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Taking it One Step at a Time: The Growth of a Program to Support the Doctorates of Tomorrow

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Abstract

First-generation, low-income students, and racially minoritized students face structural educational inequities, resulting in lower rates of graduate degree attainment compared to their counterparts [1]. A Step to the Doctorate Institute (S2D) at Virginia Tech's Center for the Enhancement of Engineering Diversity (VT CEED) bridges the gap between undergraduate and graduate programs, boosting underrepresented minority engagement in graduate education by providing an opportunity to work with professionals in preparing for graduate school. The purpose of the exploratory study is to (a) provide a brief literature review on graduate education for underserved populations, (b) describe an overview of Virginia Tech's A Step to the Doctorate Institute and administrative efforts in identifying key program components, and (c) conclude with an assessment of program effectiveness in supporting student academic trajectories.

Introduction

Established programs, such as the Ronald E. McNair Post-Baccalaureate Achievement Program (McNair Scholars Program), have demonstrated success in supporting underrepresented students in the form of program development: the McNair Scholars Program doing so by boosting self-efficacy in the areas of academia, research, and socialization [2], [3].

While significant strides have been made in supporting students to unlock hidden potential and achieve success as a graduate student, there is still work to be done. Bridge programs have proven to be fruitful in propelling participants toward academic and professional success, yet there remain unreached scholars seeking opportunity to take the next step.

The Center for the Enhancement of Engineering Diversity (CEED) at Virginia Tech (VT CEED) offers many programs that support engineering students at every stage of higher education: pre-college, undergraduate, and graduate. Having studied the success of the McNair Scholars program, VT CEED have used the McNair Scholars program as a framework to develop a similar program: S2D. The program was designed specifically to help undergraduate students take their next step toward graduate education, supporting students in an untraditionally shorter amount of time. The authors look to identify key components contributing to the success of the time-affordable bridge program. This data and research are a part of a larger IRB approved project between Virginia State University (VSU) and Virginia Tech.

Literature Review

In this section of the paper, the researchers examined the literature on graduate preparation initiatives for underserved populations. The literature review will explore the topics of graduate education diversity and inclusion, graduate education self-efficacy, mentoring, and curriculum development.

Graduate Education Diversity, Equity, and Inclusion (DEI)

Baum and Steele discussed the implications of existing demographic data regarding graduate school enrollment in *Who Goes to Graduate School and Who Succeeds?* The data presented in this paper demonstrates the monetary and professional value a graduate education degree offers and how such degree opportunities are within reach for all. However, the authors highlight the imbalances in advanced degree attainment and return on investment from a demographic context. The authors conclude with the following statement:

> "Black college graduates—who make up a *much smaller* share of their age group than white and Asian college graduates—are actually *more likely* than those from other racial and ethnic groups to go to graduate school. But they *disproportionately* enroll in *master's degree* programs, which generate the lowest earning premiums; a very small percentage pursue *professional degrees* that lead to the *highest average earnings* [4]."

While earnings for a doctoral degree do not rank the highest, Baum and Steele present findings that earnings with a doctoral degree *rank second*. Furthermore, in a study of 2007-2008 bachelor's degree recipients who enrolled in graduate school as of 2012, the lowest rate of degree enrollment (master's, professional, and doctoral) for Black and Hispanic college graduates is doctoral, *7% and 4%, respectively* [4]. As of 2020, this rate of doctoral attainment has increased to 9% within science and engineering degrees for Hispanic of Latino recipients, with Black or African American doctoral recipients at 6.6%, and Native American or Alaska Native at .4% [5].

Graduate Education Self-Efficacy

Chemers and colleagues find science self-efficacy and identification as a scientist to be *strong indicators of commitment to a career in science* [6]. The motivation for the article is derived from the lack of diversity and inclusion in United States science education. Using a statistical analysis approach, the authors identify program components associated with underlying psychology that propel undergraduates to a commitment to scientific careers. The authors acknowledge that previous studies found "...academic self-efficacy was a strong and significant predictor of academic goals, academic performance, personal adjustment, and health [6]." This study sets a solid foundation for DEI development in other career fields such as engineering.

Establishment of a program helps students take their next steps, whether that be toward career or graduate education. To understand a program's influence on its participants, component and psychological analysis is critical. As Chemers et al. state:

> "From both a policy and practice perspective, understanding the underlying *psychological mechanisms* provides guidance to select new programs for funding to improve the effectiveness of existing programs [6]."

In *Underrepresented First-Generation, Low-Income College Students' Pursuit of a Graduate Education: Investigating the Influence of Self-Efficacy, Coping Efficacy, and Family Influence*, Tate et al. find strong research self-efficacy increases the likelihood students will set themselves on a track to graduate degree attainment: "Additionally, when students reported a high level of graduate education *research self-efficacy*, there was an increase in their pursuit of graduate studies,"; "Specifically, we found that when students' self-efficacy for conducting *graduate-level research increased*, so did their active pursuit of graduate school. *Graduate school is a time when students become immersed in research* [1]." Immersion in research during graduate school to develop research-self efficacy is too late, as interest in graduate school typically emerges at the undergraduate level or in earlier stages of higher education.

Development of academic, social, and research self-efficacy within undergraduate students each play a key role en route to graduate school enrollment.

Mentoring

Graduate degree attainment requires guidance which can be derived from an approach encompassing intervention and integrated support strategies led by experienced people.

In *Assessing the Effectiveness of the GradTrack Virtual Mentoring Program*, Arinze et al. provide a survey-driven GradTrack program evaluation. The purpose of the paper is to provide a program evaluation of the current state of Purdue Engineering's GradTrack program. While still in the initial stages of development, Purdue Engineering's GradTrack program has proven to positively influence undergraduate and graduate students *via mentorship*. Qualitative and quantitative *survey data* provided by participants present critical findings in the realm of mentoring: "This data suggests that GradTrack increases [a mentees] sense of connectedness with two communities: 1) graduate students and 2) engineering community."; "We found that GradTrack significantly increases our mentor's feelings of experience in three areas: reviewing application materials, reviewing resumes/CVs[,] and moderating a roundtable discussion [7]." Mentorship supports the development of self-efficacy in both future and current graduate students.

Building upon the effectiveness of graduate preparation, Geary, Fonseca, Blackowski, and Matusovich explored the identities and roles of mentors for rising minority doctoral students in engineering. The findings revealed that various individuals, including family members, informal undergraduate mentors, and peers, played significant roles in supporting the decision of minoritized students to enroll in doctoral programs. These mentors provided different forms of

support, ranging from emotional encouragement to practical guidance, thereby influencing the students' academic and career trajectories. The study highlighted the importance of recognizing and leveraging the diverse mentorship networks available to minoritized students to promote their success in doctoral programs [8].

Curriculum Building

According to *Should You Go to Graduate School?* by Tomas Chamorro-Premuzic, the decision of going to graduate school continues to hold a level of *uncertainty*. The author notes that efforts at the university level can be made to nurture curiosity and progress toward clarifying the unknown. The value of holding a master's degree is evolving: "...the most in-demand jobs require graduate credentials, to the point of surpassing current levels of supply."; "...the numbers of people enrolling in university continues to rise, effectively devaluing the undergraduate degree."; "...27% of employers now require master's degrees for roles in which historically undergraduate degrees sufficed [9]."

With an evident call to action, the authors note one approach seen throughout the literature. That is to develop undergraduate programs that set students on track to graduate degree attainment, such as the McNair Scholars program and Purdue Engineering's GradTrack program [3],[7],[10]. In establishing a program, it is crucial to be mindful of how the program's components impact subsequent steps to ensure desired outcomes are successfully attained. With the right collection of activities tailored to participants, students will be led to academic, research, and social opportunities that could not be found elsewhere.

While degree attainment continues to hold uncertainty, establishing pre-graduate degree programs can support undergraduates to make well-informed decisions toward pursuit of graduate education.

VT CEED's A Step to the Doctorate Institute (S2D)

VT CEED used the McNair Scholars program as a framework to develop S2D, a program designed to help undergraduate students take their next step toward graduate degree attainment.

S2D administrators recognize that incoming S2D participants have varying levels of knowledge about graduate school. Hence, S2D administrators have spent time developing program curriculum such that participation advances all students regardless of where they are on their journey to graduate education. Specifically, the program is designed to support underrepresented minority (URM) students seeking a doctoral degree, and in turn URM students seeking a master's degree.

While S2D continues to provide similar resources to participants from year to year, the curriculum has experienced change upon participant evaluation to provide a more supportive environment for the participants' needs. The seven-month program typically beginning in March and wrapping up in September consists of a 1) “What is graduate school?” presentation, 2) a graduate panel, 3) a faculty panel, 4) fellowship application workshop, and 5) graduate school application preparation. The first four program components previously listed are packaged into a one-day bootcamp, minimizing the cost of time and maximizing delivery of information to participants. One key program component is working with the writing coaches to develop a personal statement for graduate school applications.

Graduate preparation programs have proven to be highly effective in equipping aspiring graduate students with the necessary tools, knowledge, and skills to succeed in their advanced studies. These programs offer a structured pathway for students to bridge the gap between undergraduate and graduate education, preparing them for the rigors of postgraduate work. By providing instruction on research methodologies, academic writing, critical thinking, and time management, graduate preparation programs empower students to navigate the complexities of their chosen fields with confidence. Moreover, these programs often include mentorship opportunities to connect current graduate students with S2D participants along with resources that can enhance students' academic and professional development.

We extend an invitation to junior-level students from a range of educational institutions, including Virginia Tech, Historically Black Colleges and Universities (HBCUs), and international universities, to participate in our S2D program. To qualify for this program, students must complete an application and a pre-program self-evaluation survey. We utilize email communications to reach out to potential participants, connecting with students, minority-serving institutions, and directors of engineering programs to ensure a diverse and inclusive representation in the program.

Just from the three years that A Step to the Doctorate has been around, the program has seen its participants achieve enrollment in master’s and doctoral programs at prestigious institutions such as MIT, UCLA, and others, with some attributing their success directly to the program. The 2023 cohort of S2D consisted of students from ten universities.

Methods

The following describes an initial exploration of the program effectiveness of S2D using the data available from participant information. As a newer program, the data collected over four years allows for comprehensive exploration resulting in future considerations for subsequent cohorts that will continually expand the dataset.

Data Collection

Data collection is executed using three QuestionPro surveys: a pre-program self-evaluation survey utilizing the Graduate Education Self-Efficacy Scale (GESES), program application, and post-program evaluation survey [2]. The surveys support student self-reflection regarding graduate education self-efficacy, highlight the importance of gathering graduate application materials, and assess DEI efforts via participant program evaluation. The questions provided in the GESES have remained the same each time it was employed.

Data collection has been an ongoing process since the inception of S2D in 2020. Data has been collected by cohort consisting of student participants. To optimize data quality and survey completion, timing of survey completion requests is key. The primary data collection windows occurred before and after program participation: students complete the application and GESES assessment in the initial phase and provide program evaluations in the later phase. The data is collected using QuestionPro and exported to be cleaned and managed using Microsoft Excel.

Data Transformation

Since the program's inception in 2020, data collection has migrated from Qualtrics to QuestionPro resulting in the need for extensive data cleaning involving variable renaming, duplicate removal, and data transformation to ensure consistent data types. Furthermore, we augmented the dataset with corresponding university and Carnegie Classification of Institutions of Higher Education (CCIHE) data, categorizing responses by cohort, Virginia Tech, and Carnegie classification to uncover trends critical for effective curriculum building [11]. S2D programming is structured in a cohort model, so having S2D cohort as a category allows for analysis of trends from year to year. S2D is a Virginia Tech program, hence Virginia Tech students are a crucial subset to further analyze. Carnegie Classification will enhance program analysis from the perspective of comprehending prior research experience.

Concurrent Triangulation Strategy (CTS)

CTS involves simultaneous collection of quantitative and qualitative data. After compilation and data cleaning, information was categorized into quantitative (GESES data, numerical) and qualitative (S2D application responses, primarily text) datasets. This separation enabled distinct quantitative and qualitative analyses. In the subsequent phase of CTS, Creswell recommends employing one quantitative (QUAN) and one qualitative (QUAL) method to analyze these data sets individually, thus minimizing potential weaknesses in a single method [12].

Quantitative Analysis

In our study, we have chosen to use Tableau for its robust dashboard-building capabilities. Tableau allows us to craft intricate yet comprehensible visualizations and dashboards to be used by S2D administrators. Tableau provides interactive functionality that supports a tailored experience in informing dashboard viewers. For example, Tableau allows for one visualization to serve as a filter for another visualization and for viewers to select multiple data points at a time to further evaluate overlapping data points. The final phase of the quantitative analysis involves compiling visualizations into dashboards. The two types of data visualizations the researchers have elected to use are box & whisker plots and bar plots: bar plots visualize quantitative differences and box & whisker plots visualize multiple distributions (survey questions with responses ranging from one to ten) in a compact manner

Dashboard design provides researchers with the ability to juxtapose plots for comprehensive analysis. For each category (Virginia Tech, S2D cohort, and Carnegie Classification), three dashboards will be produced. The three dashboards for each category will display unique sets of question distributions grouped by GESES domain (academic, social, and research), resulting in nine total dashboards. To effectively display all dashboards, the tab feature of Tableau will be employed. Regarding positioning plots, horizontal box & whiskers and a horizontal bar plot will be displayed with the bar plot above the box & whiskers plot. From a sequencing perspective, reading top down is a natural human behavior. Thus, the numbers specified in the bar plots will contextualize the question response distributions. Additional functionality is provided to S2D administrators utilizing the bar plot to specify box & whisker distributions for specified subgroups (i.e., 2024 cohort R1 participants).

Qualitative Analysis

To execute qualitative analysis, we adopt a programmatic approach. A program was developed to perform data processing, frequency analysis, categorical mapping, categorical analysis, and qualitative visualization. In selecting a programming language for this task, the researchers have chosen Python based on experience and its data analysis capabilities.

Preliminary Analysis

In the initial QUAL analysis phase, our researchers seek to identify commonly used words within the application statement of purpose by conducting frequency analysis. To effectively conduct frequency analysis, data processing must take place in the form of tokenization. Tokenization is the process of transforming text into a list of words (tokens). To uphold the quality of analysis, stop words and punctuation are removed in the process. Once the tokenization of each statement is complete, all generated tokens are merged into one list. Frequency analysis is then performed detailing commonly used words across all statements. Identifying commonly used words across all statements is an effort to assess self-efficacy trends in the form of writing across S2D participants prior to categorical analysis.

Categorical Mapping

To ensure cross validation, the QUAN survey will be utilized as input for categorical weighing to be performed in the secondary QUAL analysis. Given the effective categorization established in QUAN analysis, the GESES statements will be utilized for QUAL categorization as they contain keywords that we seek to see S2D participants carry over into a qualitative context.

For each collection of GESES statements (academic, social, and research) the following process was performed: tokenize each statement, merge the tokens as a list, and keep only unique values. Tokenization provides word-to-word comparison when calculating the presence of a category in a statement of purpose. Merging the tokens allows for related words to contribute to the same categorical weight. Keeping only unique values provides optimized computing efficiency and eliminates algorithmic complications and misclassification. Detailed categorical mapping serves to elucidate the "why?" for program interest along with established participant self-efficacy.

With each category now having a set of associated words, the next step is to iterate through all the statements of purpose to calculate how much each category is present in each statement of purpose. The academic, social, and research categorical weights will be calculated using the following formula:

$$\frac{\sum_{i=1}^{number\ of\ words\ in\ category} Frequency\ of\ word_i\ in\ statement\ of\ purpose}{Number\ of\ words\ in\ statement\ of\ purpose}$$

Given not all words in a statement of purpose will fall under the academic, social, and research categories, a category labeled "uncategorized" will be used to catch all uncategorized words. However, *the uncategorized category will not be used to categorize the statements of purpose.*

Each statement of purpose now has an academic, social, research, and uncategorized weight attached to it. Each statement of purpose will be categorized as primarily either academic, social, or research by identifying the greatest categorical proportion for each statement of purpose. Upon classification of statements of purpose, the qualitative results will be assessed alongside the quantitative results to identify any discrepancies.

Secondary Analysis

For each category, including the uncategorized category, the minimum and maximum values for each category will be determined to provide further insight and analysis of qualitative trends.

Through the detailed systematic qualitative analysis approach, we aim to extract insights from the statements of purpose provided by participants, enriching the data-driven decision-making

process for S2D administrators in program development. The final categorization discussed lends itself to the broader mixed methods approach being employed. Visualizing qualitative results is discussed in the following section.

Qualitative Visualization

The qualitative analysis within the Concurrent Triangulation Strategy (CTS) method involves both analysis and visualization. This section aims to provide the rationale behind our visualization decisions. The researchers have employed the four-question approach as detailed as detailed by Dr. Stephanie Evergreen: Individual, Aggregate, or Themes? Pure Qual, Light Quant, or Concept? Yes/No or a Range? Time?

Heat Map Given the researchers' interest in providing a visualization highlighting graduate self-efficacy themes at program entry with “Light QUAN” analysis on a range of data, the researchers have elected to present a heat map visualization. On the y-axis will be the academic, social, and research categories. On the x-axis will be the participants involved in the study [13].

Reporting Out

A compilation of categorized findings will be reported out. This endeavor is crucial for recognizing pre-program trends amongst participants, enabling S2D administrators to pinpoint barriers and in turn seek support as needed for program development.

Results

The following figures are screenshots of interactive (dashboards) and static (heatmap) visualizations to be used by S2D administrators to assess the need for curriculum modifications.

Quantitative Results

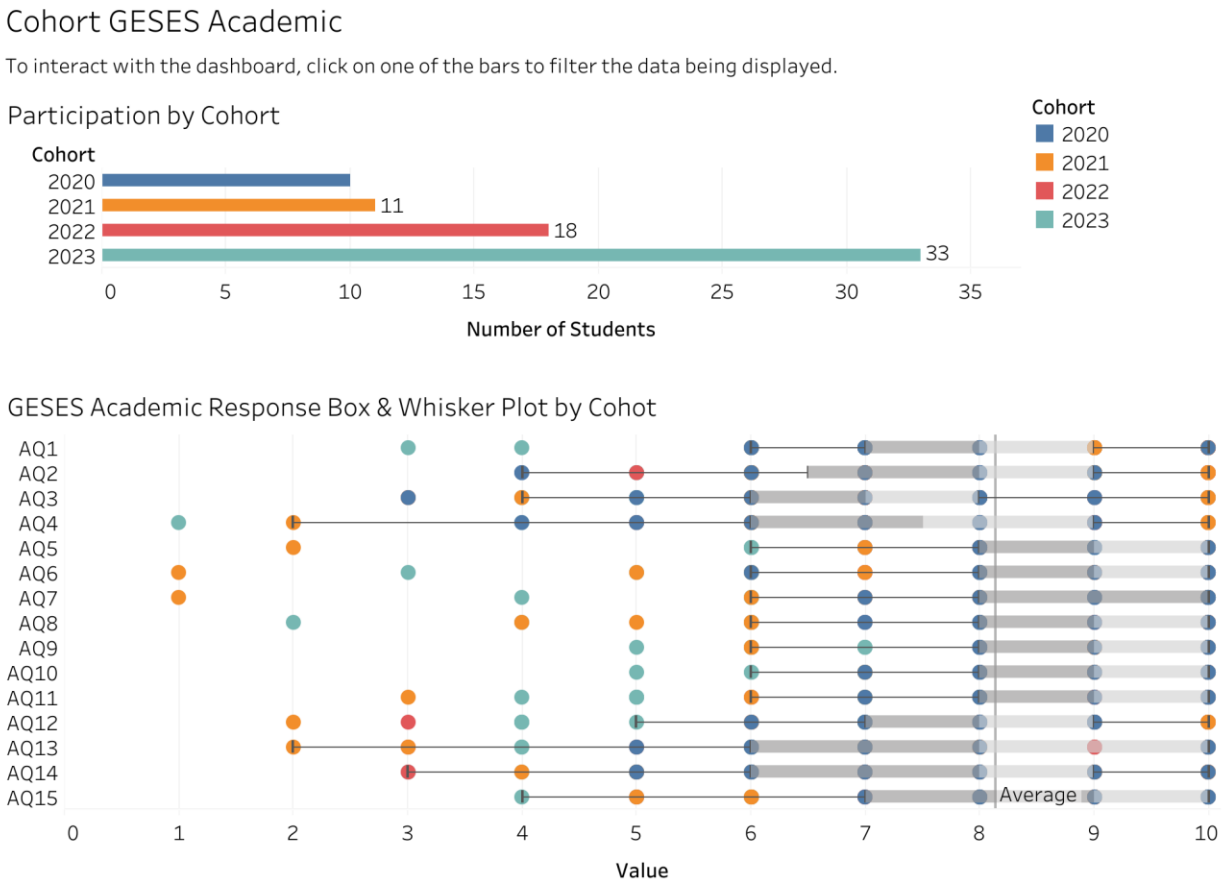

Fig. 1: Complete GESES academic analysis by cohort

Figure 1 presents a bar chart to inform the viewer of participation numbers by cohort prior to viewing the response distributions from the GESES survey. The bar chart at the top of the dashboard also serves as a filter for the box & whisker plot below. We have chosen to filter by cohort given the data was collected on a cohort-by-cohort basis. Furthermore, filtering by cohort allows for S2D administrators to visualize trends by cohort. Since no bar is selected in the bar chart, the box & whisker plots display the response distributions for all participants. Given Figure 1, the box & whisker plots below the bar chart illustrate the response distributions for each academic question found in the GESES survey. The dashboards for VT participant GESES analysis are formatted the same way.

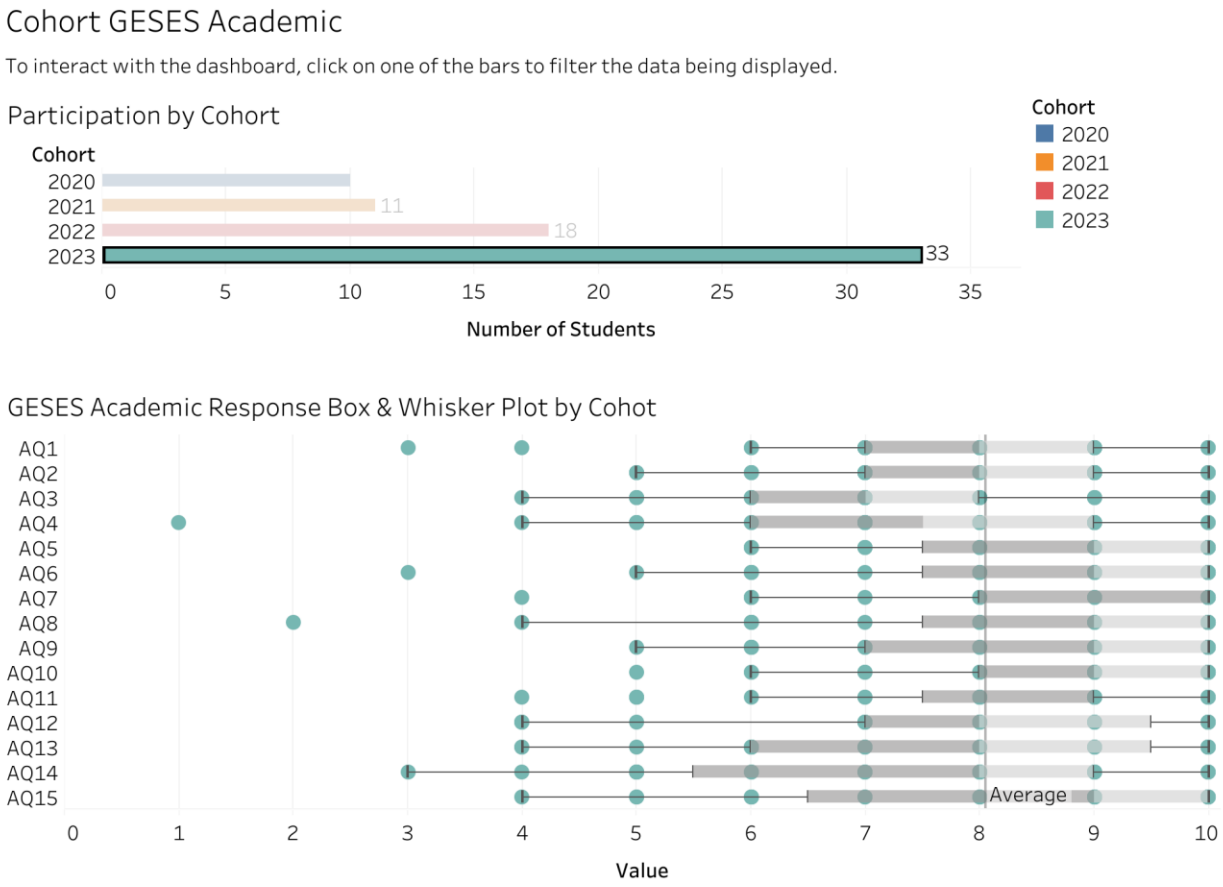

Fig. 2: Cohort GESES Academic dashboard demonstrating filtering for 2023 cohort data

Figure 2 presents a bar chart to inform the viewer of participation by cohort prior to viewing the response distributions from the GESES survey. The bar chart at the top of the dashboard also serves as a filter for the box & whisker plot below. We have chosen to filter by cohort given the data was collected on a cohort-by-cohort basis. Filtering by cohort allows for S2D administrators to visualize trends by cohort. Since the 2023 bar is selected in the bar chart, the box & whisker plots display the response distributions for the 2023 cohort participants. Given Figure 2, the box & whisker plots below the bar chart illustrate the response distribution for each academic question (AQ) found in the GESES survey.

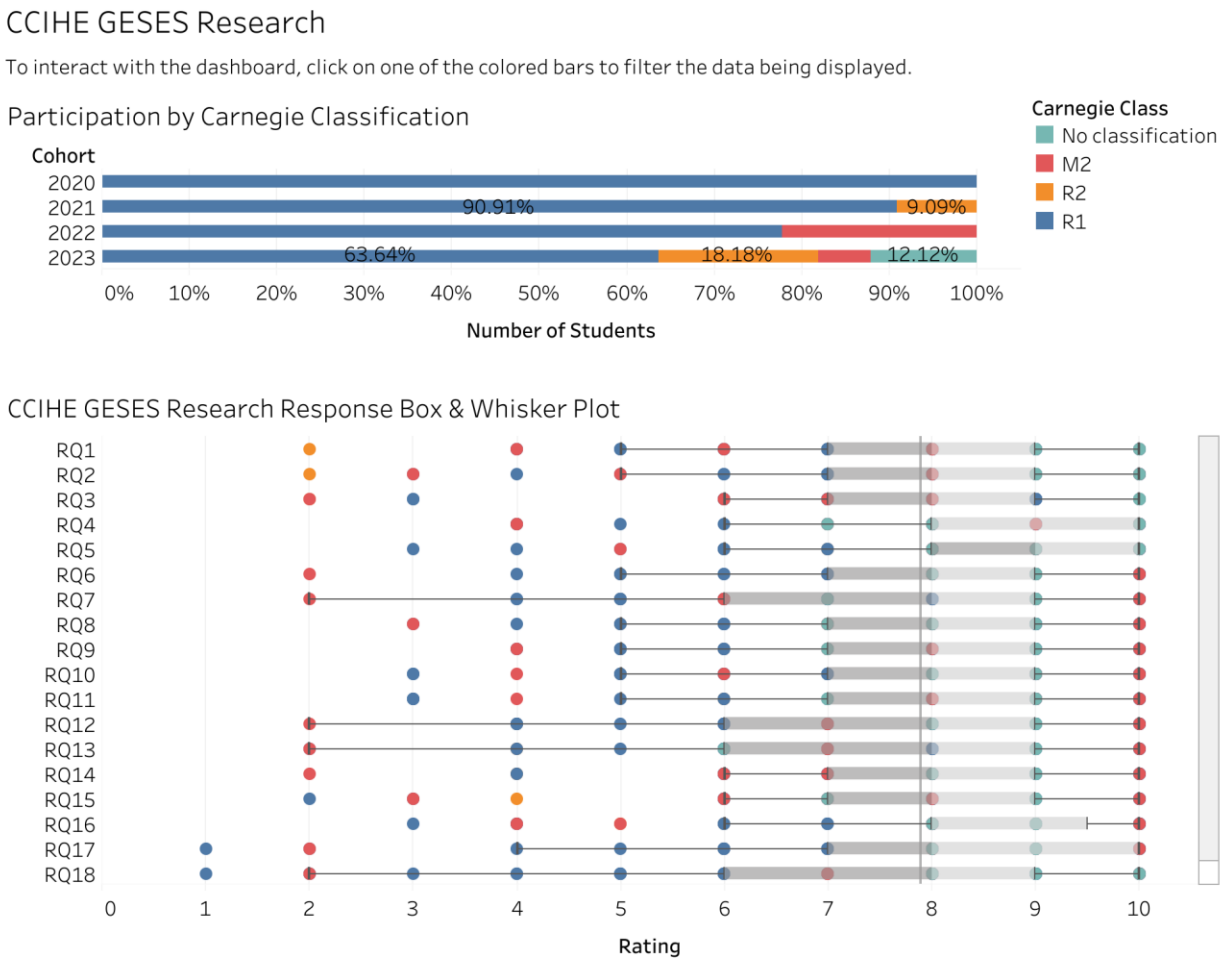

Fig. 3: Complete GESES research analysis by CCIHE

Figure 3 shows a bar chart to inform the viewer of CCIHE (Carnegie Classification) participation before viewing the response distributions from the GESES survey. The bar chart at the top of the dashboard also serves as a filter for the box & whisker plot below. We have chosen to filter by cohort given the data was collected on a cohort-by-cohort basis. Furthermore, filtering by cohort allows for S2D administrators to visualize trends from by cohort. Since no bar is selected in the bar chart, the box & whisker plots display the response distributions for all participants. The box & whisker plots below the bar chart illustrate the response distributions for each research question (RQ) found in the GESES survey.

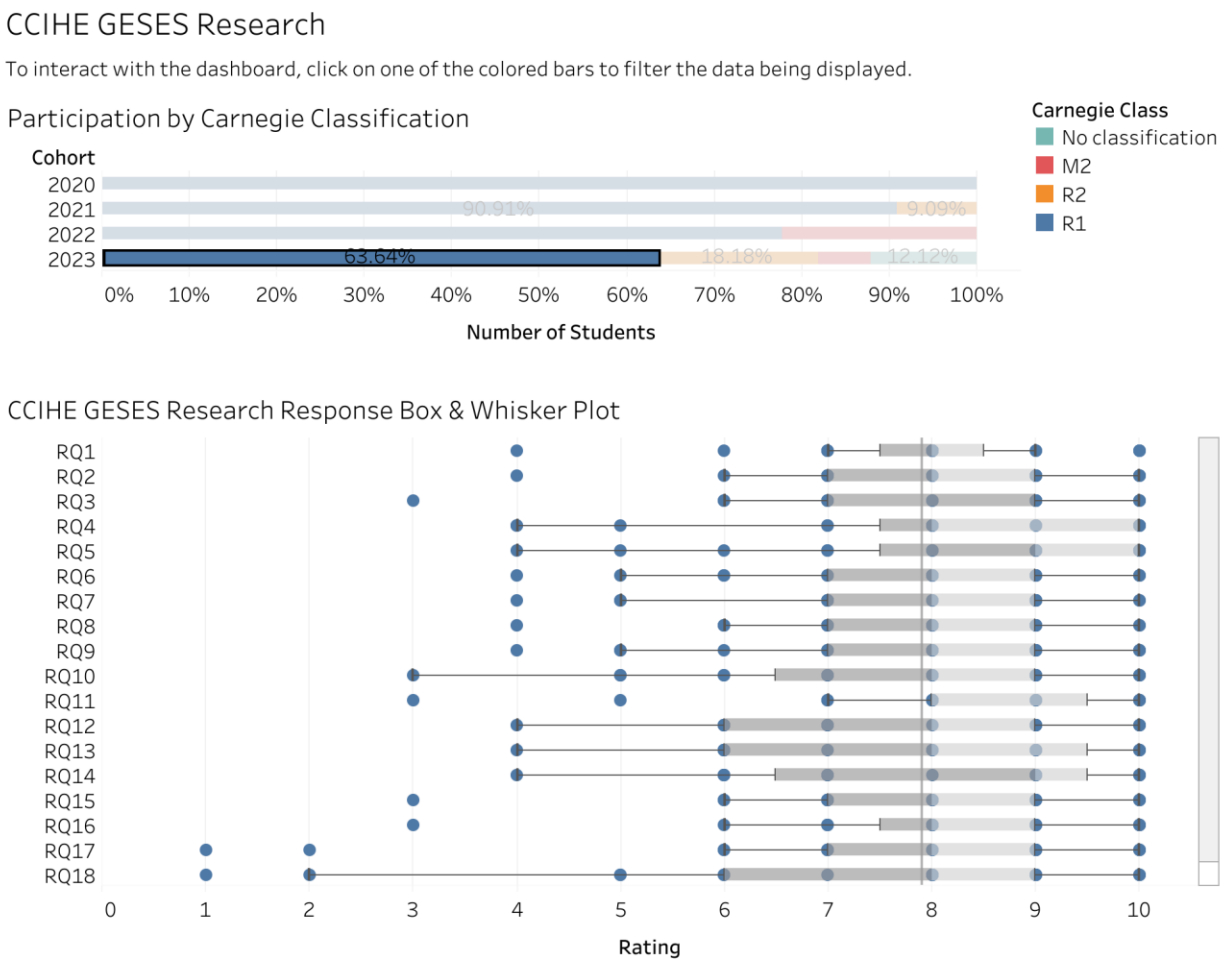

Fig. 4: CCIHE GESES Research dashboard demonstrating filtering for 2023 cohort R1 CCIHE participant data

Figure 4 shows a bar chart to inform the viewer of CCIHE participation before viewing the response distributions from the GESES survey. The bar chart at the top of the dashboard also serves as a filter for the box & whisker plot below. We have chosen to filter by cohort and CCIHE given the data was collected on a cohort-by-cohort basis and CCIHE further contextualizes research self-efficacy. Furthermore, filtering by cohort and CCIHE allows for S2D administrators to visualize trends from cohort to cohort via individual cohort and CCIHE analysis. Since the 2023 R1 bar is selected in the bar chart, the box & whisker plots display the response distributions for the 2023 cohort R1 participants. The box & whisker plots below the bar chart illustrate the response distributions for each research question (RQ) found in the GESES survey.

Qualitative Results

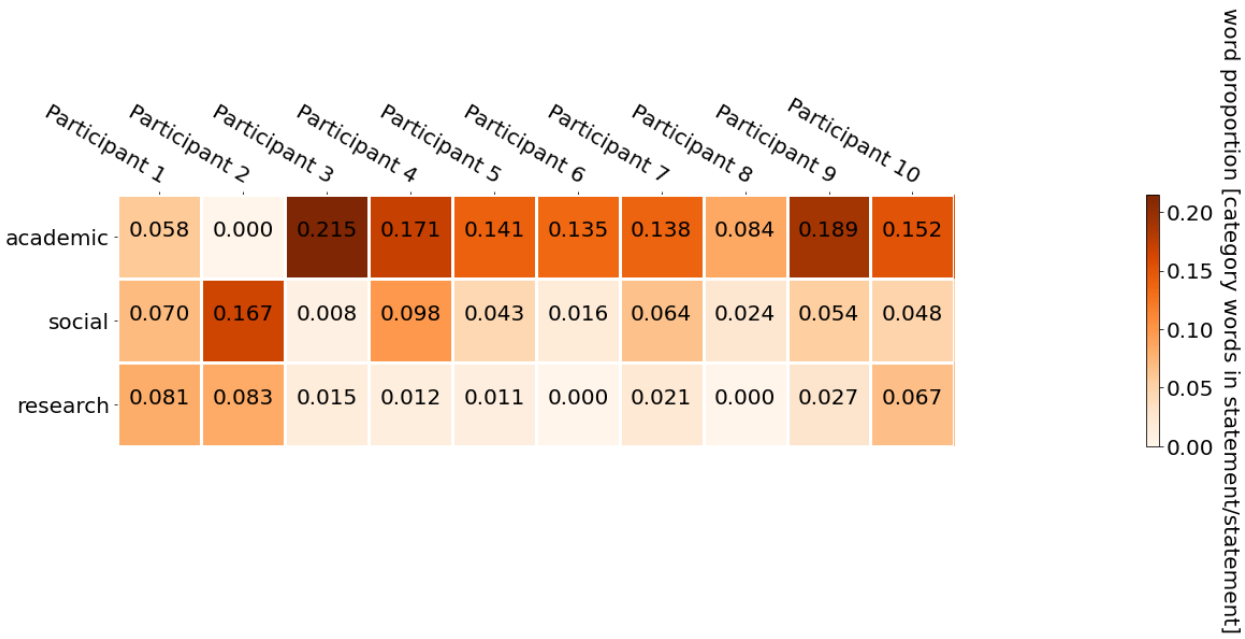

Fig. 5: Excerpt of qualitative heatmap

Figure 5 presents an excerpt from the heatmap categorizing participants' statement of purpose into one of the GESES categories: academic, social, research. The word proportions found in each cell of the heat map is the categorical mapping calculation utilizing the formula corresponding to the category identified on the y-axis and the participant identified on the x-axis. As illustrated in the color bar provided to the right in Figure 5, the categorization values presented in the excerpt range from 0.000 to 0.215 with the colors ranging from light to dark, respectively. The heatmap displays both the variability and trends in expressing self-efficacy in statements of purpose across all S2D participants. The proportions detailed in the heatmap are consistent with the notion of expressing self-efficacy being one of the many components that contribute to a comprehensive statement of purpose.

* See Author Notes [1]

Discussion

The three qualitative categories — cohort, Virginia Tech (VT), and Carnegie Classification Institution for Higher Education (CCIHE) — along with the three quantitative categories — academic, social, and research — will be used to structure the following report of findings.

Quantitative Discussion

When observing collective trends, the Cohort and CCIHE categories produce the same output given all participants are considered. The difference in statistical output lies in the comparison between the VT category and the other two categories (Cohort and CCIHE). Rank is utilized to evaluate the relative prominence of each self-efficacy domain. Providing the minimum value provided for a given self-efficacy domain along with corresponding number of questions that had the minimum value serves to emphasize the importance of addressing domain-specific self-efficacy short comings in the form of data-informed S2D programming improvements.

Key

- Cohort: S2D cohort
- CCIHE: Carnegie Classification of Institutions of Higher Education
- N: Number of participants in cohort/CCIHE
- Rank: Ranking among GESES categories (academic, social, research)
- Min: Minimum response values
- nq: Question count for given GESES category
- np: Participant count for given GESES category
- NC: No classification

Cohort

Table 1: Category rankings, minimum response values, and question count by cohort

		Academic			Social			Research		
Cohort	N	Rank	Min	nq	Rank	Min	nq	Rank	Min	nq
2020	10	2nd	3	1	1st	1	3	3rd	2	3
2021	11	2nd	1	2	1st	2	1	3rd	2	3
2022	18	2nd	3	4	1st	4	1	3rd	2	9
2023	33	2nd	1	1	1st	1	10	3rd	1	2

Across all cohorts, academic questions appearing as a minimum value multiple times across cohorts are as follows: Q3 (2020, 2022) Be accepted into one of your top 3 choices of graduate school. Acceptance into top graduate programs is a continuing academic achievement dependent

on academic self-efficacy. What contributes to the lack of self-efficacy in this regard is unknown, but S2D programming contributes to the development of skills and preparation required to achieve academic success: statement of purpose writing and demystify what it takes to achieve admission into desired graduate programs.

Across all cohorts, social questions appearing as a minimum value multiple times across cohorts are as follows: *Q3 (2020, 2023)* Visit a professor in his/her home; *Q7 (2020, 2023) Introduce yourself to a professor with whom you have not had a class; Q8 (all cohorts) Make a significant contribution to a conversation with a group of professors*. Being invited to visit a professor in his/her home (a traditionally personal space) could signal meaningful relationship building, a key component of social self-efficacy. Furthermore, discussion with professors outside of the classroom environment is often found in the form of professional networking events which are often provided at the college and organization level, especially given the experience of an undergraduate student. Finally, being amongst professors as a student could present imposter syndrome. To effectively express self-efficacy among professors, one must acquire professor interaction elsewhere (i.e., in a research lab or in class).

Across all cohorts, research questions appearing as a minimum value multiple times across cohorts are as follows: *Q3 (2021, 2022) Evaluate journal articles to determine usefulness in a literature review, Q17 (2022, 2023) Report your research results orally to an audience; Q18 (2022, 2023) Defend your research results to a critical audience*. Skills to conduct an effective literature review are primarily found via research experience. Research may not be the only place to acquire self-efficacy in the domains of literature review development, reporting research, and defending research. Further research includes investigation into how technical writing and public speaking abilities gained via coursework (often required for completion of undergraduate degrees) translates to confidence in critical research skills.

VT

Table 2: Category rankings, minimum response value, and question count for VT participants

		Academic			Social			Research		
Cohort	N	Rank	Min	nq	Rank	Min	nq	Rank	Min	nq
2020	10	2nd	3	1	1st	1	3	3rd	2	3
2021	11	2nd	1	2	1st	4	2	3rd	3	5
2022	18	2nd	3	1	1st	6	1	3rd	4	1
2023	33	3rd	2	1	3rd	1	10	1st	4	1

In evaluation of self-efficacy trends among VT participants, social questions appearing as a minimum value multiple times not already discussed in cohort analysis are as follows: *Q10 (2021, 2023) Introduce yourself to a prominent or important person*. Barriers that arise from the established hierarchy found in the educational landscape can limit student interaction with

prominent people. However, in the right setting (such as S2D), students can become empowered to seek such interaction that can propel graduate school trajectory.

CCIHE

Table 3: Category rankings, minimum response value, and question count by CCIHE

			Academic			Social			Research		
CCHIE	Cohort	N	Rank	Min	nq	Rank	Min	nq	Rank	Min	nq
R1	2020	10	2nd	3	1	1st	1	3	3rd	2	3
	2021	10	2nd	1	2	1st	4	2	3rd	3	5
	2022	14	2nd	3	1	1st	6	1	3rd	4	1
	2023	21	3rd	2	1	1st	1	10	2nd	1	2
R2	2021	1	1st	6	5	2nd	2	1	3rd	2	3
	2023	6	3rd	1	1	2nd	3	1	1st	6	11
M2	2022	4	2nd	3	3	1st	4	1	3rd	2	9
	2023	2	3rd	4	3	2nd	4	1	1st	5	2
NC	2023	4	1st	6	2	2nd	5	1	3rd	6	1

R1

Academic questions appearing as a minimum value multiple times across R1 are as follows: *Q3 (2020, 2022) Be accepted into one of your top 3 choices of graduate school*. Even among participants with the least barrier to entry into undergraduate research, belief in oneself to get accepted into top graduate programs is lacking.

Social questions appearing as a minimum value multiple times across R1 are as follows: *Q3 (2020, 2022) Visit a professor in his/her home; Q7 (2020, 2023) Introduce yourself to a professor with whom you have not had a class; Q8 (2020, 2023) Make a significant contribution to a conversation with a group of professors; Q10 (2021, 2023) Introduce yourself to a prominent or important person*. Since R1 encompasses VT participants found across all cohorts, the discussion about social questions 3, 7, 8, and 10 from the Cohort and VT sections is held.

Research questions appearing as a minimum value multiple times across R1 are as follows: *Q18 (all cohorts) Defend your research results to a critical audience*. Even among participants with the least barrier to entry into undergraduate research, defending research is a skill that requires external support (such as S2D).

R2

Academic questions appearing as a minimum value multiple times across R2 are as follows: *Q4 (2021, 2023) Score well enough on the graduate admission test (e.g., GRE, GMAT, LSAT, MCAT, etc.) to get into one of your top 3 choices of graduate school*. This is the *first time* we

have seen academic question 4 reported with minimum response value. While S2D administrators recognize performance on graduate admission tests is a critical component of graduate school admission, graduate admission test preparation is beyond the scope of current S2D programming. Consider graduate admission test preparation for future iterations of S2D programming.

Given the small number of students that fall under the R2 CCIHE category (7), **zero** questions appeared multiple times for the social GESES category.

Research questions appearing as a minimum value multiple times not already discussed in cohort analysis are as follows: *Q1 (2021, 2023) Brainstorm research ideas, Q3 (2021, 2023) Evaluate journal articles to determine usefulness in a literature review*. Brainstorming research ideas and conducting an effective literature review are foundational research skills not all S2D participants hailing from R2 universities have fully developed.

M2 and No Classification

Given the small number of students that fall under M2 and No Classification CCIHE categories, 6 and 4 respectively, **zero** questions appeared multiple times for all categories.

Qualitative Discussion

Preliminary Analysis

Upon completion of data processing, 1712 words were used in categorizing personal statements. Of the 1712 words, the *mean frequency was ~3.929*. Given the unique nature of a personal statement for a program supporting graduate education, *more than 50% of words have a frequency of 1* and that the top three (3) words are graduate (187), school (185), program (134).

Categorization

Reviewing the categorizations, most of the personal statements were categorized as academic (60), with research having the second highest number of categorized personal statements (6), and social domain having the least categorized personal statements (3).

Secondary Analysis

Across all personal statements, there were personal statements that reflected zero academic, social, and/or research characteristics when compared with the GESES survey questions. Across all self-efficacy domains, the academic category had a maximum categorization value of 0.263. The research category was second with a maximum categorization value of 0.167 and the social category last with a maximum categorization value of 0.093.

Cohort

Table 4: Category rankings and participant count by cohort*

		Academic		Social		Research	
Cohort	N	Rank	np	Rank	np	Rank	np
2020	10	1st	8	T-2nd	1	T-2nd	1
2021	11	1st	10	2nd	1	3rd	0
2022	14	1st	12	2nd	2	3rd	0
2023	33	1st	29	T-2nd	2	T-2nd	2

Assessing statement of purpose categorization by cohort, statements of purpose were overwhelmingly categorized as academic for all cohorts. Such categorization suggests that discussion of academic self-efficacy in the context of writing a statement of purpose is a common occurrence. It is important to note that social self-efficacy was the second most common theme in statements of purpose, with research self-efficacy being the least common theme.

VT

Table 5: GESES category rankings and participant count for VT participants*

		Academic		Social		Research	
Cohort	N	Rank	np	Rank	np	Rank	np
2020	10	1st	8	T-2nd	1	T-2nd	1
2021	11	1st	9	2nd	1	3rd	0
2022	11	1st	9	2nd	2	3rd	0
2023	19	1st	17	T-2nd	1	T-2nd	1

Assessing statement of purpose categorization for VT participants, statements of purpose were overwhelmingly categorized as academic for all cohorts. Such categorization suggests that discussion of academic self-efficacy in the context of writing a statement of purpose is a common occurrence among VT students applying to participate in S2D. It is important to note that social self-efficacy was the second most common theme in statements of purpose, with research self-efficacy being the least common theme. Even among VT students enrolled in an R1 research university, research self-efficacy as a prominent theme in a statement of purpose is still least common.

CCIHE

Table 6: GESES category rankings and participant count by CCIHE*

			Academic		Social		Research	
CCIHE	Cohort	N	Rank	np	Rank	np	Rank	np

R1	2020	10	1st	8	2nd	1	3rd	1
	2021	10	1st	9	2nd	1	3rd	0
	2022	11	1st	9	2nd	2	3rd	0
	2023	21	1st	19	2nd	1	3rd	1
R2	2021	1	1st	1	2nd	0	3rd	0
	2023	6	1st	6	2nd	0	3rd	0
M2	2022	3	1st	3	2nd	0	3rd	0
	2023	2	1st	1	2nd	1	3rd	0
NC	2023	4	1st	3	2nd	1	3rd	0

Assessing statement of purpose categorization by CCIHE, statements of purpose were overwhelmingly categorized as academic for all R1, R2, and no CCIHE classification participants. Such categorization suggests that discussion of academic self-efficacy in the context of writing a statement of purpose is a common occurrence. It is important to note that social self-efficacy was the second most common theme in statements of purpose, with research self-efficacy being the least common theme.

* See Author Notes [2]

Cross Validation

For all qualitative categories (Cohort, VT, CCIHE), mean self-efficacy ranking from QUAN analysis *differed* from mean self-efficacy ranking from QUAL analysis. To effectively cross validate findings between QUAL and QUAN analysis, we will be utilizing the self-efficacy domain rankings. Employing a ranking system supports effective cross-validation.

The academic self-efficacy domain was most frequently ranked a top two self-efficacy domain across both QUAL (most frequently ranked 1st) and QUAN analysis (most frequently ranked 2nd). In both the numerical scale assessment and statement of purpose context, S2D participants expressed strength in the academic self-efficacy domain.

The social self-efficacy domain was also most frequently ranked a top two self-efficacy domain across both QUAL (most frequently ranked 2nd) and QUAN analysis (most frequently ranked 1st). In both the numerical scale assessment and statement of purpose context, S2D participants expressed strength in the social self-efficacy domain.

The ranking that remains consistent across both QUAL and QUAN analysis is the most frequently ranking of the research self-efficacy domain as 3rd. In both the numerical scale assessment and statement of purpose context, S2D participants expressed the least strength in the research self-efficacy domain.

Conclusion

In part one of a multistep analytical effort to explore S2D program effectiveness via participant data, the results demonstrate the continued self-efficacy imbalance across academic, research, and social domains. S2D presents new levels of participant self-efficacy: prevalent academic and social self-efficacy with a need for support in the research self-efficacy domain. Incorporation of program components for research self-efficacy development is critical to ensure complete graduate school preparedness.

In analyzing the participant survey results that utilize the GESES, we found that S2D participants expressed the greatest amount of self-efficacy in the social domain. From a QUAN perspective, we found social self-efficacy to rank highest among S2D participants suggesting S2D participants express social self-efficacy when reflecting upon graduate school preparedness.

In analyzing the statements of purpose for the program application, we found that S2D participants expressed the greatest amount of self-efficacy in the academic domain. From a QUAL perspective, we found academic self-efficacy to rank highest among S2D participants suggesting S2D participants highlight academic self-efficacy in application writing.

Future Work

Future work will look at other components relevant to the evaluation of S2D programming: a) personal statements b) exit survey analysis c) post program analysis. Crafted by S2D participants with the support of writing coaches, personal statements written during the program reflect participant stories and the effectiveness of programming and staff. The exit survey provides feedback on programming from the participant perspective which will help administrators take steps toward enhanced curriculum building. *Currently, research is being conducted to perform post program analysis. The research details where past S2D participants are now, how S2D contributed to their academic journeys, and which component(s) of past S2D programming past S2D participants found most useful. Post program analysis provides administrators with insight regarding long term outcomes of S2D programming.*

Bias

Two types of bias to be highlighted for of our research are *researcher bias* and *response bias*. Regarding *researcher bias*, while comparable research has been conducted previously with the McNair program, the results from the McNair study did not influence the development of our methodology to attempt to replicate results. Addressing *response bias*, we trust that S2D participants provided accurate responses, and any response falsification is unknown.

Threats to validity

While a robust process has been established for QUAL analysis, please note commonly used words still exist among category lists. However, these commonly used words existed across all category lists. Removal of words did not produce significantly different results and thus were kept. No further qualitative coding was conducted and thus presents limitations to our results.

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Author Notes

[1] Data visualizations and GESES survey questions available upon request.

[2] For our qualitative discussion please note the following: 4 SOPs not reported for the 2022 cohort in Table 4, 3 SOPs not reported for the 2022 cohort in Table 5, 3 SOPs not reported for the R1 2022, 1 SOP not reported for M2 2022 in Table 6.