Shifts in Perceptions of Career Pathways: The Impact of an S-STEM Program on Lower-Income Computing Students

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1 Pathways into Computing Education & Professions

The demand for computing professionals has grown exponentially due to the rapid expansion of technology and digitalization in various industries. As a result, understanding the importance of pathways into computing education and professions has become crucial. These pathways serve as structured routes that guide individuals in acquiring the necessary skills and knowledge to pursue careers in the computing field. Hence, it is essential for educational institutions to understand students' perspectives, particularly those from lower-income socio-economic status, to broaden participation within computing education and professional fields. Though there are various pathways into computing education and professions, for the purposes of this research and the program, we review the existing literature about three primary pathways: graduate school, internship or industry profession, and entrepreneurship.

Pursuing a graduate degree in computing is sought after by individuals seeking advanced knowledge and specialization [1], [2], [3]. Kapoor & Gardener-McCune [1] delve into the motivations behind students' choices to pursue graduate education in computing, where they studied how students weigh career goals, industry demands, financial considerations, and personal interests when pursuing a higher degree. Another study revealed that there is also a looming ambiguity around how financial aid works while pursuing graduate degrees since economic stability is particularly important for lower-income students [4]. Existing research also suggests that students pursue graduate degrees when interested in pursuing a specific specialization within the field to improve their skillset in the competitive technological job market [3]. Nevertheless, these specialization skills are now available in coding boot camps and online certifications, resulting in fewer students choosing graduate degrees [5], [6].

Internships serve as crucial bridges between academic learning and real-world work experiences [7]. Saidani and Colleagues [8] examined the employability predictions of internships on computing students and found that students needed to have internships to be employable in the future. Furthermore, the authors suggested a need to increase the training hours and mentorship to support students in gaining internships and securing employment after graduation. Similarly, McHugh and colleagues [9] developed an on-campus internship model to increase computing students' employability preparedness from both the students' and employers' perspectives. The authors find that by understanding the expectations of employers and students, educators can tailor internship programs to better align with industry needs, thus enhancing students' chances of success in the job market. Furthermore, some studies highlight the significance of internships in improving computing students' employability skills and career prospects [7], [8], [9]. Students also better understand how to find and apply for internships but have lower chances of getting an internship [8]. In prior work, we found that students from lower-income backgrounds tend to prefer internships more than graduate school or entrepreneurship since they guarantee economic stability [4], [10].

Promoting entrepreneurship within computer science education encourages students to develop innovative solutions, create startups, and contribute to the tech ecosystem. Smith et al. [11] discuss the intrinsic and extrinsic factors to determine if undergraduate students intend to pursue entrepreneurship after graduation. The students selected passion and job satisfaction as the two most important factors in deciding their career pathway after graduation. Understanding the impact of entrepreneurship education on students' intentions and actions is essential for designing effective programs [11]. However, previous research suggests a need to demystify entrepreneurial pathway knowledge for students coming from a lower-income background [4], [12].

Additional research has shown that social and cultural factors, such as family background, the student's sense of belonging, etc., can influence students' perceptions of the feasibility and potential for success in these pathways [3], [13], [14]. Students' perceptions of their future career pathways can influence their decision-making process when considering a career in computing. Some students may perceive traditional computer science graduate degrees as time-consuming and academically challenging, leading them to opt for alternative pathways like coding boot camps and online courses, often seen as more practical and industry oriented. Perception of these pathways can significantly impact enrollment numbers in different programs and ultimately shape the composition of the tech workforce. Hence, understanding different pathways and students' perceptions, especially those from lower-income backgrounds, can help educators, policymakers, and industry stakeholders design more inclusive and effective programs that meet the needs of an evolving technological landscape.

One prominent intervention to support lower-income students' pathways in STEM is the National Science Foundation's (NSF) Scholarships in Science Technology Engineering and Mathematics (S-STEM) program through valuable financial support and programming/mentoring [4], [10]. Though several S-STEM programs support and investigate students' retention and attrition, academic performance, and sociocultural factors impacting their persistence within STEM degrees [15], [16], [17], [18], fewer programs focus and publish on supporting their career trajectories and understanding their perspectives. Our prior qualitative research with the Florida Information Technology Graduate Attainment Pathways (Flit-GAP), an NSF S-STEM program found that students prefer to get an industry job by pursuing internships during their undergraduate degree program, which they see as more economically secure than venturing into entrepreneurship or graduate school [4]. This study expands on this prior work to investigate the impacts of Flit-GAP by addressing the following research question:

> *RQ: What is the impact of an S-STEM program on computing students' knowledge and interest in computing career pathways?*

2 Theoretical Guidance: Metaphors for Broadening Participation

Lee [19] highlights three metaphors - pipelines, pathways, and ecosystems - that guide discussions on broadening participation in engineering fields. We draw inspiration from these metaphors to frame our research and to think about different roles that educational institutions and their stakeholders can perform to support students career trajectories within computing better. Each metaphor provides a different lens on the challenge of increasing participation within computing.

The first metaphor, the pipeline, focuses on students' progression through an educational system toward the computing workforce. It emphasizes student retention, aiming to address the issue of individuals dropping out of the pipeline before reaching professional roles. Lee [19] emphasizes that this metaphor highlights the deficits of students who do not continue along the pipeline, often implying that these individuals lack the necessary skills or attributes to remain in the computing field. For instance, the "leaky" pipeline metaphor might attribute the underrepresentation of women in computing to a lack of self-efficacy or skills to sustain their interest and commitment to computing careers (e.g., [20]). We also align with scholars who critique the pipeline metaphor for its narrow view of success and lack of recognition of the diversity of valuable skills and attributes students possess (e.g., [21], [22], [23]).

In contrast to the pipeline metaphor, the pathway metaphor focuses on students' persistence and highlights their heterogeneous trajectories, assets, and abilities [19]. Here, the institution's and its stakeholders' goal is to enable students to pursue computing degrees and support their journey toward any career destination within the computing field. This metaphor recognizes that students have different strengths, and it is essential to highlight and leverage those strengths to enhance their chances of success. By shifting the focus from deficits to assets, the pathway metaphor encourages a more inclusive approach to computing education and celebrates the diversity of talents and interests among students [19]. Lee [20] and many other scholars [25] and [26] emphasize that an asset focus can help foster a more supportive and empowering learning environment, leading to retention and success among students from diverse backgrounds and emphasizing student abilities and agency. While we align with the focus on empowering and valuing students' development towards diverse trajectories, we problematize this metaphor because the responsibility (or pressure) to persist within the computing education/workforce rests solely or primarily on the student. For example, to enable their computing pathway, students sometimes feel forced to look for internship opportunities valued in the software industry (e.g.,[4]). Hence, the pathway metaphor does not highlight the shared responsibility for student trajectories between students, universities, and the broader computing community.

The third metaphor, ecosystem [19], takes a broader and more sociocultural perspective on broadening participation in computing. The ecosystem metaphor goes beyond individual students and their journeys to encompass the entire learning environment, including the interactions between students, teachers, and the computing culture. The metaphor both values student experiences and considers the impact of the learning environment on their engagement and sense of belonging with all the stakeholders in a computing education ecosystem [19]. It encourages constructive critique and examination of systemic factors that may hinder participation in computing. Educators and policymakers can better identify and address structural barriers, biases, and inequities in computing by adopting the ecosystem metaphor. Though we align with this metaphor's approach to promote a more holistic, inclusive computing culture that supports the success of all students, regardless of their background, we would like to mention that sometimes we, as researchers, might not have the complete context of all the stakeholders in students' trajectories. There can be many mitigating institutional, family, and other factors that we might not know while writing about the students' perspectives [26].

Drawing on pathway and ecosystem metaphors as theoretical guidance, we emphasize that all the stakeholders in a computing education ecosystem can support a student's trajectory toward diverse career pathways. We conceive of student interest not as fixed but as a data point to allow local program leaders to adjust their presentation, shift their language, and address specific pressing questions or fears we find students hold about the pathways. We see this paper as one contribution to that local and broader computing ecosystem, enabling better and more supportive conditions for diverse student pathways in computing.

3 Program Context

This research was conducted as part of Flit-GAP, a National Science Foundation (NSF) Scholarships in Science, Technology, Engineering, and Mathematics Program (S-STEM) program. S-STEM programs are intended to support lower-income STEM students by providing them with financial assistance and academic and career support through curricular and co-curricular activities [27]. Flit-GAP was launched in 2021 as a collaboration between three public universities namely, Florida International University (FIU), University of Central Florida (UCF), and University of South Florida (USF). The program offers financial aid and career pathway support for students pursuing computer science, information technology, cybersecurity, or computer engineering degrees. The scholarship portion of Flit-GAP provides students with between 500 and 10,000 dollars per year based on their unmet financial need, which is calculated by subtracting the student's expected family contribution and their private, state, and institutional scholarships from the cost of attendance at their university [27]. Students can receive up to three years of financial support to complete their bachelor's degree and one additional year of support if they decide to pursue a graduate degree in a computing field at one of the three participating universities. The career pathway support portion of Flit-GAP allows participants to participate in one or more of the following career pathway experiences based on their interests: an internship (professional pathway), a mentored research experience (graduate pathway), or a zero-credit-hour course about entrepreneurship with the opportunity to present their idea to potential funders at the end of the course (entrepreneurship pathway). However, the entrepreneurship pathway was not available for the Year 1 cohort due to program logistics and the start time of Flit-GAP and has been established in the Year 2 cohort only at UCF. Throughout the academic year, Flit-GAP offers a variety of hybrid co-curricular events that aim to inform students about different post-graduation pathway options and foster community among participants across the three institutions.

For the 2022-2023 school year, Flit-GAP events included an orientation for students to learn more about the program, a LinkedIn event where students learned tips and tricks for networking on the site; a graduate school showcase that spotlighted the computing graduate programs offered by the three universities; an alumni panel where participants from a prior computing-focused S-STEM program at the three universities answered Flit-GAP students' questions about industry and graduate school pathways, and an end-of-the-year symposium for students to showcase their work. The 2022-2023 cohort had 90 scholars from all three universities, including some retained scholars from Cohort 1.

As the education research team on Flit-GAP, we support the program by collecting data and students' opinions on the program activities, observing the activities, and providing feedback to the lead Principal Investigators (PIs). For instance, during the first-year graduate school showcase, we noticed that the information presented was not helpful for the scholars in the program because the presenters did not discuss the funding opportunities, which is essential for lower-income students, as we found in our qualitative study [4]. Hence, we asked the PIs to change messaging around the grad school within computing, which was reflected in the recent year showcase, and we find that the students' understanding of graduate school functions has improved. Similarly, we are trying to bridge the gap between students' perceptions of these pathways and the institutional messaging around them. Being a stakeholder, the education research team within Flit-GAP also plays an essential role in the computing education ecosystem to meet the students where they are.

4 Methods: Data Collection & Analysis

The survey instrument adapted previous instruments [28], [29] that asked for a sense of belonging in computing and career preferences by adding protocol items on knowledge of and exposure to the three pathways, pathways selection. The research team developed the items focused on pathway selection and knowledge of and exposure to three pathways based on an interview study conducted with Flit-GAP students from FIU in early Fall 2021 [4]. This study focused on participants' career desires and perceptions of graduate, research, and entrepreneurial career pathways. In collaboration with the project's external evaluator, the research team also developed items about students' experiences in the program. We first distributed the pilot survey in Spring 2022 via Qualtrics, collaborating with the external evaluation team to all the students from all three universities. We performed an exploratory analysis of the factors that influence students' future career decisions. However, we could not draw significant conclusions from the data due to a lower response rate and incomplete surveys.

In Fall 2022, we modified some survey items from the pilot survey to distribute as a pre-survey. Participants for the study were recruited based on their participation in Flit-GAP and were informed that their participation was voluntary. We distributed it to the incoming Year 2 cohort on orientation day through Qualtrics and paper surveys to increase the response rate. Furthermore, we collaborated with the external evaluation team to distribute the end-of-year survey during the program symposium in Spring 2023, which was all paper surveys, to increase the response rate for the end-of-year survey. The research and evaluation team transferred the paper survey to Qualtrics. Survey responses were exported from Qualtrics as an Excel spreadsheet. The average response rates for the pre-and post-surveys are 96% and 67%.

respectively. We note that the significant variation in response rates is due to the difference in cohort members, as the end-of-year survey included some retained scholars from Cohort 1 and survey dissemination methods. The research team cleaned and imported the data into RStudio to perform matched pair t-tests and independent t-tests on the items focusing on the career pathway statements to understand the student perspectives of these pathways from Year 1 and Year 2 data. The matched pair results are presented in the following sections.

Statements	T Value	P Value	MeanPre	MeanPost	Difference	SE
E1: Entrepreneurship Understanding	**3.73**	**0.00090**	**3.43**	**4.14**	**0.714**	**0.19**
E2: Entrepreneurship Interest	-0.197	0.84566	3.21	3.18	-0.0357	0.18
E3: Entrepreneurship Choice	0.197	0.84566	2.79	2.82	0.0357	0.18
E4: Knowledge Securing Capital	**3.67**	**0.00106**	**2.04**	**2.82**	**0.786**	**0.21**
I1: Internship Understanding	1.87	0.07287	4.36	4.64	0.286	0.15
I2: Internship Interest	0	1	4.57	4.57	0	0.10
I3: Internship Choice	1.69	0.10335	4.21	4.5	0.286	0.17
I4: Knowledge Securing Internship	**2.92**	**0.00690**	**3.86**	**4.43**	**0.571**	**0.19**
R1: Research Understanding	1.14	0.26432	3.89	4.11	0.214	0.19
R2: Research Interest	1.8	0.08304	3.61	3.93	0.321	0.18
R3: Research Choice	1.06	0.29714	3.29	3.5	0.214	0.20
R4: Knowledge Graduate Degrees	2.71	0.01145	2.96	3.82	0.857	0.32
R5: Knowledge Course Requirements	**2.92**	**0.00697**	**2.96**	**3.75**	**0.786**	**0.27**
R6: Knowledge Graduate Research	**3.99**	**0.00046**	**3.04**	**3.86**	**0.821**	**0.20**
R7: Knowledge Funding	1.2	0.24000	3.32	3.64	0.321	0.27
R8: Knowledge Research Areas	1.44	0.16104	3.29	3.64	0.357	0.25
R9: Knowledge Career Opportunities	**2.84**	**0.00841**	**3.36**	**4.07**	**0.714**	**0.25**

Table 1 Results of Matched Pairs T-Test for Year 2 Cohort Members

5 Findings

Table 1 shows the results of the matched pairs t-test for Year 2 cohort members. Their pre- and post-survey results formed the matched pairs. Only students who took both pre- and post-surveys were included in the matched pairs dataset for a sample size n = 28. The statements column consists of the protocol item number. For ease of reading, we have included short topics (e.g., Entrepreneurship Understanding refers to the question “To what extent do you understand entrepreneurship career pathway?”) that indicate the protocol question topic. We have included the t-value and p-value for the matched pairs t-test, which was performed 2-tailed. We represent the mean pre-test value, mean post-test value, the difference in mean, and the standard error for each item so that the reader can understand the direction and size of movement on these measures.

The items highlighted in **bold** are significant at level $\alpha = 0.05$ and positive increase. Nearly all statements in Table 1 represent positive shifts, but we do not stress the insignificant positive shifts as we note they may represent statistical noise. Interest in entrepreneurship was the only item with a negative pre-post shift in means. As can be seen in the table, general shifts in Understanding and Knowledge were the only significant shifts, specifically understanding about entrepreneurship in general, knowledge of how to secure capital, knowledge of how to secure an internship, knowledge of graduate course requirements, knowledge of graduate research, and knowledge of career opportunities for graduate pathways. All other shifts in Knowledge and Understanding and all shifts in Choice and Interest were insignificant.

These shifts in Knowledge and Understanding might be particularly strong in Year 2 because of programmatic improvements to messaging about Graduate School and entrepreneurship pathways. We attempted to compare the years; however, a matched pairs analysis was impossible since the cohorts are different. An independent samples t-test was run between all students who took Year 1 and Year 2 post-surveys, but the results were all insignificant, so we are not reporting them here.

6 Discussion

6.1 Analysis of the Flit-GAP's Impact

We conducted the matched pairs t-test to look at programmatic outcomes for the Year 2 cohort, for which we had a dataset with pre- and post-surveys. Although we anticipated that we might see shifts in career pathway interest and choice, as these align with the goals of the program, it is logical that we did not have significant results / and could not reject the null hypotheses for interest and choice measures. Ultimately, student pathway interest and choice are phenomena that diverge student by student, and it seems unlikely that the entire cohort would have a significant movement of interest or selection towards one career pathway or another. We do see individual student movements in different directions. However, these are relatively small numbers of students in divergent directions, so they do not lend themselves well to statistical arguments. Within the insignificant shifts in Interest, we see some nearly significant results for Research Interest and Internship Choice, which could exhibit more significance with a larger sample size. The Internship Pathway choice and interest are likely constrained by particularly high interest in the pre-survey (all items above 4.5 out of 5). The Research Pathway improvement may be explored in subsequent work combining multiple cohorts for greater statistical power. We also have other work [10] indicating some factors (e.g., job security, salary, independence) that students indicated drive their thinking about future career pathways and how those factors correlate with student pathway selections in the program. Combining these two threads with further student cohorts will help us better characterize the views and preferences of these lower-income computing students to support the program further increase interest in pathways that may be conceived as riskier (e.g., entrepreneurship and research).

In contrast, the significant impact on nearly every knowledge item shows that students understood more about entrepreneurship, internship/professional, and research/graduate school pathways. This is a crucial programmatic finding, as this is indeed something the program has control of and should be able to have a positive significant impact. We note that in Year 1 of the program, we gave feedback to the program administrators on ways to strengthen Research and Entrepreneurship presentations to respond to student confusion, questions, and fears about these pathways, which we had assessed qualitatively [4]. Thus, we anticipate the substantial increases in Knowledge on nearly every item represent a programmatic improvement. As an area of further improvement, the program could focus on helping students know how to find funding and knowing the areas of computing research they could focus on, as these were positive but insignificant item increases. However, increased knowledge alone will not alleviate all students' fears and personal constraints regarding selecting their career pathway.

Suppose the program truly wants to broaden participation in entrepreneurship and graduate school attendance for lower-income computing students. In that case, they should attend carefully to the affective aspects (e.g., fears) and personal aspects (e.g., having to support a family) that can create barriers to students considering these career options. Overall, students did not gain interest or likelihood to choose any particular pathway. While this could, in part, indicate a programmatic limitation towards broadening participation, it is also mediated by the fact that students are learning new knowledge and deciding on outcomes for themselves. We may not expect all 28 students in the cohort to shift in the same direction toward any one of these three pathways. Nevertheless, we see a tendency for most students to remain focused on the pathway they initially selected (i.e., professional pathway/internship).

We found no significant increase in Knowledge in our independent samples t-tests between Year 1 and Year 2. Thus, although we have a sense (from our qualitative research and programmatic observations) that the program improved in messaging on Graduate School and Entrepreneurship from Year 1 to Year 2. This messaging did not shift the students' interest to choose different career pathways, and we cannot showcase this with statistical evidence at this time. As further cohorts continue to enter the program, we can have all of them take pre-surveys to better account for programmatic improvements over time.

6.2 Contribution and Comparison to Computing Education Literature

Our study contributes to the literature on computing education through our integrated approach to considering the ecosystem of the Flit-GAP intervention program and the student' perceptions of their computing career pathways. By describing not only the intervention program but also students' perspectives and considering these perspectives not as fixed selections but as interwoven with programmatic choices, we hope to model a method of creating education research that is locally and broadly valuable. Much of the literature in computing education tends to examine identity formation, for instance [1], [29], [30] without directly researching the ecosystem or the systemic barriers associated with the formation in an integrated way. Within this type of literature, the student perspective is typically treated as a static or predictive outcome for success/persistence or failure/attrition in computing, for example [15], [16], [30]. We add to this pathway literature by broadening the range of student information to consider knowledge, interest, and perspectives on their career pathways, and we treat the student perspective data as a dependent variable of interest rather than a predictive variable, similar to [1], [17], [31]. This integrated ecosystem and pathways operationalization allows us to respect and value the perspective of students while also considering how the student perspective on computing careers might be limited or naïve. Similarly, research on student motivation tends to predict certain career pathways [1], [31] without examining how student motivations may be malleable, reasonable yet naïve, and shaped by intervention programs. Our research helps contextualize student motivations to showcase the complexities of student motivations.

7 Implications for Broadening Participation in Computing

Our research offers some practical implications for programs and stakeholders in support roles for broadening participation in computing, particularly programs like S-STEM focused on lower-income students. First, we emphasize meeting students where they are and using tools like surveys and interviews to understand their perspectives. For example, when first embedding with Flit-GAP, we learned that students would be asked to select which career pathway they wanted to participate in and learn about (internship, entrepreneurship, graduate school). We immediately thought that students may need equal, accurate, or sufficient information about these three pathways to select for themselves, and therefore would only gain access in the areas familiar to them. By gaining a sense of where students are, programs can increase their ability to meet students where they are. As another example, Flit-GAP was designed based on a prior program [32] that had focused purely on retention in computing education, and in response to feedback, the administrators adapted the next iteration of the grant to focus on computing career preparation.

While the strategy of understanding student perspectives and meeting students where they are is important for all broadening participation topics, we note the relatively small amount of focus on lower-income computing students (with select S-STEM programs being a notable exception) and highlight the intersection between socioeconomic status and computer science as necessary for further intervention. While many lower-income students become interested in computing careers for pragmatic and economic reasons (for upward mobility for themselves and their families) [4], [10], [14], [33], the normative computer science student and the normative computer science professor / professional will remain a person from a middle- or upper-class background. Within this landscape, it is essential to creatively reorient the basic assumptions of computing education and co-curricular programming to address various concerns, background knowledge, and realities to expand access to computing careers beyond upper-income individuals.

In conclusion, the prevailing focus of many STEM support initiatives on lower-income students often needs to be more balanced with the nuanced realities and priorities these students face. While these programs aim to bolster knowledge, shift attitudes, and offer financial assistance, they frequently fail to address the broader systemic barriers that hinder these students' access to prestigious majors or careers. Lower-income students, often constrained by immediate needs and practical considerations, navigate their educational and career choices within the context of their socioeconomic backgrounds. Consequently, any effective support initiative must extend beyond the confines of educational institutions to consider involving key stakeholders such as families, communities, and societal structures. By broadening the scope of support to encompass these macro-level factors, these student support initiatives can better empower lower-income students to pursue their academic and professional aspirations.

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