Master's at Scale: Five Years in a Scalable Online Graduate Degree

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ABSTRACT
In 2014, Georgia Tech launched the first for-credit MOOC-based graduate degree program. In the five years since, the program has proven generally successful, enrolling over 14,000 unique students, and several other similar programs have followed in its footsteps. Existing research on the program has focused largely on details of individual classes; program-level research, however, has been scarce. In this paper, we delve into the program-level details of an at-scale Master's degree, from the story of its creation through the data generated by the program, including the numbers of applications, admissions, matriculations, and graduations; enrollment details including demographic information and retention patterns; trends in student grades and experience as compared to the on-campus student body; and alumni perceptions. Among our findings, we note that the program has stabilized at a retention rate of around 70%; that the program's growth has not slowed; that the program has not cannibalized its on-campus counterpart; and that the program has seen an upward trend in the number of women enrolled as well as a persistently higher number of underrepresented minorities than the on-campus program. Throughout this analysis, we abstract out distinct lessons that should inform the development and growth of similar programs.

Author Keywords
Affordable degrees at scale, online education, retention, graduation

ACM Classification Keywords
Applied computing~Distance learning

INTRODUCTION
Seven years after what the New York Times dubbed the Year of the MOOC (Massive Open Online Course) [24], higher education is preparing to undergo what we might consider the second phase of this push toward affordable, scalable education using the internet as its delivery mechanism. While much has been written on the struggles MOOCs have encountered with retention rates and other outcome variables [25], early successes in offering affordable degrees at scale are leading to a wave of incoming for-credit programs either in partnership with MOOC platforms or using lessons learned from MOOCs [27]. These early successes included an online MSCS program launched in 2014, an online MBA program launched in 2016, and an online MS in Accounting in 2017. Now, a deluge of similar programs is set to arrive, with MOOC provider edX scheduled reach 16 such programs in the next year and Coursera set to reach 13.

L@S '19, June 24–25, 2019, Chicago, IL, USA

ACM 978-1-4503-6804-9/19/06…$15.00
DOI: 10.1145/3330430.3333630

This year also marks the fifth year since that first MOOC-based online Master's degree in computer science was launched by Georgia Tech. Given its experience, it may offer significant lessons to these emerging programs, as well as rare insights into the administration and demand for such a program. Significant work has already been devoted to investigating pedagogical issues in the program, but one of the persistent undercurrents in these analyses has been acknowledgement of program-level questions and issues.

This work tackles learning at scale not at the class and student level, but at the program and institute level. In this analysis, we will investigate the program's application, admissions, and matriculation rates; enrollment patterns including gender, ethnicity, and citizenship status; retention trends at both the course and the program level; and graduation rates and alumni perceptions. To complement this data-driven case study, we also share the narrative of the program's creation, which may give lessons for other programs seeking to navigate the complex organizational landscape of accreditation and procurement. We close with insights from current program staff into ongoing challenges that new programs should anticipate. Throughout the analysis, we specify particular findings, and at the conclusion of this paper we connect these findings to lessons for use by new and emerging programs.

RELATED WORK
Broadly, this work exists in the contexts of two recent trends: the rise (and arguably, the subsequent fall) of MOOCs [25] and the ongoing crisis regarding college affordability and student loan debt [23]. There exist alternate ideas to reducing the cost of graduate-level education, such as an emphasis on competency-based education [26]. The idea of reducing cost through scale was pioneered previously by the Open University, which led early research into financial models

[30], student attrition [19], and pedagogy in distance learning [13]. Research has noted, however, that specific components of American universities, especially the focus on in-course assessments and projects, present additional challenges [8].

Significant prior research has been performed specifically on this program as well. Broad-level research has looked at the motivations of the program's teaching assistants [14], the policies and workflows developed program-wide [15], the potential for the program to raise the population of MSCS graduates [12], and the specific relevance of computing as a content area for learning at scale [16]. More specific prior work has compared students between delivery mediums for a particular class [10], examined sentiment trends in forum posts and course reviews [4][22], evaluated artificially intelligent teaching assistants [11], and examined peer review at scale [17][20]. This work, however, examines facets of the program heretofore unpublished, including its applications, admissions, and matriculation rates; patterns in enrollment, retention, and attrition; program-level demographics, student experience, and grade data; alumni attitudes; and non-pedagogical challenges to scale.

METHODOLOGY

This study is a heavily data-driven case study. We began by curating a library of data sources about the program. These included publicly-available disclosures of admission and grade data, historical survey results, raw enrollment logs, and public student contributions to course review sites. We then evaluated these for notable trends, informed by institutional knowledge of the program's operations and history as well as informal interviews with instructors, staff, and students. These conversations provide context in which to understand the data, as well as provide the narrative behind the program's inception and current challenges.

In organizing and reporting the results of these analyses, we adopt the perspective of a student: we begin with the program's creation, and then trace through data sources describing the typical student's journey beginning with application, admission, and matriculation. We then examine enrollment patterns within the program, including patterns in program growth; in gender, ethnicity, and residency; and in grades and the student experience. We then examine graduation data, tying back into matriculation data to investigate program retention, as well as alumni perceptions. Finally, we close with the present challenges to scale encountered by the program's staff and instructors. Through this, we will highlight major findings and their corresponding lessons for future efforts toward for-credit learning at scale.

PROGRAM CREATION

A detailed narrative of the creation of the program can be found in DeMillo & Young 2015 [8]. This background provides a brief look into the administrative obstacles to overcome to launch this program.

Ideation for the program began in September 2012. Zvi Galil, the Dean of the College of Comuting at Georgia Tech, and Sebastian Thrun, the CEO of Silicon Valley startup Udacity specializing in massive open online courses (MOOCs), proposed a Master's degree using MOOC technology at a fraction of the cost of an on-campus program (initially, $1,000 in total tuition). The degree would have equal accreditation with the on-campus program and would admit *anyone* that met the minimum admissions qualifications, without capacity constraints.

Galil then initiated a series of town halls to discuss the idea with the college's faculty. Put to a vote, 75% of faculty supported the initiative, and the Graduate Curriculum Committee approved it as well. However, funding presented an issue: the startup costs for such a program would be very high. To address this, the leaders of the initiative approached a corporate vendor and secured a pair of $2 million gifts to support the program's creation. With the support of the faculty and the funding to get started, the program was approved by the Board of Regents in May 2013, with a final total tuition of around $5000 (plus semesterly fees). The program initially cost $134 per credit hour and required 36 credits to complete, but it was later amended (along with the on-campus program) to require 30 credits at $170 per credit hour. Importantly, this approval process specifically approved the creation of an online *campus* for an existing degree; the degree itself was not new. This approach provided an easier mechanism to achieve approval for the program, but also represented a considerably higher risk: attaching equal credit meant that the program would have to be identically rigorous, while also letting in students who are not competitive in on-campus admissions even while meeting minimum admissions criteria.

With approval and funding, course production began in Summer 2013. The corporate partner for course production provided video producers, course developers, and equipment to support faculty members in creating their courses, but just as on campus, courses were faculty driven. The program launched in January 2014, receiving 1,583 applications for its first cohort.

To date 30 courses have been produced for the program. Of these 30 courses, 28 were developed by tenure-track faculty and 2 were developed by research scientists. 22 courses are still taught by the same faculty member who developed the course; of the other 8, four are now taught by research scientists, two are taught by other tenure-track professors, one is taught by a member of the teaching faculty, and one has been deprecated. Additional information regarding the development of the program from the faculty point of view can be found in Joyner 2018 [15]; the remainder of this analysis focuses instead on the student body.

APPLICATIONS, ADMISSIONS, AND MATRICULATION

A key component of the program's mission statement is that the program will admit as many students as meet the admissions requirements. Scale, in this context, is defined as

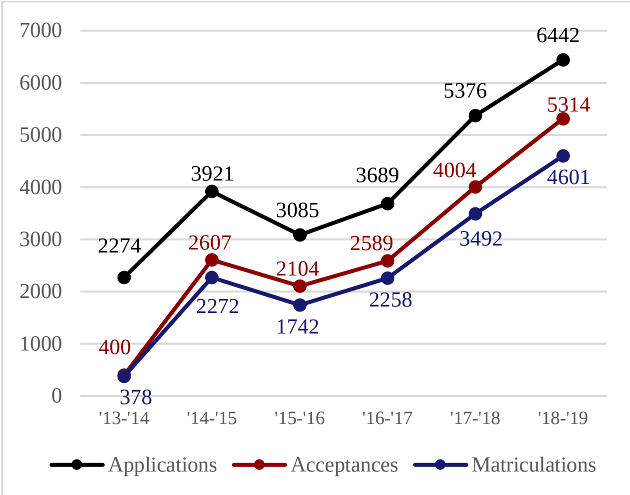

Figure 1. The number of applications, admissions, and matriculations for each term in the online program's history.

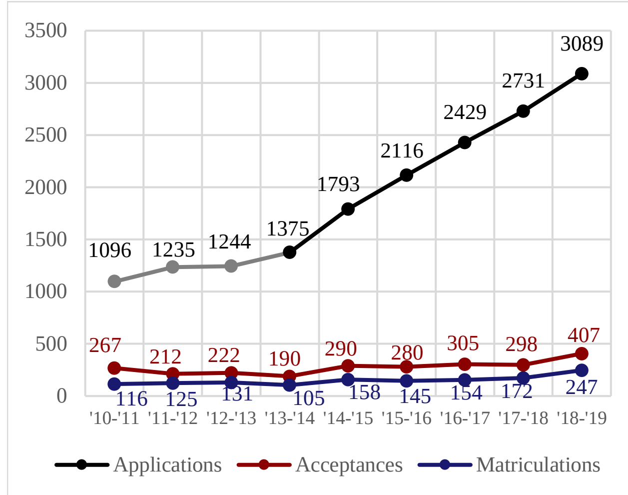

Figure 2. The number of applications, admissions, and matriculations for the on-campus program since 2010. The gray portion of the Applications line marks the time before the launch of the online program.

the ability to handle as many students are as interested in and qualified. This stands in contrast to on-campus programs both at Georgia Tech and elsewhere, where capacity is limited by physical constraints and selectivity is considered a positive criterion. This can be seen in the most recent semester: for the 2018-2019 year, the online program received 6,442 applications, while the on-campus program received 3,089. The online program admitted 5,314 students and saw 4,600 matriculate, while the on-campus program admitted only 407 and saw 247 matriculate. The online and on-campus program have the same admissions requirements, but capacity constraints prevented the on-campus program from admitting more than 15% of its applicants, while the online program admitted over 82%.

Figure 1 shows the number of applications, admissions, and matriculations throughout the program's history. Notably, during the first term (Spring 2014, the only term from the 2013-2014 school year), admissions were capped to provide a more manageable initial cohort. Uncapped admissions began in the 2014-2015 school year and continue to the current term. Applications remained fairly consistent through the first three years until Spring 2017, then began to rise tremendously, nearly doubling from the 2016-2017 school year to the 2018-2019 school year. Also notably, the admission rate has actually risen, from 66.5% during the program's first full year to 82.5% during the most recent year, suggesting that the increased applications are specifically from well-qualified applicants. This refutes a hypothesis that a program at scale would quickly exhaust its target audience; **there exists a very large body of potentially interested students in a program like this** (Lesson 1 under Lessons Learned at the end of this paper).

Although the hypothesis that the program would quickly exhaust its target audience appears obviously false (especially in retrospect), a more believable hypothesis was that an affordable online program with equal accreditation would cannibalize Georgia Tech's corresponding on-campus program. Figure 2 shows applications, admissions, and matriculations in the corresponding on-campus program from three years prior to the launch of the online program through the present.

Contrary to the hypothesis, applications to the on-campus program have risen 224% since the online program was launched. Admission percentage dropped from 17.8% the year before the online program launched to 10.9% until the 2018-2019 matriculating class was expanded to accommodate 13.2% of applicants. During this time, the yield rate (the percentage of admitted students who matriculated) remained relatively steady, dropping from 59.0% to 50.5% before climbing back to 60.7% for the 2018-2019 year.

This, combined with demographic differences in the student body, leads to the finding that **the online and on-campus program draw from different student profiles, and thus online applications do not diminish interest in the on-campus program** (Lesson 2). In fact, an at-scale online program may increase interest through greater publicity, recognition, or visibility: in the three years prior to the launch of the online program (from 2010 to 2013), on-campus applications rose only 25%, from 1,096 to 1,375.

PROGRAM ENROLLMENT

Once admitted, students must complete ten courses to graduate. They may complete up to three courses per term, although as the program has experimented with different limits through its history; at present, students are limited to two courses during Spring and Fall semester and one course during Summer semesters, but exceptions may be granted. These limitations have primarily been issued for students' protection; prior withdrawal data indicated students were significantly more likely to withdraw if they enrolled in more

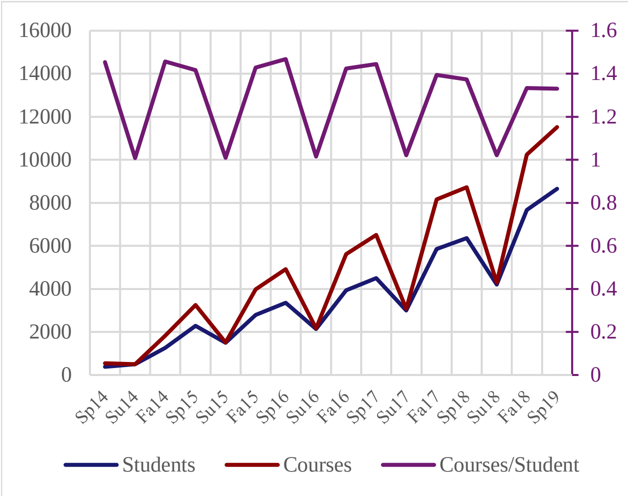

Figure 3. Total students (blue), total courses attempted (red), and course/student ratio (purple, axis on right).

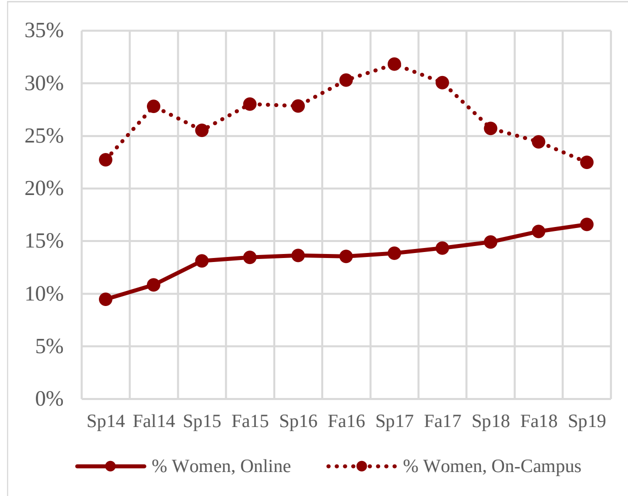

Figure 4. Female percentage of the student body per-semester for the online and on-campus programs.

classes. A first-semester one-course limit has been proposed but never implemented.

Figure 3 below shows the total enrollments and total courses attempted during each term of the program's history. One student counts as one enrollment regardless of how many courses they take, while they can count as 1, 2, or 3 course attempts depending on how many courses they take.

In Spring and Fall terms, students take approximately 1.4 courses, meaning that more than half take only one course, less than half take two courses, and a small number take three courses. This number has been shrinking slowly since the program began. In Summer terms (which are 5 weeks shorter than Spring and Fall terms), significantly fewer students enroll: ~⅔ as many students as the preceding Spring and ~½ as many students as the following Fall. Very few students enroll in multiple courses during summer, indicated by the courses/student ratio dropping to almost exactly 1 during these terms.

Each course in the program counts for 3 credit hours. Each credit hour costs $170 in tuition, and each semester of enrollment costs on average $200 in fees regardless of the number of courses taken. Altogether, there have been 47,047 total enrollments (one student, one semester) and 230,482 credit hours attempted, comprising approximately $39.1 million in tuition and $9.5 million in student fees. The total cost to an individual student is dependent on how many classes they take per semester, ranging from $5,900 (for four semesters) to $7,100 (for ten semesters) to complete the degree requirements. This cost may also grow if the student withdraws from a or fails a class and must thus pay to take it again, or if a student decides to postpone graduation to take additional classes.

Student Demographic Trends

One question raised about online education regards its equity based on student gender and ethnicity. Prior research has indicated that there are barriers to participation in online and distance learning based on gender [3][6] and ethnicity [1][18]. It has also been observed that, perhaps surprisingly, online education is preferred by domestic students, while on-campus education may be preferred by international students due in part to advantages it grants regarding immigration status. To examine this, we look trends in enrollment based on gender, ethnicity, and citizenship status, especially as compared to the on-campus program. Due to dramatically lower enrollment on-campus during Summer, we look only at Spring and Fall semesters.

Gender

Figure 4 shows the trends in gender ratios for the two programs. The on-campus program hovers around 27% women, although that number has declined seemingly steadily the past five semesters. The online program began at 9% women but has steadily climbed to 17%.

We have used enrollment data rather than matriculation data to control for possible disparities in retention, although this disproportionately represents earlier matriculating classes due to the larger number of subsequent course enrollments, especially online where students take more semesters to graduate. For example, while the percentage of women enrolling in the online program peaked at 17% in the most recent term, both admissions and matriculations were 19% women.

Notably, there have not been significant active efforts to affect this trend, suggesting that this evolution is somewhat organic. We note that research on impostor syndrome finds it prevalent especially among women in higher education [29] and women in computer science [21], and that impostor syndrome can drive people away from risking enrollment in experimental or unproven programs they may have to defend later [28]. We also note that early adopters of new technologies tend to be male [7]. The trend observed in this program and this prior research suggests that a gender bias in online education may be a temporary phenomenon that

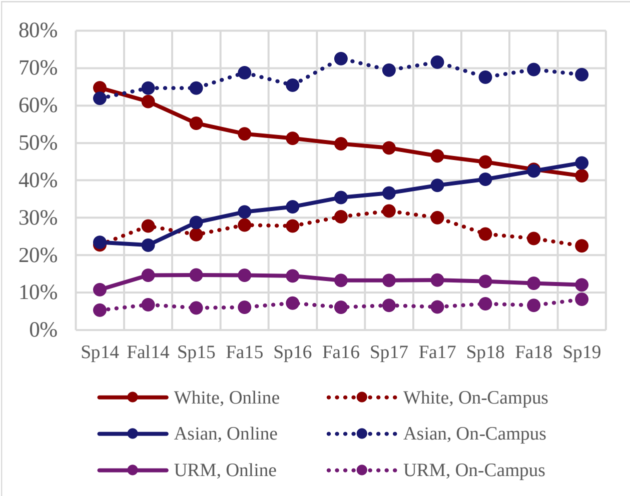

Figure 5. Percentages of the student body identified as White, Asian, and underrepresented minorities. Other ethnicities make up fewer than 2% of the student body.

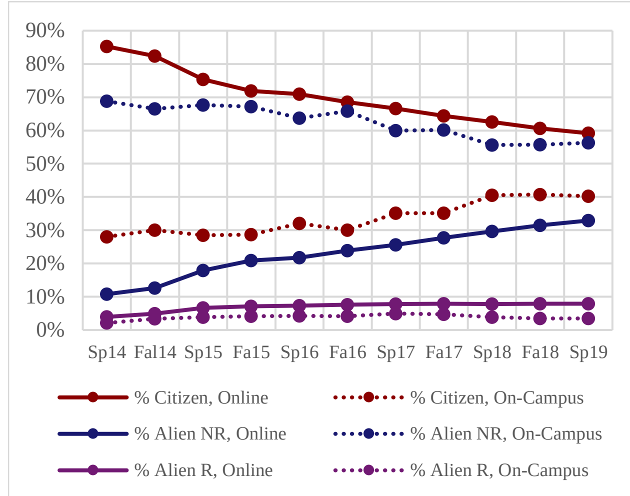

Figure 6. Percentage of each campus's student body by citizenship. Alien is further subdivided into US residents (R) and non-US residents (NR).

can be resolved—and may even resolve naturally over time, although active efforts are needed to ensure it resolves soon to avoid further widening existing gender gaps.

Ethnicity

Figure 5 breaks down the reported program ethnicities by three largest categories: White, Asian, and underrepresented minorities. The on-campus program hovers consistently around 7% underrepresented minorities, while the online program has held relatively steady (or decreasing slightly) around 13%. This supports the hypothesis that online programs may expand access to disadvantaged populations. The combination of these trends in gender and ethnicity leads to the finding: **there is promising evidence that online education can help equalize accessibility among women and underrepresented minorities** (Lesson 3).

Figure 5 also highlights an interesting change in majority demographics in the online program: while the program began majority-White at 61% in the first large semester (Fall 2014), the Asian population has grown from 23% that term to 45% in the most recent term. While the ratio of underrepresented minorities has dropped slightly from a peak of 15% to 12%, it has grown as a percentage of the White population, suggesting this trend is actually due to the larger influx of Asian students rather than a drop in underrepresented minority students. Meanwhile, on-campus demographics remain relatively consistent, with a large majority Asian population (68% on average).

Citizenship

Data reports break citizenship into three categories: citizens, alien non-residents, and alien residents. Figure 6 shows the relative percentages of the study body in all three categories for the two campuses.

First, the online program has a significantly higher percentage of citizens than the on-campus program, which counters the hypothesis that the online program would appeal to students unable to immigrate to the United States. Rather, based on our conversations, it appears a significant motivation for international students to come to campus is United States student visa program; a major motivation for citizens and residents to attend the online program is avoid the opportunity cost of taking time off work. This provides an explanation for the trend noted in Figures 1 and 2: the online program does not draw enrollments away from the on-campus program because it attracts a different student body.

Interestingly, the populations of the two programs are converging: the online program has steadily dropped from 85% citizens to 59% citizens, while the on-campus program has risen from 28% citizens to 41% citizens.

Grading Trends

Prior research has found that performance by online students in this program surprisingly matches or exceeds the performance of on-campus students on shared assessments [10]. The online program admits any students who meet the minimum qualifications (ranging from 66% to 82% of applicants), while the on-campus program admits the top few percent (ranging from 11% to 13% of applicants). Combined with the greater number of competing obligations among online students, a reasonable hypothesis would have been that online students, on the whole, perform worse. That earlier research examined only one course in the program; here, we look at multiple courses.

We found 39 instances where an instructor taught both the online and on-campus sections of the same course in the same term. We selected this subset to control for differences between instructors or significant changes between semesters. 16 courses were present at least once in this set.

For each of these instances, we performed a Student's t-test to compare the average GPA of students who completed each course. Due to the likelihood of Type I error introduced by these repeated tests, we used $\alpha = 0.01$ as our threshold for declaring statistically significant differences.

In total, on-campus students have outperformed online students nine times, and six of these come from a single class. Online students outperformed on-campus students one time. These results are compatible with prior hypotheses regarding the qualifications and time available among online students, although the results still reflect that online students typically match their on-campus counterparts' performance. Although we can only speculate about why one class seems to disproportionately advantage on-campus students, we note that it is rated by students as one of the program's toughest courses and requires the C programming language; almost all other classes instead use Python, Java, or R.

Course Withdrawals

At this university, students may withdraw up until week 10 of the 17-week semester and receive a W on their transcript instead of a letter grade. Students withdrawing from all classes will receive a pro-rated refund; given that most students in this online program register for only one class per term, a single course withdrawal often triggers this refund.

On the same set of 39 courses used in the grading trend analysis previously, we also attempted N-1 Chi-squared difference of proportions tests [5] on the proportion of students withdrawing from the online and on-campus sections. 9 of these tests could not be performed as no students in the on-campus sections withdrew. Of the other 30 tests, 18 saw statistically significant differences at $\alpha = 0.01$, all showing more students withdrawing from the online section. Overall for these pairs, the average withdrawal rate online was 23.67%, while the average on campus was 5.87%.

To investigate these differences, the online program conducted withdrawal surveys. These surveys let students select one or more reasons for their withdrawal, as well as supply their own additional context. Withdrawal surveys for three terms were available for this analysis. In all three surveys, a significant majority of students listed "Difficulty balancing course with home and/or work responsibilities" as a reason: 70.9%, 73.4%, and 80.7%. Course difficulty was a distant second-most common reason (20.7%, 17.7%, and 22.4%), followed by lacking the prerequisites to succeed in the course (20.1%, 20.3%, 21.5%). Responses related to course quality did not exceed 20%. Free-response text echoed these sentiments: in one term, 45.7% of free responses mentioned work conflicts, 26.1% mentioned family or personal conflicts, and 23.9% referenced lacking course prerequisites.

Notably, many of the issues cited by students would warrant support by the university, but online students were unaware of these services. This leads to the finding: **mechanisms for communicating available services, accommodations, and prerequisites may not transfer smoothly to the online student body** (Lesson 6). Emerging online programs often emphasize instruction, leaving online students at a disadvantage regarding program information communicated at orientations or advising sessions absent online.

Withdrawal surveys also indicate that online students have fewer disincentives to withdraw. Tuition is lower, so withdrawing costs less money and is more likely to trigger a partial refund. Online students typically work full-time, and so the opportunity cost of spending another term in school is lower. Each course is offered bi- or tri-annually online, while many courses are only offered annually or biennially on-campus; online students thus have more opportunity to retry a dropped course. We call these "strategic withdrawals", and they are related to the finding: **online students are less likely to complete a course in which they enroll even while continuing in the program as a whole** (Lesson 9).

Overall, these trends are likely expected, but their operationalizations and nuances lead to specific lessons: the more inclusive admissions and competing obligations cause online students to struggle more than their on-campus counterparts, as reflected in the occasionally lower grade distributions, and online programs provide structurally fewer incentives to complete a course in a given term, as reflected in the dramatically higher withdrawal rates.

GRADUATION

The first eighteen students graduated in Fall 2015. Since then, graduations have risen every term: 1,640 students have graduated, peaking at 496 graduates in Fall 2018, the most recent term. The on-campus program has graduated 646 students since the online program's first graduating class. If the 70% retention rate holds for matriculated students, those students alone will comprise over 10,000 graduates.

Program Retention

Withdrawal data earlier in this analysis refers to in-semester course withdrawals, but data is not publicly available regarding the amount of program-level, inter-semester attrition. However, these numbers can largely be inferred through the combination of matriculation, enrollment, and graduation data.

Figure 7 shows cumulative matriculations and graduations from the program alongside per-term enrollment. At 100% retention, cumulative matriculation would equal term enrollments plus cumulative graduations. Instead, enrollments and graduations add to ~70% of matriculations, suggesting a 70% retention rate; students deliberately skipping a term, however, would artificially lower this rate, and thus 70% is lower bound. The on-campus program's rate is higher, however, and thus, we find **retention in an online for-credit program at scale may be significantly higher than retention for MOOCs, but lower than for on-campus programs** (Lesson 8). We hypothesize that factors at play include: lower tuition means less to lose by withdrawing; online students have additional competing obligations; and pre-existing expectations about the difficulty of online education may conflict with the reality encountered after enrollment.

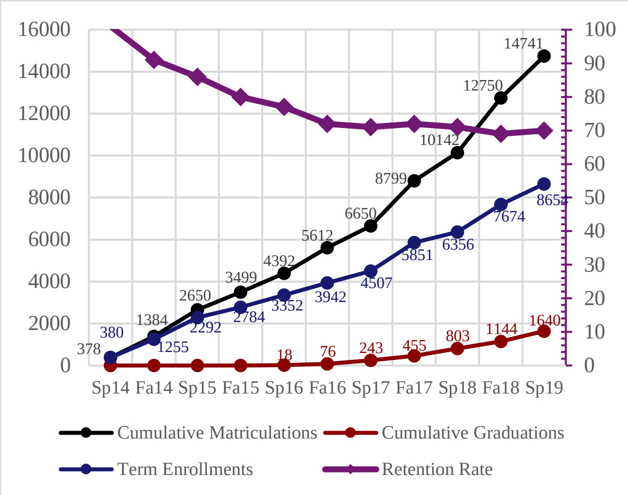

Figure 7. Cumulative matriculations, cumulative graduations, and per-term enrollments for each term since the online program's inception.

Alumni Experience

In January 2019, the program conducted its first alumni survey. The survey focused on three general themes: retrospective impressions of the program; relevance of the program to ongoing career development; and self-perceptions related to program completion. Survey invitations were sent to 1780 alumni at their school email addresses, which can be set up for forwarding after graduation; 308 invitations bounced. 498 alumni completed the survey. Most questions asked alumni to rate agreement on a 1 (Strongly Disagree) to 5 (Strongly Agree) scale.

On perceptions of the program's value, 97% of alumni agreed (4 or 5) the program was worth the investment and 97% agreed they would recommend the program to others; 1% disagreed with each prompt. On the career impact of the program. 83% agreed that the program helped their career, while 3% disagreed. 51% agreed that the program helped them secure a higher salary, while 12% disagreed. The juxtaposition between the ecstatic impression of the program value and the more modest impression of the program's career impact lends further support to a finding from prior research [14]: **many students in this non-traditional program are enrolled for personal benefits rather than career benefits** (Lesson 4). These numbers show the program's value is not tied to its career or salary benefits.

Third, alumni were asked about self-perceptions of their status as alumni. 93% agreed (4 or 5 on a 5-point scale) that they identify as alumni of the university, while 2% disagreed. When asked whether they identify themselves more as graduates of the online program or of the university itself, however, 38% identified more with the program and 22% identified more with the university (40% identified as each equally). This contrasts with the equal accreditation attached to the degrees, and provides the finding: **alumni of equally-accredited online programs may still struggle to feel personally tied to the university rather than the online**

Table 1: Percentage of alumni agreeing or disagreeing with the statement, "I am likely to donate money to _____".

I am likely to donate money to the…	Agree	Neither	Disagree
The Program	32%	44%	24%
The College	25%	45%	30%
The University	22%	42%	36%

program (Lesson 5). This trend was echoed in questions asking alumni their likelihood to donate money to the program's various parent organizations, shown in Table 1.

OPEN CHALLENGES

Prior research on this program has focused on learning within courses and experiments with teaching at scale. However, these opportunities require systems to support a degree program and enrolling students in classes in the first place. To examine this, we discussed non-pedagogical challenges to scale with instructors and staff in the program. Some lessons may be unique to this university, but they provide examples of the kinds of issues others must address.

At the Program Level

Outside instruction, the program is responsible for advising, student support, and admissions. Nearly 25,000 applications have been received in five years, 22% of all graduate applications received by the university in that time. This intersects with an interesting obstacle: while on-campus admissions have minimum requirements, what they *are* is relatively insignificant: capacity limitations dictate that the students accepted far exceed those minimums. If the program's capacity is 200 students, then the best 200 students will be taken regardless of how many more students met the minimum qualifications. With the stated goal of letting in any qualified student, the placement of minimum standards becomes significant. This presents an ongoing challenge, especially among students with non-traditional backgrounds: absent a need to rank and prioritize students, how do you determine who is likely succeed?

Once admitted, many students require academic advising, but maintaining the same advisor-to-student ratio online as exists on campus would require dozens of advisers. To alleviate this, the program adopts a highly pro-active communication style: nearly every week, advisors send out mass emails to students about upcoming deadlines and changing requirements. Thus, when students ask questions in one of the program's various social media areas, there is likely a classmate with the answer. Our early research suggests that this amounts to crowdsourced peer advising.

One requirement that cannot be crowdsourced, however, is grading. For rigor, pedagogy, and accreditation, grading must take place by paid instructors or, more commonly, teaching assistants (TAs) under the direction of paid instructors. Online students applied to serve in the role in massive numbers [14], pivoting the challenge from securing an adequate number of people to onboarding as many as 250 TAs per term. This, however, is still not a trivial challenge, especially as these students are hired and governed by policies designed for on-campus, full-time students.

At the University Level

While this program supports its own admissions, advising, and hiring, other programs may need to interact more closely with the central university for these components. Similarly, this program integrates with existing campus systems regarding student integrity and student advocacy.

Regarding integrity, there exist institute policies that govern cheating and plagiarism cases, and those policies must apply to students in this online program as well. The process is not built for scale, however: it typically involves live meetings between accused parties, professors (not TAs), and institute representatives. Additionally, the program's scale has provided resources to develop more sophisticated tools for discovering violations, leading to more cases. Yet, student rights to due process must be preserved. This program has created streamlined approaches for documenting violations and worked closely with the central office to ensure consistency and comprehensiveness across courses. There is still considerable progress to be made, however.

Student advocacy resides on the other side of a similar issue: the central university advocates on behalf of students suffering medical hardships, family tragedies, and other excused absences. The scale of the program alone presents challenges to this department, further compounded by online students' increased likelihood to need these accommodations due to family illness or localized disasters. This challenge has been addressed through the development of specialized tools for tracking students' needs for exceptions.

These suggestions scratch the surface of the administrative and organizational challenges to supporting learning at scale, and they lead to our final finding: **launching a fully-accredited online program at scale requires integrating with university-level resources and setting up program-level infrastructure beyond course delivery** (Lesson 7), and yet these factors may be forgotten or deprioritized.

LESSONS LEARNED

At time of writing, there are only a handful of active similar programs; however, over 30 similar programs have been announced to begin soon. Thus, the lessons from this research may directly inform the production and launch of new programs, as well as decisions about whether to start such programs. To close, we reiterate the findings from this paper, tying them to lessons for emerging programs. These lessons are grouped into categories: allaying fears about launching such a program; preparing for the unique student body; and anticipating needed policies and resources.

Allaying Fears

Among many universities, there are fears about establishing a program like this one: whether the returns will offset the costs, whether a student body will be available, and whether the program will empower disadvantaged populations.

Lesson 1: Offsetting Startup Costs

Start-up costs for a program like this are high; this program required a multi-million dollar gift to launch. To justify such a cost, it is important to know that a sufficient student body will be present to recoup those expenses. Five years into this program's history, growth has not slowed; the number of applications continues to rise, and the quality of students continues to rise as well. Since this program's inception, 230,473 credit hours have been attempted at $170 per credit hour, representing over 10x the initial gift in tuition received.

Lesson 2: Cannibalizing On-Campus Programs

Some fear that an equivalent and more affordable online program would diminish interest in on-campus programs, undercutting existing revenues. Instead, we found that there is little overlap in the students that are interested in each program; the online program attracts largely students who never could have attended the on-campus program, while the on-campus program attracts students interested in peripheral features absent from the online program. The growth rate of applications to the on-campus program tripled after the launch of the online program. Instructors also note that teaching online improved their on-campus courses and provided resources to expand course offerings.

Lesson 3: Women and Underrepresented Minorities

While concerns have been raised that MOOCs increase inequity as the average student is white, male, and from an affluent country [9][25], the results from this program have been more promising, although there is much progress to be made. The ratio of women in the student body has doubled during the first five years. Early matriculation data indicates that trend will continue and likely match that of the on-campus program within three years. Although this does not solve the gender divide in computer science, it does help allay the fear that online programs will *increase* the divide.

Even more promising evidence exists that an affordable degree at scale can increase access among underrepresented minorities. The online program has had nearly twice as large a relative population of underrepresented students, and when factoring in raw enrollment, more than 10x more such students are receiving access than the on-campus program. So far, 238 degrees have been granted to women and 157 to members of underrepresented minorities.

Preparing for Students

Once a decision is made by a university to pursue a scalable program, this research provides insights into preparations that must be made and issues that must be anticipated.

Lesson 4: Student Motivations

Online learners' motivations are different from on-campus learners, presenting opportunities and challenges. Well-designed online classes put students in a greater position to influence the course and their classmates, but with learning as the primary motivation (rather than a credential), these students are less tolerant of perceived inadequacies even if their grades are unaffected. Professors have reflected they encounter student complaints unlike any they have heard on-campus, and the demographics and professional experience of online students further empower them. Additionally, the large enrollment means that there *are* still many students primarily motivated by earning a credential, so classes cannot be developed *exclusively* for personally-motivated learners; they must be engaging for these learners, while also rigorous and valid for credential-motivated learners.

Lesson 5: Alumni Relations

Alumni of equally-accredited online programs may still struggle to feel personally tied to the university rather than the program. Attending college is about more than learning material and obtaining a degree; an alumna's alma mater becomes part of her personal and professional identity. The physical campus environment likely contributes to this identity, and thus may not inherently be present online. Proactive measures must be taken to help alumni of an online program integrate their status as graduates into their identity.

Lesson 6: Orientation and Student Services

One component of many on-campus programs is an "orientation" phase, where attendance at orientations merges with a general overarching feeling of "newness" to ensure students absorb information. Online, these components are absent unless deliberately offered, and students' lives are largely unchanged relative to before matriculation. Thus, a culture of confusion can emerge. For example, online students receive droves of information via easily-overlooked emailed packets. Effort must be made to ensure online students know of the opportunities available to them.

Lesson 7: Program- and University-Level Infrastructure

Although details vary by university, there are components outside of course delivery that must be created online to be compatible with existing regulations. At Georgia Tech, these include policies regarding student rights in the face of absences or integrity violations, procedures for admissions and advising, and expectations for assessment and feedback. Many policies have been written for on-campus students and are somewhat incompatible with online environments. Early attention must be paid to the demand created on and for university and program-level infrastructures.

Anticipating Policy and Resource Needs

Finally, beyond the community and pedagogy of learning at scale, there are administrative and financial demands to support such a large program. These final lessons provide insights into some of the policies and resources needed for the successful launch and maintenance of such a program.

Lesson 8: Program-Level Retention

Program-level retention has been positive after the much-maligned high drop-out rate of MOOCs: after five years, 70% of all matriculated students are either enrolled or have graduated, significantly higher than MOOC retention rates but lower than on-campus retention rates. Online students are expected to have a larger number of competing demands than on-campus students, as well as less inherent incentive to complete as the monetary investment will have been lower. These effects should be noted in planning. This number also provides a baseline for evaluating other new programs.

Lesson 9: Course-Level Retention

In this program, we found a many students "strategically" withdrawing from individual classes, due to the lower cost of retaking a class or requiring an extra term. Without a physical lecture hall, course capacity may only be constrained by available TAs. However, if resource allocation decisions are made based on enrollment, then unnecessary expenses may be incurred due to the higher withdrawal rate. Resources ought to be allocated in a way that adjusts to withdrawal trends; for example, in this program, TAs are paid at an hourly rate. As enrollment drops, so also does the workload.

This also means online courses are likely to have students who have enrolled, withdrawn, and re-enrolled in a later semester. They may have already taken tests, received grades on assignments, and seen answer keys. This possibility is compounded by the inability to present anything online that is truly transient: students may have saved anything they saw. These risks must be accounted for in course design.

CONCLUSION

In this analysis, we have examined program-level trends in the efforts of a major public research university to deliver graduate-level for-credit learning at scale. Several small findings, along with prior research on this program, point to two significant results: one, that there are significant obstacles to anticipate in developing a program like this, and two, that the potential of scalable degree programs is worth overcoming those obstacles. Future programs ought to anticipate these findings with regard to retention rates, alumni relations, demographic trends, and scaling services, but these obstacles have not threatened the existence and feasibility of graduate-level degrees at scale. The questions now may turn to whether these findings transfer to other subject matter areas besides computer science, to other levels besides the Master's degrees, and to other contexts, including those lacking corporate partners for funding and development and those with differing legislative and institutional infrastructures and priorities.

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