

An MS in CS for non-CS Majors: Moving to Increase Diversity of Thought and Demographics in CS

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ABSTRACT

We have created, piloted and are growing the Align program, a Master of Science in Computer Science (MS in CS) for post-secondary graduates who did not major in CS. Our goal is to create a pathway to CS for all students, with particular attention to women and underrepresented minorities. Indeed, women represent 57% and underrepresented minorities represent 25% of all bachelor's recipients in the U.S., but only 19.5% and 12.6% of CS graduates, respectively. If we can fill this opportunity gap, we will satisfy a major economic need and address an issue of social equity and inclusion. In this paper, we present our "Bridge" curriculum, which is a two-semester preparation for students to then join the traditional MS in CS students in master's-level classes. We describe co-curricular activities designed to help students succeed in the program. We present our empirical findings around enrollment, demographics, retention and job outcomes. Among our findings is that Align students outperform our traditional MS in CS students in grade point average. To date we have graduated 137 students and 827 are enrolled.

CCS CONCEPTS

• **Social and professional topics** → **Computer science education**; *Model curricula*; *Adult education*.

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1 INTRODUCTION

Technology is among the world's fastest growing economic sectors. For example, the U.S. Bureau of Labor Statistics *Occupational Outlook Handbook* forecasts 13% growth in U.S. computing and IT occupations between 2016 and 2026 [19]. Not only is technical competence in high demand, but there is also a need for technical innovation [4, 5]. Yet the current trajectory of the tech talent pipeline falls far short of meeting this demand.

For example, though undergraduate programs across the U.S. have more than doubled in size over the last decade [3, 6], they are insufficient to fill the required talent pipeline. Furthermore, these programs have not substantially increased in diversity: women represent 57% [16] and underrepresented minorities (URMs)¹ represent 25% [17] of all bachelor's recipients in the U.S., but only 19.5% and 12.6% of CS graduates, respectively [6]. Jobs in the tech space are some of the highest paying jobs [20], and yet women and URMs are missing out on this opportunity. If we can fill this opportunity gap,

¹URMs in CS include all U.S. minorities except Asian Americans who are well represented.

we will not only satisfy a major economic need, but also address an issue of social equity and inclusion.

To address both the issue of the talent gap in tech and the underrepresentation of women and URM students in CS,² Northeastern University has created the *Align MS in CS*, which is a Master of Science in Computer Science program for college and university graduates who did not major in CS. Our hope is that in creating Align, we will not only help fill the gap in the tech talent pipeline, but that we will also increase diversity of thought, as defined by the range of fields from which students come. We are very intentional about enrollment of a diverse student body and our support of students during the program. Since the start of the program in Fall 2013, our students have come from over 100 different disciplines spanning the humanities, arts, social sciences, business, and STEM. We have graduated 137 students. As of Fall 2019 we have 827 students enrolled: 47% of these students are women, 55% are U.S. domestic, and 20% of our domestic students are URM students.

In the next section, we describe the structure of Align and the rationale for its design, and we situate the program in the space of post-baccalaureate and MS programs in CS. We describe our bridge curriculum that prepares students for MS courses, as well as student support prior to and during the program. We then provide program outcomes, including statistics on student demographics, academic standing, retention, and employment and salary results for graduates.

2 OUR PROGRAM IN CONTEXT

The Align MS in CS for non-majors takes 2-2.5 years (students attend classes year round) to complete and includes a two-semester “Bridge” program designed to prepare students for our MS-level curriculum. Note that the Bridge is not meant to be a standalone post-baccalaureate certificate program³ and students are admitted directly to the Align MS program.⁴ The decision to configure the program in this way – direct admission to the MS in CS via the Bridge – was an important one. On a practical level, it allowed us to design the Bridge specifically as an on-ramp to our master’s program. More importantly, it acknowledges students’ previous academic backgrounds and degrees as important contributors to their professional development, which likely builds students’ confidence. This is particularly important for students who might be subject to stereotype threat [18].⁵ Finally, we are intentional about the recruitment and retention of a diverse student body. Specifically, our goal is to reach significant numbers of students with demographics that match those of U.S. post-secondary degree recipients: at least 50% women and 25% domestic URM students.

Admitted students are not required to have *any* prior coding or CS-related course-work. After successful completion of the Bridge,

²We embrace all diversity in CS, including non-binary gender identification, disability status, etc. We discuss women and URM students specifically, as we have concentrated our efforts in these areas. In particular, as underrepresentation of racial and ethnic groups is relative to location, we focus on U.S. domestic URM students.

³As, for example, the program at Oregon State University (<http://eecs.oregonstate.edu/academic/online-cs-postbacc>).

⁴This is in contrast to programs that require certificate students to apply to their MS programs with no guarantee of admission, such as NYU (https://cs.nyu.edu/home/master/prospective_pac.html).

⁵Stereotype threat is a situation in which individuals fear that they will confirm negative stereotypes about their group. This can have adverse effects on performance as well as persistence, as for women and URM students in STEM.

students proceed to join regular MS classes, which include traditional master’s students who did complete a prior degree in CS or a closely related discipline. In addition, all students are given the opportunity to spend from 3-8 months in internships. The degree awarded to students who complete the program that begins with the Bridge is the same degree received by students who are admitted directly to the MS in CS program.

Certainly the range of MS programs in CS and closely related disciplines is large and varied [7], and many programs, both master’s and post-baccalaureate, are designed with tech-capacity building or diversity in mind. For example, Alhazmi et al. [2] address diversity of master’s students’ previous experience by providing choice in the assignments they complete in a programming fundamentals course for students from non-CS majors. Compared with their previous, more traditional assignment approach, they find that this leads to substantial improvement in learning outcomes and student perception. Herbert-Berger et al. [10] propose a post-baccalaureate certificate curriculum to assist students transitioning to CS from other fields with consideration of both technical and professional (“soft”) skills that are essential to future employers. And Lundqvist et al. [15] describe a “conversion” Master of Software Development degree for graduates with little or no CS degree background.

Most closely related to our program is the ARC program described by Klawe et al. [11], a two-year post-baccalaureate program for students with little to no programming experience specifically designed to appeal to women. In the first years of their program, Klawe et al. learned many lessons that our program confirms, including the importance of refreshing students’ math knowledge, clear messaging to students about the level of commitment required, and the need for robust resources for advising and administration.

Our program is a complement to the above in its combination of level and disciplinary degree focus (MS in CS), as well as its attention to diversity.

3 BRIDGE CURRICULUM

The Bridge was designed to achieve the core learning outcomes of Northeastern University’s BS in CS as well as to cover the Core-Tier 1 topics and learning outcomes in the ACM/IEEE-Computer Society Guidelines for Undergraduate Curricula in CS (CS2013) [1].

The bridge curriculum develops students’ skills in software, theory, and systems, as well as their ability to work collaboratively. The Bridge does not include any elective courses. Instead we expose students to various areas of specialization through a co-curricular seminar, described in Section 4. Students develop mastery of specialized areas in elective courses at the MS level.

The Bridge consists of five courses as shown in Table 1. At the MS level, a full-time load at Northeastern is 8 credits per term; our goal was to prepare students for the MS while keeping the time needed for the Bridge to two academic terms.⁶ Each course has a lecture section that meets once per week in the evening for 195 minutes. CS5001 and 5004 also have a weekly 3-hour lab session. Longer but less frequent class meetings held after regular working hours are especially helpful for students who work full-time.⁷

⁶The MS in CS consists of eight courses; CS5004 of the Bridge overlaps significantly with one of those; thus Align students complete seven courses beyond the Bridge.

⁷Our faculty employ active learning to keep students fully engaged.

First Semester		
Course	Credit	Pre-req
CS5001: Intensive Foundations of CS	4	None
CS5002: Discrete & Data Structures	4	5001:Pre or Co
Second Semester		
CS5004: Object-Oriented Design	4	5001
CS5006: Algorithms	2	5002, 5007
CS5007: Computer Systems	2	5002

Table 1: The Bridge to prepare students for the MS in CS.

CS5001 focuses on algorithmic thinking and problem solving through programming in Python. CS5002 focuses primarily on discrete mathematics and structures. CS5004 introduces Java for presentation and practice of object-oriented design concepts. Though this is not a data structures course *per se* – and indeed data structures and algorithms are discussed in **all** bridge courses – many fundamental abstract data types and implementations are presented in CS5004. CS5006 and 5007 introduce the C programming language to explore course material. More on each of these courses is available at <https://www.khoury.northeastern.edu/academics/masters/course-charters/>.

3.1 Mapping Learning Outcomes to Courses

The bridge curriculum is designed such that students can achieve the high-level learning outcomes given below.

Software: After the Bridge, a student should be able to:

- Write correct, legible, well-designed code
- Understand, use, and extend code written by others, following appropriate design principles
- Understand, use, and create documentation, following appropriate documentation standards
- Design and use systems for persistent data storage
- Translate and elaborate informal descriptions of problems to computer-based solutions
- Choose appropriate data structures for programming tasks
- Design, write, implement, and interpret tests
- Design good, durable solutions using established design principles
- Follow a system development life cycle in a software development project
- Present code, explain design decisions, and answer questions about them

Students begin to develop these skills in CS5001 and further develop them in all second-semester courses (CS5004, 06, 07).

Theory: After the Bridge, a student should be able to

- Analyze algorithms for efficiency
- Compare/choose algorithms for given problem definitions
- Demonstrate knowledge of discrete mathematics and its applications to practical problems

Students develop a strong theoretical foundation in CS5002. They focus on the theory behind algorithms primarily in CS5006, but concepts in this area are introduced in several courses (CS5001, 02, and 04). We note that all Northeastern MS in CS students take an

intensive graduate algorithms course. Thus we can focus on preparing our students for this course, rather than teaching a complete algorithms course during the Bridge.

Systems: After the Bridge, a student should be able to show:

- Awareness of computer hardware components and uses
- Awareness of how hardware and software interact
- Understanding of basic system-level software such as operating systems
- Understanding of computer networks

Students develop these in CS5007. Rather than provide depth in systems equivalent to that in an undergraduate program, we emphasize a breadth of fundamental concepts that are relevant to software development and analysis. Interested students take additional systems courses in the MS.

People/Group Skills. The historic stereotype of the lone programmer is becoming less prevalent. Computing – especially in this era of large software systems and broad applications – is a naturally collaborative discipline. A number of bridge courses require that students work collaboratively (e.g., CS5001, 04, and 07). By the end of the Bridge, a student should be able to collaborate in a group toward a common solution, work with people of different skills, temperaments, and work habits, and work in a group equitably. We note that Align students come from a wide range of disciplines; thus they already value other disciplines and can speak to individuals from areas outside of CS. Furthermore, many of our students have been in the workforce for several years after college and have significant collaboration experience.

3.2 Part-Time Students and Waivers

Some students (currently 9%) choose to enroll in Align part-time, completing four credits per semester rather than eight. We have strived to minimize dependencies among bridge courses, but as is always the case in CS, there remain courses that cannot be taken out of sequence. Pre- and co-requisites are given in Table 1.

Although the Bridge is designed for students with no computing background, some incoming students do have some CS experience (e.g., the student who took CS1 as a senior or the Math major who has had discrete math). In this case, students may apply for bridge-course waivers. As a matter of policy, we do not allow a student to waive more than two bridge courses; a student with sufficient experience to waive a majority of the Bridge does not fit the profile of a non-CS student and may be a better candidate for direct admission to the MS. At present we handle waiver requests on a case-by-case basis.

3.3 Pre-Bridge Preparation

Students admitted to Align are not formally required to do any pre-bridge preparation. However, for two primary reasons we recommend that students review the highest level of mathematics they have completed. First, we want students to be ready for Discrete & Data Structures (CS5002); if they are struggling to recall concepts such as factoring of polynomials, students will be focusing on them during the semester, rather than on new concepts being introduced. Second, many fundamental skills of mathematics are also helpful

in computing. For example, taking a problem described in human language and expressing it in a formal language.

As our students enter Align having majored in a wide array of disciplines, we cannot presume that they have seen any formal mathematics beyond high school. Therefore, we assume knowledge of Algebra and work to develop students' core discrete math background, familiarity with CS theory, and also confidence to learn additional mathematics, as needed for electives.

To help students prepare, we provide links to free online resources. In Summer 2019 we piloted an optional two-week pre-bridge math session. This program is designed not to teach new math concepts but to help students refresh their background and develop confidence with ideas they may not have seen for a while.

We also administer a Quantitative Skills Assessment modeled on the instrument developed by Gaze et al. [8] This short test (20 multiple-choice questions) assesses knowledge of concepts such as percentages, ability to interpret charts and graphs, and basic algebra skills. It allows us to identify students who may need additional support in their early bridge courses.

3.4 Curriculum Evolution

We have modified the bridge curriculum over time to better prepare students for the MS. For example, we now include more material on discrete mathematics than we did previously; we follow the good practice [9] of using just one programming language in the first term; and we introduce, use, and implement data structures in several bridge courses. We now order CS5006 after 5007, as this provides students exposure to CS5006 closer to the time they will take the required graduate algorithms course.

4 STUDENT SUPPORT

The Bridge can be challenging for a variety of reasons. Some students need time to readjust to school after years in the workforce. Some come from disciplines where study methods differ from strategies commonly employed in computing. For others, it may have been some time since they last took a math course or used algebra concepts. Of particular concern are the students who are at risk of experiencing stereotype threat [18].

Researchers have demonstrated that Social Cognitive Career Theory (SCCT) [12] applies to computing and, in particular, to underrepresented students in computing [13, 14]. SCCT states that interest in and choice of a particular career path is increased by interventions that improve one or more of the following: (1) outcome expectations: understanding and valuing the rewards of a particular outcome, (2) self-efficacy: a belief that one can successfully achieve an outcome, and (3) social support that helps one persist and overcome obstacles. We have developed programming and practices that address these explicitly.

4.1 Academic Resources

Each student is assigned an academic advisor who understands the program well and is familiar with the questions and concerns of the Align population. The primary role of our academic advisors is to ensure that students have the resources they need to succeed; this means not only passing bridge courses but also being well-prepared

for the MS and beyond. Indeed good academic standing requires at least a B average as well as a minimum grade of B in select courses.

Our usual ratio of Teaching Assistants (TAs) to students is 1:25; for bridge courses it is 1:15. TAs for bridge courses are typically graduates of the courses themselves and therefore can help current students gain confidence that they, too, will overcome challenges.

Mid-semester, we ask faculty to identify students who are at risk of falling below the grade required for good academic standing. Our goal is to identify students who may need extra help in order to stay on track. Academic advisors meet one-on-one with these students to develop an academic plan that may include working with tutors (provided at no cost to the student).

4.2 Mentors and Seminars

We provide individualized mentoring and group-mentoring seminars. At orientation, students are invited to sign up for a mentor program. This is optional, but many of our students choose to participate. (For example, 86% of our Fall 2019 incoming class signed up.) Each new Align student is matched with a student who has completed the Bridge. The top reasons students reach out to their mentors are for advice on academics and career preparation.

Once a month we take an hour of our students' scheduled lab time for a seminar. The seminar series is designed to provide advice and perspective, as well as to give students a sense of the breadth of computing areas and careers. We invite our own faculty and staff to cover topics such as study skills for CS or the transition to the MS; student panels, e.g., for advice on exam preparation; academic and industry researchers to present their research; and speakers from industry to discuss their work, company culture, etc. We emphasize bringing in speakers who have followed non-traditional paths.

5 INVITING A DIVERSE STUDENT BODY

In the last five years, we have learned that ensuring the success of our mission requires more than just offering the program. In Sections 3 and 4, we discussed the curriculum and the co-curricular activities needed to educate, mentor, and retain students. Here we discuss additional considerations, particularly around recruitment.

5.1 Working with Prospective Students

Our hope for the future is that all post-secondary graduates will know that an MS in CS for non-majors is a graduate school option, just as they know they can pursue an MBA or JD after any undergraduate degree. However, this is not yet a reality. In addition to recruiting through traditional means (e.g., websites, conference sponsorships), we have created a suite of in-person recruiting events. These include: (1) Preview nights, where we talk with prospective students in a casual setting (e.g., a pub near a university campus). (2) Information sessions, where we meet with students at our own or other campuses (with the permission and advertising of the host college). (3) Workshops, which begin with a meet and greet with current students, followed by an interactive session on an algorithm relevant to every-day life. For instance, we may teach Dijkstra's shortest path algorithm to illustrate how a GPS might work. (4) Weekly application support webinars.

In the two years we have actively recruited students we have observed that prospective students, particularly those converting

from non-STEM disciplines, want multiple touch points. Changing fields is a challenging decision for many, and a sequence of events that allow individuals to meet the faculty and advising staff helps build their confidence. Talking with current students and alumni from similar educational backgrounds is particularly helpful. Indeed, many prospective students come to three events prior to submitting an application and will have had close contact with several members of the team (recruiters, advisors, and faculty).

5.2 First-Semester Scholarships

First-semester scholarships are a key part of giving prospective students the confidence to try CS. It is difficult for someone who might already have student debt, to contemplate additional debt simply to *try* computer science. We have found that the majority of students know by the end of the first semester whether they like CS, and a first semester scholarship allows them to “try before they buy.” After ascertaining that they like CS enough to make a career transition, students can better balance considerations such as future earning potential with education cost. We have secured philanthropic support to fund first-semester scholarships for over 200 students since Fall 2018 alone.

6 STATISTICS TO DATE

We enrolled our first eleven Align students in Fall 2013. As of Fall 2019, we have graduated 137 students and have 827 currently enrolled. In this section we detail empirical measures, discussing program successes as well as areas for further work.

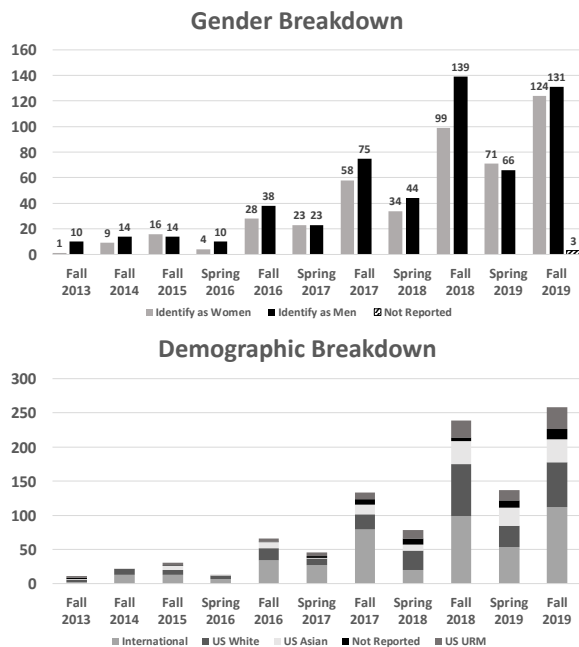


Figure 1: Program demographics by enrollment semester; y-axis gives number of students.

6.1 Enrollment Demographics

Figure 1 shows the demographics of each student cohort beginning the Align program.⁸ First we show the number of students who identify as women and men in each cohort. Below that, we show the distribution of international students, domestic U.S. students who are URMs, and all other domestic U.S. students. Note that early on, we kept the program small; we wanted to be sure it would work for students and that tech companies would hire MS graduates who did not study CS as undergraduates. Note also that the percentage of people who identify as women in our program was strong from the start.

In Fall 2017 we began an active campaign to recruit students typically underrepresented in CS. As we prepared to grow Align significantly, we expected we would need to be very intentional in order to achieve and maintain a diverse student body. In our three most recent cohorts (Fall 2018, Spring 2019, and Fall 2019), women comprise 42%, 52% and 48% of incoming students. U.S. domestic students comprise 58%, 61%, and 57% of incoming students; of these, 18%, 18% and 22%, respectively, are URMs. Although we have not yet achieved our aspirational goal of 50% women and 25% URMs, our recruitment activities have led to strong representation in the diversity of incoming students.

In terms of our goal of increasing diversity of thought, students come from over 100 different undergraduate majors. The percentages clustered by area are: 29.3% Science, 27.5% Humanities, 23.7% Business, 16.4% Engineering, and 3.1% Fine and Performing Arts.

6.2 GPA Analysis

After students complete the Bridge, they begin to take MS-level classes with the traditional MS students. To evaluate how well the Bridge prepares them for the MS-level classes, we compared the grade distributions of students with and without a prior CS degree.

For this analysis, we examined the GPAs of Align students who have completed 5-7 MS-level courses. These 139 students began taking MS-level classes in Fall 2014; we do not include students who began the program after Fall 2017.⁹ The GPAs we report are for MS-level courses only — not bridge courses. As a comparison group we consider all traditional MS students admitted between Fall 2014 and Fall 2017, which totals 932 students.

As we can see in Figure 2, Align students perform very well in comparison with our traditional MS students. This is notable, given that our admissions process for traditional MS students is highly selective — during Fall 2014-Fall 2017 we admitted only 16% of total applicants. We show the grade analysis for a 4.0–3.0 GPA range, because 3.0 (B) is a required GPA for good academic standing in our MS in CS program. In further analyses we do not see any significant differences for groups by gender, URM status, or date of beginning the program.

6.3 Employment Outcomes

As of Fall 2019, 137 students have graduated. We currently have data on the employment outcomes for 122. Of these, 100% have tech positions. Our two top employers are Amazon and Facebook; other notable employers include Google, Nordstrom, TripAdvisor,

⁸Since Fall 2016 we have admitted students to start both in Fall and Spring terms.

⁹They have, on average, completed fewer MS-level classes at this point.

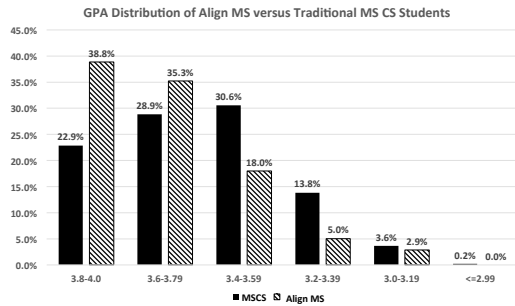


Figure 2: Student performance in the MS in CS.

Microsoft, and LinkedIn. At this time, we are not aware of any graduate of the program who has decided not to work in tech.

In Summer 2019, we conducted a survey to understand the salary impact of the program on graduates. Of the 100 graduates to whom the survey was sent, 20 have responded thus far. Of those, the average salary increase from pre-program to post was \$43,750.¹⁰

6.4 Retention

In Figure 3 we show (a) the size of each entering cohort and then the retention rates at three key transition points in the program: (b) from first to second semester of the Bridge; (c) from the Bridge to the MS; (d) from start of the MS to graduation.

We see the largest average attrition from the first semester to second, as some students decide that CS is not for them, or that they cannot balance graduate school with other life commitments. We provide scholarships to many students in the first semester; thus this transition is where many students realistically determine their ability or willingness to pay for the program. In Figure 3(b), we note significantly lower retention rates in the Spring 2017 and 2018 cohorts. We conjecture that spring is a less traditional time to begin an academic program; the percentage of spring-admitted students managing multiple life priorities may be higher than for fall. We have observed a correlation between heavy personal obligations and leaving the program. This is especially true for students from non-STEM backgrounds, who may be making larger adjustments to a CS curriculum than their STEM peers. To help mitigate this, we have adjusted our messaging to prospective students. We discuss the challenges of balancing full-time academics with other full-time obligations and proactively suggest the part-time academic option.

We see in Figures 3(c) and (d) that students also leave after completing the Bridge. Some of these departures are due to level of interest, but others are due to life commitments. Attrition at the later stage (already in MS courses) is most typically due to life issues that preclude continuing graduate school. We surmise (but do not yet have hard data) that many of these students still move into tech positions. Of all students who have left the program, only six have been asked to do so for issues of academic standing; an additional 11 cited academic reasons for withdrawing.

¹⁰ All 20 were previously employed, so this does not capture any student who came directly to the program from their undergraduate degree.

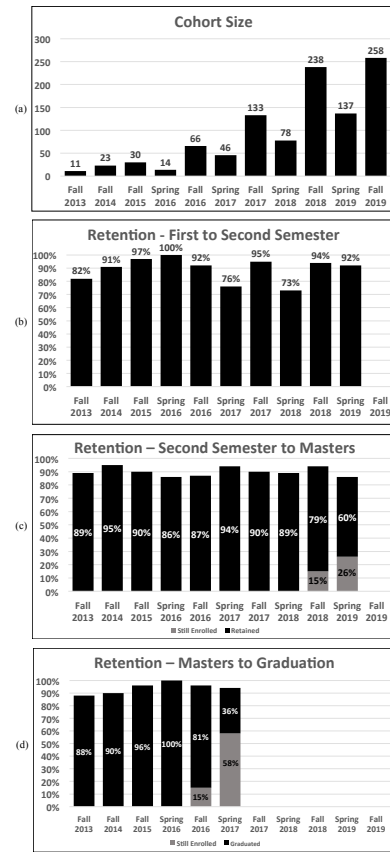


Figure 3: Percent retention through graduation, by cohort. "Still enrolled" indicates that a student is still in the program, but has not yet completed the relevant outcome.

7 THE ROAD FORWARD

In this paper we have described the Align MS in CS, an MS for post-secondary graduates who did not major in CS. Students in this program graduate with the same degree as students directly admitted to Northeastern's MS in CS. What differs is that Align students complete 16 credits of coursework over two semesters (if full-time) to prepare for MS-level CS courses. Our goal is not just to grow the tech pipeline but to increase the diversity of demographics and thought in the field. After six years of developing and growing the program, we find that it is possible for non-CS undergraduate majors to thrive in an MS in CS program and that it is possible to develop a cohort of students that is diverse across many dimensions. We continue to closely monitor retention and are continuously evolving our curriculum and advising practices to improve the Align program.

In 2019 we formed the Align Consortium, which brings together other universities to scale this work. We hope that such a widespread effort will develop new ideas and best practices and make a significant contribution to tech in terms of both numbers and diversity nationally.

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