WIP: Boosting CS Freshmen: The Impact of Summer Bridge Programs on Academic Success and Attitudes

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***Abstract*—This Work-In-Progress Research paper details a quantitative analysis of the impact of a summer bridge program for incoming Freshmen majoring in Computer Science, mainly focusing on post-program academic outcomes. We designed and delivered a summer bridge program to serve students who are members of a historically underserved group in Computer Science. The program is designed to help participants build a foundation in mathematics and programming while fostering an environment for community and confidence building.**

In our study, we utilize data from a Likert-scale survey administered to students before and after the program to compare attitudes towards non-academic factors such as programming and mathematics self-concept, science motivation, and sense of belonging, alongside post-program academic performance indicators such as performance in the first engineering mathematics course, performance in the first programming course, academic standing, and major declaration and retention outcomes. This data, collected over four cohorts of participants from 2020 to 2023, includes two cohorts participating online due to the COVID-19 pandemic (2020 and 2021) and two in-person cohorts (2022 and 2023). We aim to address three primary research questions:

(RQ1) To what extent does the overall post-program academic performance vary between online (2020, 2021) and in-person (2022, 2023) modalities?

(RQ2) Can a potential change in attitudes towards non-academic indicators influence or explain a student's post-program academic indicators?

(RQ3) Can a student's non-academic indicators and math/programming self-concept influence or explain a student's persistence in STEM?

***Index Terms*—retention, academic support, multi-modal approaches, equity, underrepresented students**

I. Introduction

Summer bridge programs have emerged as pivotal interventions to support the transition of incoming students, particularly those in Science, Technology, Engineering, and Mathematics (STEM) disciplines, as they embark on their collegiate journey [1]. These programs, typically held in the summer preceding the first semester of college, offer intensive experiences aimed at equipping students with essential skills, fostering peer connections, and familiarizing them with institutional resources [2].

Therefore, in response to the growing need for tailored support and online compatibility ever since the Covid-19 pandemic, this summer bridge program was built and implemented specifically for incoming first-generation computing students at UC Santa Cruz [3]. This program targets underserved students by recognizing the unique challenges they may face in accessing higher education [4]. It focuses on academic readiness, aims to foster a growth mindset, and nurtures a sense of belonging in all participants, boosting them to thrive in their Computing studies and beyond.

From 2020 to 2023, pre- and post-program surveys were assigned to the underserved students enrolled in the summer bridge program. These anonymized surveys, comprising a validated questionnaire encompassing various dimensions of STEM education and student experiences, provided invaluable insights into the effectiveness of the bridge program in enhancing non-academic indicators crucial for student retention [5], [6] and upward social mobility [7].

To measure the program's impact, the grades of the first required Mathematics and Programming course and information about students' overall academic path were analyzed. For earlier cohorts (2020 and 2021 - 50 students), information about their declaration status was used, whereas for the later cohorts (2022 and 2023 - 56 students), information about academic standing along with proposed majors was used.

Through quantitative and statistical methods like exploratory data analysis, correlation analysis, and regression coefficient analysis, this paper examines the impact of the bridge program on the academic performance and persistence of participants. Furthermore, this paper discerns the differential impact of this program across online and in-person modalities, which have distinct implications for program accessibility, scalability, and resource allocation.

By presenting a detailed analysis of the findings of the aforementioned techniques and highlighting the comparative effectiveness of online versus in-person modalities, this paper sheds light on the nuanced dynamics of summer bridge programs in the context of Computing education. The results of this research will be used to inform strategic decision-making and resource allocation, ultimately advancing accessibility, equity, and inclusivity in STEM education. Through rigorous assessment and thoughtful reflection, this paper contributes to the ongoing discourse [8] on effective educational interventions for diverse student populations.

II. Prior Work

Summer bridge programs have garnered significant attention in higher education due to their proven positive impacts on underserved students' success and retention, particularly within STEM disciplines [9]. Programs such as these offer incoming students intensive experiences aimed at preparing them academically, fostering social connections, and familiarizing them with institutional resources.

Within the realm of summer bridge programs, there has been a growing emphasis on in-person and online initiatives [10] targeted specifically at underserved students. These programs aim to address disparities in STEM participation and success by providing tailored support to historically marginalized student populations. The focus on underserved students reflects a recognition of the unique challenges they face in accessing and persisting in STEM fields, necessitating targeted interventions to promote equity and inclusivity in higher education [11].

In designing the summer bridge program for Computing students, we drew upon a comprehensive analysis of non-academic indicators. Each of these categories was selected based on their documented importance in predicting student retention and success, which are listed below in Table I. Furthermore, specific Likert-style questions (with scale ranges 1-4 and 1-6) within each category were carefully crafted to assess students' attitudes, perceptions, and experiences relevant to their academic and socio-emotional well-being.

TABLE I: Program goals

Program Goal	Example of Likert-Style Question
Programming and Math preparedness [12], [13]	I often need help in math/programming.
Growth mindset [14]	Your intelligence is something about you that you can't change very much.
Help-Seeking and Concealment [15]	I ask for help understanding the material.
Science Identity and Motivation [16]	I have come to think of myself as a 'STEM scientist'.
Peer community [17], [18]	I anticipate feeling connected to my peers around me at UC Santa Cruz.
Campus belonging [19]	I see myself as part of the campus community.

This work builds upon the foundational analysis conducted by Norouzi et. al. [20], which provided a brief overview of observational differences between pre- and post-data. While their paper identified potential for deeper analysis in the future, this thesis aims to address this gap by conducting a comprehensive examination of the impact of a summer bridge program on the academic path and performance of intended underserved Computing students.

Additionally, the study situates itself within the broader landscape of summer bridge programs and provides insights into the effectiveness of program modalities. Drawing upon insights from other summer programs [21]–[23], this paper aims to identify promising practices and approaches that can enhance the impact and scalability of bridge programs via efficient resource allocation to ultimately advancing equity and inclusivity in STEM education.

III. Methodology

A. Correlation Analysis

We measured two groups of correlations in this study.

Correlation between first required Math/Programming Course grade and persistence:

This summer bridge program trained participants in foundational Mathematics and Programming concepts. This ensured that students were comfortable learning deeper and more nuanced concepts in their first required Mathematics and Programming classes, potentially acting as a catalyst to better performance in those classes. Measuring the correlation between their persistence and their respective Mathematics and Programming grades is essential to verify the effectiveness of the academic component of the summer bridge program. If there is a high correlation, it implies that a relatively high grade in foundational Mathematics and Programming (potentially impacted by participation in the bridge program) leads to a relatively better academic standing (a more persistent student) in a student's overall academic path in college.

In this paper, a ***persistent student*** is one who has either declared a Bachelor of Arts (BA) or a Bachelor of Science (BS) degree or has a "moderate" to "good" standing mentioned on their transcripts. This is because a student with a decent academic standing is likely to persist and eventually graduate. Due to the timeline of the program, the 2020 and 2021 cohorts have more students with confirmed major declaration statuses than standing information. It is the opposite for the 2022 and 2023 cohorts since a lot of students declare their majors later in their 2nd year/early in their 3rd year at college.

Correlation between first required Math/Programming course grade and non-academic indicators:

In this analysis, we focus on two types of non-academic indicator scores: post-program scores and delta scores (the difference between post-program and pre-program scores). These scores were obtained from pre- and post-program surveys administered to students [3].

After creating the cleaned, scaled version of post-program and delta scores, we used Least Absolute Shrinkage and Selection Operator (LASSO) regression across combinations of modalities and target variables (Math/Programming grade) to identify top indicators that explain the target variables. Therefore, there were 6 combinations (hence regressions) per modality, as shown in Table II below. This correlation analysis is important as it has the potential to underscore the importance of developing certain non-academic indicators for a relatively higher Mathematics/Programming score.

TABLE II: Combinations

Target Variable/ Modality	Online	In-Person
Mathematics	Post, Delta	Post, Delta
Programming	Post, Delta	Post, Delta
Are Persistent: Declared BS or BA OR in moderate-good academic standing	Post, Delta	Post, Delta

B. Regression Coefficient Analysis

We conducted multivariate logistic regression on an aggregate dataset (combining information from all years) across 6 different models, with the target variable being student persistence (labeled 1 if persistent, 0 otherwise). We recorded coefficients assigned to each feature in each model, focusing on the impact of mathematics and programming self-concept before vs. after the program on a students' persistence. These are the descriptions and goals for each mode:

- **Model A- Pre:** To measure the impact of average pre-program non-academic categories' score on persistence. This model doesn't include Mathematics or Programming self-concept and is purely based on students' perceptions before the program was held.
- **Model A- Post:** To measure the impact of average post-program non-academic categories' score on persistence, regardless of mathematics/programming self-concept.
- **Model B- Pre:** To measure the impact of pre-program Mathematics Self Concept on other non-academic indicators, as well as the overall impact on persistence.
- **Model B- Post:** To measure the impact of post-program Mathematics Self Concept on other non-academic indicators, as well as the overall impact on persistence.
- **Model C- Pre:** To measure the impact of pre-program Programming Self Concept on other non-academic indicators, as well as the overall impact on persistence.
- **Model C- Post:** To measure the impact of post-program Programming Self Concept on other non-academic indicators, as well as the overall impact on persistence.

IV. Results

A. RQ1: Differential effect on students' academic performance based on modality

Before detailing the results of correlation analyses, exploratory data analysis revealed the following statistics for the proportion of students who performed relatively well in the realm of academics in Table III.

TABLE III: Proportions

Students Who	Online Proportions	In-Person Proportions
Achieved 3.0+ GPA in Intro Programming	0.600	0.714
Achieved 3.0+ GPA in Intro Mathematics	0.660	0.696
Are Persistent: Declared BS or BA OR in moderate-good academic standing	0.820	0.696

B. RQ2: Links between students' academic performance and non-academic indicators

Correlations between grades and persistence: The table below lists the correlations between students being in good academic standing (are persistent) and their Mathematics/Programming grades.

TABLE IV: Correlations

Correlations	Mathematics	Programming
Online	0.0592	0.0483
In-Person	0.7373	0.5789

Correlations between grades and non-academic indicators: Figure 1 below shows the correlation between significant features picked out by LASSO regression. However, the majority of the features have weak correlations with the Math and Programming grades.

C. RQ3: Links between students' academic self-concept, non-academic indicators, and persistence

Table V shows the coefficients for each model. The first 10 rows represent the coefficients for the average score of questions within each respective category. The "In-person (Binary)" row records any in-person participant being marked as 1 and online as 0. The intercept term refers to the baseline log odds if all the other coefficients are set to 0.

V. Discussion

A. RQ1

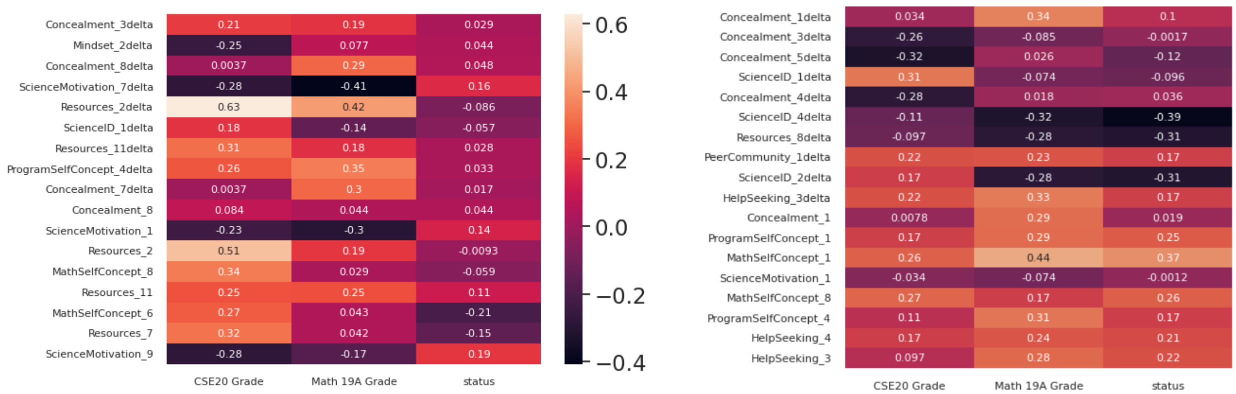
The exploratory data indicates that the college retention rate (measured by the proportion of students who either have a positive declaration status or moderate-good academic standing) is higher for the online (0.82) cohort than in-person (0.696) cohort. However, the proportion of students in the in-person cohorts performed slightly better than the online cohorts in their first programming and mathematics courses.

It is important to note that none of these differences are statistically significant enough to conclude that online learning is better than in-person learning or vice versa. Furthermore, the sample sizes are slightly different (there are 50 online students and 56 in-person students), and the samples (participants) themselves may have been inherently different because of the circumstances under which they were chosen, e.g., the 2020 and 2021 cohorts were created during the Covid-19 pandemic.

B. RQ2

1) With Persistence: There is a relatively much stronger correlation between persistence and math/programming grades in person than in the online version of the program. This indicates that students who have done the in-person version of the program are likely to persist in their field if they do well in their math/programming grades.

It is important to note that even though the correlation between the online version and persistence is lower, this does not mean that there is no underlying relationship since there



(a): Online Correlations

(b): In-Person Correlations

Fig. 1: Correlations between Significant Features and Academic Performance

TABLE V: Multivariate Logistic Regression Coefficients

Indicators	Pre: Model A	Post: Model A	Pre: Model B	Post: Model B	Pre: Model C	Post: Model C
Mathematics self-concept	-	-	0.1888	0.2727	-	-
Programming self-concept	-	-	-	-	0.3025	0.4060
Science motivation	0.4934	0.5118	0.4868	0.5035	0.4857	0.4981
Science identity	1.3421	0.5216	1.3381	0.5123	1.3289	0.5067
Help-Seeking	0.3939	0.5632	0.3938	0.5572	0.3899	0.5533
Concealment	−0.3858	−0.5003	−0.3914	−0.5054	−0.3915	−0.5113
Growth mindset	−0.0851	−0.0005	−0.0844	−0.0027	−0.0898	−0.0101
Peer community	0.2184	0.4754	0.2163	0.4383	0.2112	0.4330
Campus belonging	0.1792	0.4354	0.1745	0.4285	0.1733	0.4329
Resources	0.0127	−0.1083	0.0115	−0.1174	0.0037	−0.1241
In-person (Binary)	−0.4980	−0.5142	−0.4939	−0.5106	−0.4955	−0.5085
Intercept	0.9168	1.0312	0.7950	0.8791	0.7398	0.8040

may be a non-linear relationship that cannot be measured via correlation coefficients.

2) With Non-Academic Indicators: Even after filtering out significant features, it can be seen that none of the correlations are objectively high except for the relationship between the online Programming grade and the delta in Resources Question 2: "I know where I can find my college advisor". This indicates a relatively strong linear relationship between a student feeling more supported after the program (by having access to an advisor) and their academic performance in the first programming course.

It is also important to notice that absolute correlations with delta features are relatively higher than with just regular post-program scores. This implies that the change in attitudes had a relatively higher linear effect on grades than the final attitudes of students at the end of this summer bridge program. However, since there are no strong absolute correlation values, it seems as though non-academic indicators and the performance of students (in both online and in-person cohorts) do not definitively help explain one another.

C. RQ3

Table V demonstrates a few of the observations that have been made related to the academic components of the program:

- 1. All Post-models have a higher baseline (their intercept terms are larger than their corresponding pre-models), indicating students are more likely to persist after the program, regardless of their background in Mathematics/Programming across both modalities.
- Math and Programming Self Concept post program help explain persistence more than pre-program. For Models B and C, Post has higher coefficients for Math/Programming Self Concept than Pre. This indicates that the program had a positive impact on students' maths and programming abilities, enabling them to persist at university more than if they did not attend the program.
- In both Models B and C, the programming coefficient is consistently higher than Math coefficients. This indicates that Programming knowledge explains persistence more than Math in Computing majors, suggesting that more resources should be devoted to helping participants strengthen their foundation in programming.

These are a few of the observations that have been made related to the non-academic components of the program:

1. Peer Community and Campus Belonging indicators help explain persistence **much** more after the program than before, indicating that students' changed perceptions in these categories is needed for higher persistence.
2. Science Motivation and Help-Seeking indicators help explain persistence just slightly more after the program than before (across all models).
3. Student's growth mindset, Science Identity, and percep-

tion towards the availability of resources, when considered along with other factors, do not explain the student's persistence in STEM/engineering.

4. Being in-person is negatively associated with students' persistence and this impact is more clear post program.

These results add a new dimension to prior work conducted by Ghazzawi, Pattison, and Horn [9] as they not only shed light on the bridge program's consistent, overall positive impact on persistence but also on how modality can play a role in explaining this impact. Furthermore, out of the 8 purely non-academic indicators focused on in implementing the program and creating the validated survey, 5 have a positive effect on persistence. This is a significant result as it showcases the immense value of prior works that have linked these non-academic indicators to student retention and success.

VI. Conclusion

This study examined the impact of summer bridge programs on the academic success and attitudes of incoming Computer Science freshmen from underserved groups. Through the analysis of outcomes from four cohorts across online and in-person formats, we found that while in-person cohorts performed slightly better in introductory programming and mathematics, the overall retention rate was higher for online cohorts. Key non-academic indicators, such as peer community and campus belonging, significantly influenced student persistence in STEM, highlighting the program's success in fostering a supportive environment.

The study also found that programming self-concept played a more critical role in student persistence than mathematics self-concept, which suggests adding more targeted programming support in these summer bridge programs. These insights suggest a hybrid model for future bridge programs, combining online and in-person strengths to optimize resources and impact. Future research should include longitudinal studies with control groups to validate these findings and expand to other institutions for broader applicability.

VII. Acknowledgement

We want to thank Prof. Covorubias and their team for designing the survey that served as the foundation for this study. We are also grateful to Dr. Carmen Robinson for her exceptional leadership in the logistics and planning of the program on which this evaluation is based. This research was made possible by the support of the National Science Foundation (NSF) under grant CNS-2245904. We appreciate their funding and commitment to advancing scientific research.

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