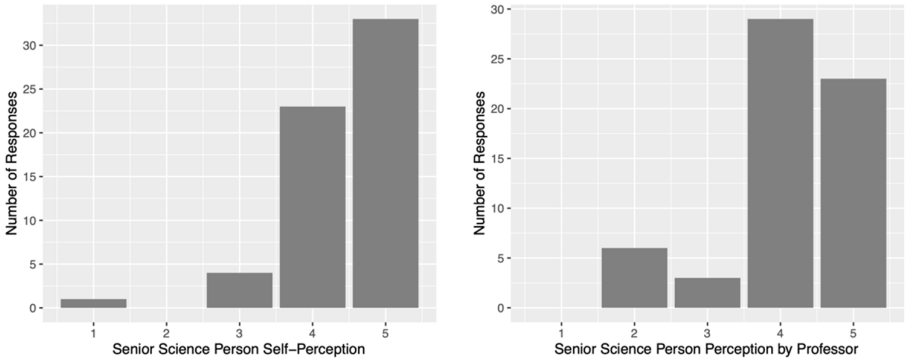
Figure 4. Frequency of pre-course and post-course responses (n = 154) from first-year biology major students about how they perceive past and current professors (questions 2 and 3 combined) view them in terms of being a science person. Median and mode data are shown in Table 3. Likert scale values were assigned as follows: 1 = strongly disagree, 2 = disagree, 3 = unsure or neutral, 4 = agree, and 5 = strongly agree.

Likewise, the first-year biology majors agreed with the statement that in the past their teachers and current biology professors viewed them as science people, which was the median response on both pre-course and post-course surveys (see Figure 4). We did not find a statistically significant change in their perception values for professors across this course. While the responses were not statistically significant, the frequency of responses for both items trended in the positive direction (see Figures 3 and 4). There are multiple possible explanations for this movement in responses, including student engagement and success in other science courses that are often described as difficult in the STEM curriculum such as calculus or chemistry [46]. Students may also have been taking science courses where they have been building a stronger sense of belonging, or have experienced other faculty members from whom they felt encouraged [18,22]. What we see at this level and across a single major course is that small positive shifts in science identity may be at play which uphold prior identity, and are a part of their identity work as they spend time engaging in scientific actions [10].

3.1.5. Senior Biology Majors Capstone Course

Because this capstone course is only for senior biology majors who are graduating, it represents the culmination of their scientific coursework and therefore we did not offer both a pre-course and post-course identity survey. The survey was administered in the latter half of the capstone course to evaluate the seniors' perceptions of themselves as science people at the end of their undergraduate studies.

Overall, the senior biology majors strongly agreed that they saw themselves as science people (see Table 3 and Figure 5). These responses were most concentrated in the strongly agree and agree categories, with very few in the neutral, to strongly disagreeing categories. Participants also mostly agreed with the statement that their biology professors viewed them as science people. We see that the mode value for this question is in the agree category compared to the self-identity mode value in the strongly agree category (Figure 5).



(**a**) (**b**)

Figure 5. (**a**) Frequency of responses from senior biology majors about their science identity self-perception (n = 61), and (**b**) frequency of responses from senior biology majors about how they perceive current professors view them in terms of being a science person. Median and mode data are shown in Table 3. Likert scale values were assigned as follows: 1 = strongly disagree, 2 = disagree, 3 = unsure or neutral, 4 = agree, and 5 = strongly agree.

It is not surprising to find that students completing a college STEM degree should strongly agree that they identified as science people. This finding is consistent with literature around those who persist in STEM and find support through science coursework, while also finding a sense of belonging in the major [17–19]. However, why might there be graduating major students still unsure of their science identities (see data for scale values 1–3 in Figure 5)? This lack of science identity might impact whether or not those students remain in STEM careers [47]. Additionally, it is interesting that not all biology majors felt that their professors saw them as science people even at the end of their college career. One reason may be the level of struggle students had with major course content or how they perceived the major was measuring success, which led to a decrease in self-confidence and science identity [48]. The recognition of individuals by those whom they perceive as experts is important for science identity development [14], so having a low perception of how faculty view you could have a negative impact on your self-perception as a science person. Arroyo University has a core theme of finding a vocation or a calling in a career. The few responses on the disagree side of science identity from some seniors may also be indicative of students who are now finding their true vocation and are deciding on a different path in life outside of science near the end of their college education—which is still a positive outcome at Arroyo University.

3.2. Response Definitions of "What It Means to Be a Science Person" across Groups

Finally, we asked participants to give their own definition of what it means to be a science person. Table 4 shows the percentage of total responses across two years separated by course group to the question, "For you, what is a science person?". We were interested in understanding any potential differences in theme response outcomes between the three cohorts. Interestingly, across all three courses, the majority of responses contained some type of feeling or emotional component, but the non-STEM majors had the lowest value of 60% with the highest value for first-year biology majors (78%). The difference between the non-STEM majors and first-year biology majors in containing an emotional theme was significant (pairwise Chi-square, $p < 0.05$, see Table 4, column 1). Response rates containing an intrinsic/identity component (i.e., science being part of who someone is) were very even across the groups but about half of the values for the emotional theme response rate (see Table 4, column 2). The most interesting finding is in the third theme category concerning the idea that being a science person requires some type of action or practice (see Table 4, column 3), because there was a significantly higher percentage of responses for the senior major students relative to the first-year major students (pairwise Chi-square, $p < 0.05$). While the difference between senior major students and non-STEM major students was not

statistically significant, there was still a 17 percentage point difference between these two groups (see Table 4). This outcome suggests that the four-year biology major curriculum had constituted science identity work resulting in a shift between the beginning and end of the curriculum in how students defined themselves and others as science persons. The identity shift is from someone who has emotional or intrinsic feelings about science to now feeling like someone who actually conducts science.

Table 4. Data breakdown of the coded descriptive responses to the open-ended question, "For you, what is a science person?" The percentage of responses containing each theme is reported individually (columns 1–3) and in theme combinations (columns 4–7).

Group	Emotion	Intrinsic	Action	Emotion + Intrinsic	Emotion + Action	Intrinsic + Action	Emotion + Intrinsic + Action
Non-STEM Major (n = 71)	61% *	34%	38%	15%	14%	4%	0
First-Year Biology (n = 172)	78% *	31%	34% **	16%	22%	1%	2%
Senior Biology Major (n = 61)	69%	39%	55% **	10%	23%	10%	8%

*, ** Statistically significant using pairwise Chi-Square ($p < 0.05$).

In the following sections, we discuss the outcome responses for each coded theme in more detail and provide examples from student definitions to explore how these themes fit into the concept of science identity and science identity work.

3.2.1. Emotion

The theme of emotion was characterized by participants using feeling words in their description of a science person, such as enjoyment, love, or fascination. The majority of responses within each participant category included some type of emotional connection as being an important part of defining a science person. This included descriptions such as, "someone who is excited and enthused about science" (student 614), "a person interested in science" (student 180), "someone who is fascinated by science and [would] like to understand the natural world as much as possible" (student 23), or "someone who enjoys science" (student 18). These descriptions are a subset of the responses, but the remaining "emotion" coded responses were similar across the groups. All of the responses described a science person as having positive feelings toward science in general or specific scientific disciplines. Generally speaking, a sense of belonging is related to emotion, so if one seeks to belong in a discipline, they will likely also have positive emotions toward that discipline [49]. Building a science identity is also partially influenced by a sense of belonging in the discipline, which includes having an emotional connection [45].

3.2.2. Intrinsic

About one in three students across all three groups described a science person using intrinsic characteristics, such as possessing science intelligence, giftedness, logical thinking, or having knowledge. These descriptions were slightly more common in the seniors' descriptions (39%) relative to first-year biology majors (31%), which could represent a growth in confidence in knowledge or ability following a four-year curriculum. This confidence is something the entering major students may not possess perhaps from anticipated anxiety of surviving a STEM degree or uncertainty about their own skills and knowledge regardless of their high school preparation (typically high for this private university). One first-year major said a science person is "someone who grasps scientific concepts with relative ease" (student 563). Similarly, a senior biology major stated that a science person is "someone who understands and trusts in the scientific method" (student 756). Both of these statements include the intrinsic understanding of science topics, but there is a shift in the senior major response that now includes trusting in the scientific method, which unites the intrinsic character to an action.

An example of an intrinsic theme response from a non-STEM major student indicated that a science person [had a] "brain that functions more mathematically/mechanically" (student 69). This statement does not address what that person is able to learn or how determined they are, but rather reflects an internal aspect of a science person being one with a brain that is particularly analytical. This type of thinking aligns with persistent societal ideas about individuals in STEM that suggest individuals are naturally more adept at certain subjects, implicitly implying that science aptitude is not equally distributed, but skewed in the population, including perhaps as being more masculine [14].

The idea that science is only for the naturally gifted or is more suited to men is connected to persistent negative beliefs and performance by women in STEM [9,50]. These intrinsic attitudes may also have a negative effect on opportunities for historically underrepresented and/or underserved students [51]. The feeling that some people are better at science than others counteracts science identity work because it may lead to a lower sense of belonging [18]. Our results point to the importance of conscious science identity work supported by faculty in both major and non-STEM major courses as a means to dismantle disparities in science education and science literacy that seem to uphold gender disparities [9,50] and ethnic disparities [51]. Students need to trust in their scientific abilities and have confidence to interact with scientific material that has real-world implications with issues such as climate change [52].

Overall, the idea of a science person having any sort of intrinsic characteristics that make them better at science than other people is one that is opposite of a growth mindset [53]. Therefore, science identity work in courses or the curriculum could shift students' perceptions that working hard in a science class does not mean they are not science people.

3.2.3. Action

Between one third (non-STEM major and first-year biology majors) to more than one half (senior biology majors) of respondents used action theme statements to characterize a science person, such as studying the natural world, using the scientific method, or working in a science field. A first-year biology major stated that a science person is "someone who is studying a type of science or works with a type of science" (student 546), with another saying that "I want to have a job in the sciences" (student 99). These participants included actions of studying and career aspirations most likely reflecting their recent secondary school science experience. A senior biology major stated that a science person is "actively participating in science throughout every aspect of life" (student 752), and a non-STEM student stated that being a science person means "finding direct causes and affects [sic]" (student 279). These two statements are similar and are more focused on what it means to be a science person in terms of being active, looking for answers, which is happening constantly. The student responses follow findings regarding science identity being formed in social practice [9], and experiences conducting science having an impact in terms of interest and/or retention in STEM [18,24,26]. Additionally, scientists' definitions of a science person include conducting research [54], teaching about science [55], or learning more science content [56]. It is interesting that the idea of action appeared to develop in our participants the longer they remained in the science major. This tells us that when educators involve students in scientific actions at all levels, especially research experiences [8,57] or participatory science projects [58], it is possible to create positive science identity shifts in students.

3.2.4. Combinations of Themes

We also found differences across populations with responses including multiple themes. Combining an emotional component with an intrinsic trait was relatively even across the populations (see Table 4, column 4). These combined themes demonstrated that some participants believe a science person should both enjoy science and possess natural skills to conduct science. This is similar to prior findings for why scientists choose

to study science, where being interested in and skilled at science were the most frequent responses [59].

The combination of emotion and action themes within responses was likewise similar across groups (see Table 4, column 5). One senior biology major stated that "a science person is someone who is interested in science, has some educational background on the subject, and knows how to approach problems using the scientific method" (student 641). A first-year major student stated that "being interested in figuring out how things work and performing experiments" (student 773) is what it means to be a science person. Finally, a non-STEM major student stated that "being a science person means that you are a person who enjoys studying parts of the world through experiments and observations" (student 32). All three of these examples demonstrate that enjoyment of conducting science is a vital part of committing to a science identity and that this identity can lead to action. Our outcomes agree with previous findings that science experiences can result in increasing enjoyment of science [24], and supports the concept that increasing satisfaction in science contributes to a sense of belonging in a science community [18,22].

Combined responses including an innate idea of what it means to be a science person along with an action theme were most common in senior biology majors compared to either first-year or non-STEM major students. Here again, the more experiences students have in science, the more likely their identity will include active engagement, and together these reinforce one's science identity [60]. For educators, science identity work that includes participating in science is an important part of identity development, providing students with the opportunity to contextualize their content knowledge [18,24,26].

4. Discussion

While much research surrounding science identity has taken place in the K–12 space [10,14,61], there is also some literature regarding intersectional identities at the undergraduate or postgraduate level [20]. This study sought to extend the research on identity work at the undergraduate level by investigating science identity self-perception among beginning and ending biology majors relative to one another, and comparing biology majors to non-STEM majors enrolled in general education biology-related lab science. Utilizing survey data across two years and six courses with both quantitative and qualitative analyses, we were able to better understand how undergraduates define science identity and perceive themselves as science people. In addition, we were able to assess whether there were shifts in science identity perhaps linked to science identity work. In our context, science identity work includes engaging in scientific action or practice, being affirmed as being a science person by an expert such as a professor or working scientist, and developing a personal sense of oneself as being able to understand and carry out science [8].

Our first research question explored how different groups of undergraduate students viewed themselves in terms of their science identity. We found that it was less likely for non-STEM majors to agree that they were science people relative to first-year biology majors. These differences were supported by Bayesian statistical modeling and were found both pre-course and post-course (we chose to discuss only this set of data; see Table 2). Generally, one would expect that undergraduate students choosing a STEM major may view themselves differently relative to those choosing a non-STEM major. This outcome may seem self-determining in that non-STEM majors probably choose to major in something other than STEM entering college because they do not identify themselves as science people [43,62]. Conversely, students who enter college with a declared science major or choose a science major in their first semester are likely to already have a positive science identity [43]. The biology major students at both levels most often responded that they agreed or strongly agreed that they felt like science people (see Table 2) but our analyses suggested that there was a small shift in distribution to higher levels of agreement for seniors over the first-year students. While small, the shift implies that even among major

declared students, science identity work within a curriculum can enhance science identity or at least maintain that identity.

Overall, science identity is important for those pursuing science majors or careers and for all engaged citizens. Supporting students' identity work by offering them opportunities to engage with scientific actions and recognizing their identity work will increase the likelihood that they will identify as science people [10,25]. In turn, this should also impact willingness and confidence to engage with science in contexts beyond school, which has implications for the collective scientific literacy of communities [63].

For our second research question, we were interested in how undergraduates' self-perception of their science identity changed over the course of one semester. This includes the level of agreement with "I am a science person" and student perceptions that their professor perceived them as a science person. Non-STEM majors were most likely to start the term disagreeing with the statement that they see themselves as science people, and moved to feeling neutral about their science identity by the end of a term with active science identity work in the class and by the professor. First-year biology majors were most likely to begin the term feeling like a science person but not strongly. At the end of the term, when asked whether they see themselves as science people, the median response was agree for first-year biology majors and strongly agree for senior biology majors. While these are results from different cohorts of students in their first and fourth year of the biology major, both groups are in the same program curriculum, so we can infer that between the end of the first year and the end of the fourth year of a biology major, students are more likely to identify as science people. The strengthening of science identity seems to be supported within the curriculum and the work of faculty. The biology curriculum is inquiry-based, lab- and field-intensive and encourages student involvement in one-on-one research with faculty members. Together, these components of the curriculum would constitute science identity work that support a positive attitude for science identity [8,10,44].

Science faculty have a large voice in students' identity development, as shown in the responses to student belief that their science professors see them as science people. Non-STEM majors initially felt neutral in terms of how their science professors saw them, but most often strongly agreed that their science professors saw them as science people by the end of the semester. First-year biology majors most frequently felt neutral at the beginning of the term about how their science professors saw them, but by the end, they most often agreed that their professors saw them as science people. In their end-of-college survey, senior biology majors also agreed that their course professors saw them as science people.

The shift in mentor perception by students combined with positive identity shifts found in our research align with the research showing that external recognition is an important contributor to individual science identity development [15,64]. The ability to shift science identity can lead to greater scientific literacy and willingness to engage in science, which are all societal benefits [22,65]. Our data show compellingly that science identity work fostered by faculty and the curriculum within the context of a one-semester general education (GE) course or across a four-year curriculum can shift science identity.

Increasing support within science education is a way to push back against the idea that some are better suited than others to pursue a science degree or career [66], along with guidance for educators who can dismantle this idea and encourage their students' identity development [10,67]. Overall, the ability to develop a science identity over time through experiences is central, and it is important for individuals to overcome the idea of a science person being fixed [21]. The pathway to change in science identity is in science identity work supported by faculty within course and program curricula.

For our final research question, we were interested in determining how biology and non-STEM majors described or defined what it means to be a science person. We found that non-STEM majors and first-year biology majors tended to describe what it means to be a science person fairly similarly, mainly focusing on emotion/feeling or something intrinsic to the individual. While senior biology majors also included these features, they more often included an action in their descriptions than either the first-year biology majors or non-

STEM majors. Here again, the more experiences students have in science, the more likely their identity will include active engagement, and together these reinforce one's science identity [60]. For educators, science identity work that includes participating in science is an important part of identity development providing students with the opportunity to contextualize their content knowledge [18,24,26]. We found all of the combination descriptive response results fascinating, because students shared sometimes contradictory ideas of what it means to be a science person within their own responses. While enjoyment and action are tied to a sense of belonging [18,22] and would be associated with a growth mindset, the idea of natural giftedness follows a fixed mindset [53], but still was found combined in many responses.

The fixed idea that science is only for the naturally gifted or is more suited to men is unfortunately connected to persistent negative beliefs and performance by women in STEM [50,61]. These intrinsic attitudes may also have a negative effect on opportunities for historically underrepresented and/or underserved students [51]. The feeling that some people are better at science than others counteracts science identity work because it may lead to a lower sense of belonging [18]. Our results point to the importance of conscious science identity work supported by faculty in both major and non-STEM general education science courses as a means to dismantle disparities in science education and science literacy that seem to uphold gender disparities [50,61] and ethnic disparities [51]. Students need to trust in their scientific abilities and have confidence to interact with scientific material that has real-world implications with issues such as climate change [52]. Strong positive science identity should be a desired outcome for all college graduates.

We have recognized limitations to this study. While we did have a high level of participation across two years, this work was performed at one university. Collecting data at other universities both public and private would be enlightening to view how college students view their science identities in a more global space. We also recognize the limitation of just two instructors teaching each type of course in this study. Both instructors were veteran teachers at this primarily teaching undergraduate university, so we do not believe that this affected the data or methodology, but it is important to mention.

In the future, we are interested in learning more about students who began as STEM majors but changed to a non-STEM field while in college, and these actions may relate to their descriptions of a science person and how they view their science identities. The groups of students that participated in the first-year biology major surveys are approaching their senior years now, so we can also match their senior survey responses to their first-year responses, which will add a layer of analysis regarding first-year to senior year science identity development. Additionally, it may be possible to track first-year students who did not feel like science people at the beginning, to determine if they decided to change majors or alternatively grew greatly in science identity. Responses that are matched by individuals between their first and fourth years would clarify these student outcomes. Adding interviews with faculty would also be enlightening to learn how they would describe what it means to be a science person and compare those ideas to undergraduates' ideas, because faculty belief in students is important in guiding them in science identity journeys.

Overall, this study sheds light on how undergraduates define what it means to be a science person and how they think about their own identity as science people. This offers insight into opportunities for educators to support all students in their identity development and can complement other forms of identity work in college students.

5. Conclusions

These results show that beginning biology majors and non-STEM majors have similar ideas about what makes a science person. Given the beliefs about who can be a part of science, it would be possible for faculty to leverage these ideas to encourage confidence in science for all students. For example, students in non-STEM majors usually enter their college science courses with some amount of trepidation [62] and a lower science identity [43],

but still believe to be a science person means to have some emotional connection to the subjects. If faculty can build enjoyment into their general education science courses, this could reasonably contribute to the science identity work by non-STEM majors.

Improved science identity through undergraduate science identity work in both STEM and non-STEM major courses may lead to graduates more likely to engage with science [68]. Encouraging a more scientifically literate public would be a benefit for all of society because of the larger implications for individual choices and understanding. If people have a stronger science identity, they can have a stronger sense of the nature of science and may be more comfortable engaging with scientific material in their daily lives [69].

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References

1. Education Commission of the States [EOC]. High School Graduation Requirements 2023. 2023. Available online: https://reports.ecs.org/comparisons/high-school-graduation-requirements-2023-04 (accessed on 14 July 2023).
2. National Center for Education Statistics [NCES]. Undergraduate degree fields. In *Condition of Education*; U.S. Department of Education, Institute of Education Sciences: Washington, DC, USA, 2024. Available online: https://nces.ed.gov/programs/coe/indicator/cta (accessed on 29 February 2024).
3. Partin, M.L.; Haney, J.J. The CLEM model: Path analysis of the mediating effects of attitudes and motivational beliefs on the relationship between perceived learning environment and course performance in an undergraduate non-major biology course. *Learn. Environ. Res.* **2012**, *15*, 103–123. [CrossRef]
4. Garcia, R.; Rahman, A.; Klein, J.G. Engaging Non–Science Majors in Biology, One Disease at a Time. *Am. Biol. Teach.* **2015**, *77*, 178–183. [CrossRef]
5. Hodson, D. Nature of science in the science curriculum: Origin, development, implications and shifting emphases. In *International Handbook of Research in History, Philosophy and Science Teaching*; Matthews, M.R., Ed.; Springer: Dordrecht, The Netherlands, 2014; pp. 911–970. ISBN 978-94-007-7653-1.
6. Chepesiuk, R. Environmental Literacy: Knowledge for a Healthier Public. *Environ. Health Perspect.* **2007**, *115*, A495–A499. [CrossRef] [PubMed]
7. National Academies of Sciences, Engineering, and Medicine. *Science Literacy: Concepts, Contexts, and Consequences*; Snow, C.E., Dibner, K.A., Eds.; National Academies Press: Washington, DC, USA, 2016; p. 23595. ISBN 978-0-309-44756-0. [CrossRef]
8. Lucas, K.L. *Examining Science Identity Work and Scientific Literacy in Non-STEM Majors*; University of California: Santa Barbara, CA, USA, 2021.
9. Carlone, H.B.; Scott, C.M.; Lowder, C. Becoming (less) scientific: A longitudinal study of students' identity work from elementary to middle school science: BECOMING (LESS) SCIENTIFIC. *J. Res. Sci. Teach.* **2014**, *51*, 836–869. [CrossRef]
10. Calabrese Barton, A.; Kang, H.; Tan, E.; O'Neill, T.B.; Bautista-Guerra, J.; Brecklin, C. Crafting a Future in Science: Tracing Middle School Girls' Identity Work Over Time and Space. *Am. Educ. Res. J.* **2013**, *50*, 37–75. [CrossRef]
11. Hazari, Z.; Sadler, P.M.; Sonnert, G. The Science Identity of College Students: Exploring the Intersection of Gender, Race, and Ethnicity. *J. Coll. Sci. Teach.* **2013**, *42*, 82–91.
12. Vincent-Ruz, P.; Schunn, C.D. The nature of science identity and its role as the driver of student choices. *Int. J. STEM Educ.* **2018**, *5*, 48. [CrossRef] [PubMed]
13. Brickhouse, N.W. Embodying science: A feminist perspective on learning. *J. Res. Sci. Teach.* **2001**, *38*, 282–295. [CrossRef]

14. Brickhouse, N.W.; Lowery, P.; Schultz, K. What Kind of a Girl Does Science? The Construction of School Science Identities. *J. Res. Sci. Teach.* **2000**, *37*, 441–458. [CrossRef]
15. Chemers, M.M.; Zurbriggen, E.L.; Syed, M.; Goza, B.K.; Bearman, S. The Role of Efficacy and Identity in Science Career Commitment Among Underrepresented Minority Students: Efficacy and Identity in Science Career Commitment. *J. Soc. Issues* **2011**, *67*, 469–491. [CrossRef]
16. Potvin, G.; Hazari, Z. The development and measurement of identity across the physical sciences. In Proceedings of the 2013 Physics Education Research Conference, Portland, OR, USA, 17–18 July 2013; American Association of Physics Teachers: Portland, OR, USA, 2013; pp. 281–284.
17. Perez, T.; Cromley, J.G.; Kaplan, A. The role of identity development, values, and costs in college STEM retention. *J. Educ. Psychol.* **2014**, *106*, 315–329. [CrossRef]
18. Rainey, K.; Dancy, M.; Mickelson, R.; Stearns, E.; Moller, S. Race and gender differences in how sense of belonging influences decisions to major in STEM. *Int. J. STEM Educ.* **2018**, *5*, 10. [CrossRef] [PubMed]
19. Robinson, K.A.; Perez, T.; Carmel, J.H.; Linnenbrink-Garcia, L. Science identity development trajectories in a gateway college chemistry course: Predictors and relations to achievement and STEM pursuit. *Contemp. Educ. Psychol.* **2019**, *56*, 180–192. [CrossRef] [PubMed]
20. Carlone, H.B.; Johnson, A. Understanding the science experiences of successful women of color: Science identity as an analytic lens. *J. Res. Sci. Teach.* **2007**, *44*, 1187–1218. [CrossRef]
21. McCartney, M.; Roddy, A.B.; Geiger, J.; Piland, N.C.; Ribeiro, M.M.; Lainoff, A. Seeing Yourself as a Scientist: Increasing Science Identity Using Professional Development Modules Designed for Undergraduate Students. *J. Microbiol. Biol. Educ.* **2022**, *23*, e00346-21. [CrossRef]
22. Aschbacher, P.R.; Li, E.; Roth, E.J. Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *J. Res. Sci. Teach.* **2010**, *47*, 564–582. [CrossRef]
23. Starr, C.R. "I'm Not a Science Nerd!": STEM Stereotypes, Identity, and Motivation Among Undergraduate Women. *Psychol. Women Q.* **2018**, *42*, 489–503. [CrossRef]
24. Dou, R.; Hazari, Z.; Dabney, K.; Sonnert, G.; Sadler, P. Early informal STEM experiences and STEM identity: The importance of talking science. *Sci. Educ.* **2019**, *103*, 623–637. [CrossRef]
25. Kelly, G.J.; Cunningham, C.M.; Ricketts, A. Engaging in identity work through engineering practices in elementary classrooms. *Linguist. Educ.* **2017**, *39*, 48–59. [CrossRef]
26. Merolla, D.M.; Serpe, R.T. STEM enrichment programs and graduate school matriculation: The role of science identity salience. *Soc. Psychol. Educ.* **2013**, *16*, 575–597. [CrossRef]
27. Chen, S.; Binning, K.R.; Manke, K.J.; Brady, S.T.; McGreevy, E.M.; Betancur, L.; Limeri, L.B.; Kaufmann, N. Am I a Science Person? A Strong Science Identity Bolsters Minority Students' Sense of Belonging and Performance in College. *Pers. Soc. Psychol. Bull.* **2021**, *47*, 593–606. [CrossRef] [PubMed]
28. Sharon, A.J.; Baram-Tsabari, A. Can science literacy help individuals identify misinformation in everyday life? *Sci. Educ.* **2020**, *104*, 873–894. [CrossRef]
29. Musa, A. Additional Measles Case Reported at Florida Elementary School as Lawmaker Urges Public Health Emergency. CNN. 2024. Available online: https://www.cnn.com/2024/02/27/health/florida-measles-outbreak/index.html (accessed on 10 May 2024).
30. Motoki, K.; Saito, T.; Takano, Y. Scientific Literacy Linked to Attitudes Toward COVID-19 Vaccinations: A Pre-Registered Study. *Front. Commun.* **2021**, *6*, 707391. [CrossRef]
31. Oliver, M.C.; Adkins, M.J. "Hot-headed" students? Scientific literacy, perceptions and awareness of climate change in 15-year olds across 54 countries. *Energy Res. Soc. Sci.* **2020**, *70*, 101641. [CrossRef]
32. Schnuerch, M.; Haaf, J.M.; Sarafoglou, A.; Rouder, J.N. Meaningful Comparisons With Ordinal-Scale Items. *Collabra Psychol.* **2022**, *8*, 38594. [CrossRef]
33. Liddell, T.M.; Kruschke, J.K. Analyzing ordinal data with metric models: What could possibly go wrong? *J. Exp. Soc. Psychol.* **2018**, *79*, 328–348. [CrossRef]
34. Bürkner, P.-C.; Vuorre, M. Ordinal Regression Models in Psychology: A Tutorial. *Adv. Methods Pract. Psychol. Sci.* **2019**, *2*, 77–101. [CrossRef]
35. Schnuerch, M.; Rouder, J.N. Bayes Factors for Ordinal Scales. Available online: https://martinschnuerch.shinyapps.io/likertBF/ (accessed on 10 May 2024).
36. Rouder, J.N. Teaching Bayes' theorem: Strength of evidence as predictive accuracy. *Am. Stat.* **2018**, *73*, 186–190. [CrossRef]
37. IBM Corp. *IBM SPSS Statistics for Macintosh*, Version 27.0; IBM Corp: Armonk, NY, USA, 2019.
38. Haahr, M.; Haahr, S. True Random Number Service. *Retrieved August* **1998**, *20*, 2008.
39. McHugh, M.L. Interrater reliability: The kappa statistic. *Biochem. Medica* **2012**, *22*, 276–282. [CrossRef]
40. R Core Team. *R: A Language and Environment for Statistical Computing*; R Core Team: Vienna, Austria, 2020.
41. Wilson, D.; Jones, D.; Bocell, F.; Crawford, J.; Kim, M.J.; Veilleux, N.; Floyd-Smith, T.; Bates, R.; Plett, M. Belonging and Academic Engagement Among Undergraduate STEM Students: A Multi-institutional Study. *Res. High Educ.* **2015**, *56*, 50–76. [CrossRef]
42. Archer, L.; DeWitt, J.; Osborne, J.; Dillon, J.; Willis, B.; Wong, B. "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Sci. Educ.* **2010**, *94*, 617–639. [CrossRef]

43. Cotner, S.; Thompson, S.; Wright, R. Do Biology Majors *Really* Differ from Non–STEM Majors? *CBE—Life Sci. Educ.* **2017**, *16*, ar48. [CrossRef] [PubMed]
44. Gardner, G.E.; Bonner, J.; Landin, J.; Ferzli, M.; Shea, D. Nonmajors' Shifts in Attitudes & Perceptions of Biology & Biologists Following an Active-Learning Course: An exploratory study. *Am. Biol. Teach.* **2016**, *78*, 43–48. [CrossRef]
45. Trujillo, G.; Tanner, K.D. Considering the Role of Affect in Learning: Monitoring Students' Self-Efficacy, Sense of Belonging, and Science Identity. *CBE—Life Sci. Educ.* **2014**, *13*, 6–15. [CrossRef] [PubMed]
46. Rask, K. Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences. *Econ. Educ. Rev.* **2010**, *29*, 892–900. [CrossRef]
47. Jelks, S.M.R.; Crain, A.M. Sticking with STEM: Understanding STEM Career Persistence among STEM Bachelor's Degree Holders. *J. High. Educ.* **2020**, *91*, 805–831. [CrossRef]
48. Weatherton, M.; Schussler, E.E. Success for All? A Call to Re-examine How Student Success Is Defined in Higher Education. *CBE—Life Sci. Educ.* **2021**, *20*, es3. [CrossRef] [PubMed]
49. Pedler, M.L.; Willis, R.; Nieuwoudt, J.E. A sense of belonging at university: Student retention, motivation and enjoyment. *J. Furth. High. Educ.* **2022**, *46*, 397–408. [CrossRef]
50. Canning, E.A.; Ozier, E.; Williams, H.E.; AlRasheed, R.; Murphy, M.C. Professors Who Signal a Fixed Mindset About Ability Undermine Women's Performance in STEM. *Soc. Psychol. Personal. Sci.* **2022**, *13*, 927–937. [CrossRef]
51. Rahm, J.; Downey, J. "A Scientist Can Be Anyone!" Oral Histories of Scientists Can Make "Real Science" Accessible to Youth. *Clear. House J. Educ. Strateg. Issues Ideas* **2002**, *75*, 253–257. [CrossRef]
52. Hornsey, M.J.; Fielding, K.S. Understanding (and Reducing) Inaction on Climate Change. *Soc. Issues Policy Rev.* **2020**, *14*, 3–35. [CrossRef]
53. Dweck, C.S. Mindsets: Developing Talent Through A Growth Mindset. *Olymp. Coach.* **2009**, *21*, 4–7.
54. Thompson, J.J.; Jensen-Ryan, D. Becoming a "Science Person": Faculty Recognition and the Development of Cultural Capital in the Context of Undergraduate Biology Research. *CBE—Life Sci. Educ.* **2018**, *17*, ar62. [CrossRef] [PubMed]
55. Robert, J.; Carlsen, W.S. Teaching and research at a large university: Case studies of science professors. *J. Res. Sci. Teach.* **2017**, *54*, 937–960. [CrossRef]
56. Schwartz, R.; Lederman, N. What Scientists Say: Scientists' views of nature of science and relation to science context. *Int. J. Sci. Educ.* **2008**, *30*, 727–771. [CrossRef]
57. Lucas, K.L.; Spina, A.D. Science Identity and Its Implications for STEM Retention and Career Aspirations Through a Research-Based First-Year Biology Seminar. *J. Coll. Sci. Teach.* **2022**, *52*, 3–5. [CrossRef]
58. Kridelbaugh, D.M. The Use of Online Citizen-Science Projects to Provide Experiential Learning Opportunities for Nonmajor Science Students. *J. Microbiol. Biol. Educ.* **2016**, *17*, 105–106. [CrossRef] [PubMed]
59. Venville, G.; Rennie, L.; Hanbury, C.; Longnecker, N. Scientists Reflect on Why They Chose to Study Science. *Res. Sci. Educ.* **2013**, *43*, 2207–2233. [CrossRef]
60. Stringer, K.; Mace, K.; Clark, T.; Donahue, T. STEM focused extracurricular programs: Who's in them and do they change STEM identity and motivation? *Res. Sci. Technol. Educ.* **2020**, *38*, 507–522. [CrossRef]
61. Carlone, H.B.; Haun-Frank, J.; Webb, A. Assessing equity beyond knowledge- and skills-based outcomes: A comparative ethnography of two fourth-grade reform-based science classrooms. *J. Res. Sci. Teach.* **2011**, *48*, 459–485. [CrossRef]
62. Desy, E.; Peterson, S.; Brockman, V. Attitudes and Interests Among University Students in Introductory Nonmajor Science Courses: Does Gender Matter? *J. Coll. Sci. Teach.* **2009**, *39*, 16.
63. Roth, W.-M.; Lee, S. Scientific literacy as collective praxis. *Public Underst. Sci.* **2002**, *11*, 33–56. [CrossRef]
64. Rodriguez, S.; Cunningham, K.; Jordan, A. STEM Identity Development for Latinas: The Role of Self- and Outside Recognition. *J. Hisp. High. Educ.* **2019**, *18*, 254–272. [CrossRef]
65. Hodson, D. Learning Science, Learning about Science, Doing Science: Different goals demand different learning methods. *Int. J. Sci. Educ.* **2014**, *36*, 2534–2553. [CrossRef]
66. Campbell, T.; Lee, H.; Kwon, H.-S.; Park, K. Student Motivation and Interests as Proxies for Forming STEM Identities. *J. Korean Assoc. Sci. Educ.* **2012**, *32*, 532–540. [CrossRef]
67. Peterson, E.; Kulakowski, E.; Mendez, S.L. "I Need to Do Better": The Promotion of Undergraduate Women's STEM Identity by Engineering Faculty. *J. Adv. Acad.* **2024**, 1932202X241240593. [CrossRef]
68. Eccles, J. Who Am I and What Am I Going to Do with My Life? Personal and Collective Identities as Motivators of Action. *Educ. Psychol.* **2009**, *44*, 78–89. [CrossRef]
69. Laugksch, R.C. Scientific literacy: A conceptual overview. *Sci. Educ.* **2000**, *84*, 71–94. [CrossRef]

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