Evaluating an Alternative CS1 for Students with Prior Programming Experience

Michael S. Kirkpatrick
Dept of Computer Science
James Madison University
Harrisonburg, Virginia, USA
kirkpams@jmu.edu

Chris Mayfield
Dept of Computer Science
James Madison University
Harrisonburg, Virginia, USA
mayfiecs@jmu.edu

ABSTRACT

Before Fall 2013, our CS majors were required to take the same 4-credit introductory programming course as part of a two-semester CS1 designed to be welcoming to novices. As CS in K-12 has expanded, the diversity of incoming students' programming backgrounds has increased, raising concerns that the climate was becoming increasingly intimidating for novices. The literature suggests these effects could disproportionately impact retention of female students and other underrepresented minorities, undermining other efforts to broaden participation in computing. To address these concerns, we split the first course based on students' prior programming experience. Using statistical techniques, we analyzed the intermediate quantitative impact of this and other curricular changes. Our results suggest that adding the alternative CS1 course had little effect on retention, but the overall structure has been successful in achieving comparable CS2 outcomes regardless of prior experience.

CCS Concepts

•Social and professional topics → Computer science education;

Keywords

curriculum design, CS1, quantitative analysis, retention, broadening participation, underrepresented minorities

1. INTRODUCTION

For many years, our department has required CS majors to complete an introductory sequence of three courses:

- **CS1: Programming Fundamentals**
  (e.g., decisions, loops, functions, algorithms)
- **CS1.5: Object-Oriented Programming**
  (e.g., class design, inheritance, polymorphism)
- **CS2: Data Structures and Algorithms**
  (e.g., linked lists, balanced trees, hash tables)

SIGCSE '17, March 08 - 11, 2017, Seattle, WA, USA

ACM 978-1-4503-4698-6/17/03…$15.00

DOI: http://dx.doi.org/10.1145/3017680.3017759

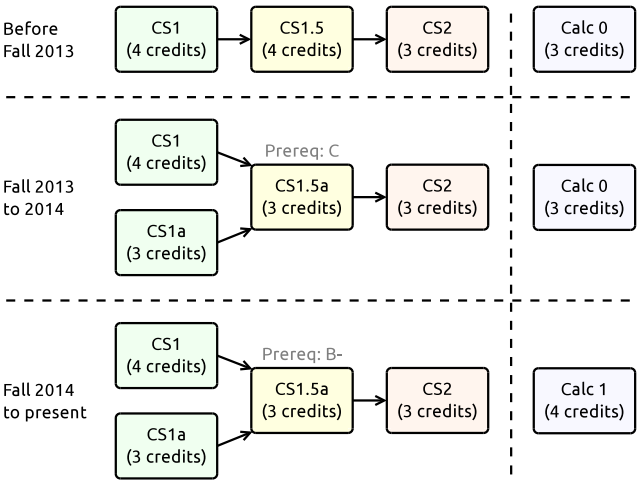


Figure 1: Summary of curriculum changes. We first added an alternative version of CS1 and reduced the credits for CS1.5. The following year, we increased the CS1.5 prerequisite and Calculus requirement.

The first two semesters (both taught in Java) correspond to what the literature denotes as CS1, and the third semester is a typical CS2 course [1, 4]. We also offer a CS0 course (in Python) that does not count towards major or minor requirements. The extended CS1 assumes no prior programming experience while also facilitating deep exploration of the material. In a typical year, one half to two thirds of our incoming CS majors have little or no programming experience. In recent years, though, an increasing number have some non-Java programming experience gained through self-study, classes, robotics competitions, or other extracurricular activities. This background is insufficient for placement directly into CS1.5, but prior research suggests placement into CS1 could have a negative impact on classroom culture and efforts to broaden participation in computing.

For example, students who ask "pseudo questions" to show their knowledge to the instructor and/or peers can create defensive climates that reinforce fixed mindsets detrimental to those without prior experience [6]. Students recognize the presence of "experts" with prior experience as a source of stress, low self-confidence, and intimidation [11]. This recognition affects motivation and personal perception of competence, which correlate with success in introductory programming [2]. In particular, classroom climate and stereotype threat can have a profound effect on retention for underrepresented minorities and women [8]. Recent research suggests

Research Questions:	Hypotheses:
1. Was there a difference in CS1/1a retention between those who took the baseline CS1 and CS1/1a after the split?	1. The split course structure improves retention for students in both CS1 and CS1a, when compared to the baseline CS1 population. *(RQ 1 and 2)*
2. Among those who continued on to CS1.5/1.5a, was there a difference in CS1.5/1.5a retention between those who took the baseline CS1 and CS1/1a after the split?	2. The introduction of the Calculus/B- change contributes to a drop in overall CS1/1a retention and overall CS1.5a retention. *(RQ 3)*
3. Was there a difference in student retention after the other two changes (increasing the CS1.5a prerequisite to a grade of B- in CS1/1a and increasing the Calculus requirement) were introduced?	3. There is no difference in CS1.5 and CS2 grades between CS1 and CS1a students when controlling for their CS1/1a grades. *(RQ 4 and 5)*
4. Was there a difference in CS1.5a grades between those who took CS1 and those who took CS1a, while controlling for their CS1/1a grade?	4. Among students with an AP CS A score of 4, there is a difference in CS1.5/1.5a grade between those who took CS1/1a and those who skipped. *(RQ 6)*
5. Was there a difference in CS2 grades between those who took CS1 and those who took CS1a, while controlling for their grades in CS1/1a and CS1.5a?	5. There is no difference in CS1.5/1.5a or CS2 grade between those who received an AP CS A score of 5 and skipped CS1/1a, compared to those who received a score of 4 and enrolled in CS1/1a. *(RQ 6)*
6. Was there a difference in CS1.5/1.5a grades among those who received either a 4 or 5 on the AP CS A exam, based on whether they chose to retake CS1/1a?	6. The CS1/1a structure improves retention among underrepresented minority and women students. *(RQ 7)*
7. Do the overall trends apply to sub-populations of interest, particularly underrepresented minorities and women?	7. The introduction of the Calculus/B- change had a disproportionate effect on underrepresented minority and women students. *(RQ 7)*

Table 1: Research questions and related hypotheses guiding the design and scope of this study.

countering implicit bias and climate threats are the most significant barriers to women in computing [7].

To address these issues, the faculty introduced a two-track approach to our extended CS1 with the intent of separating students with prior experience from those with little or none. Since Fall 2013, students can take either the original 4-credit version of CS1 or an "accelerated" 3-credit version that we denote as CS1a. Our main reason for adding CS1a to the curriculum was to create a more welcoming environment in CS1 by reducing intimidation and stereotype threat. Overall the content and assessments of these two courses are equivalent; the main difference is that CS1a meets three days per week instead of four. Faculty who serve as advisors help students decide which course to take based primarily on their self-reported experience. However enrollment is open, and students may self-select into either course (or CS0). Students with scores of 4 or 5 on the AP CS A exam enter with credit for CS1; those with a 5 are placed directly into CS1.5, while those with a 4 have the option of repeating CS1a.

This paper presents the results of analyzing ten years of student data, including demographics, course grades and retention, and enrollment in CS and Math courses. Our goal was to determine the intermediate effects of adding CS1a to the curriculum. Studying the impact of CS1a is potentially confounded by three other curriculum changes, summarized in Figure 1. First, we reduced the number of credit hours for CS1.5 by removing a small amount of data structures content that was repeated in CS2; initial analysis suggests this change was minor and is therefore beyond the scope of this paper. Second, we increased the mathematics requirement for CS majors to Calculus 1 (*i.e.,* the first semester course on differential Calculus required for Math majors). Previously, CS majors had the option of completing a less rigorous Calculus 0 course. And third, we increased the prerequisite for CS1.5 so that students would need to earn a B- or higher in CS1 or CS1a. This last decision was based on observations that less than 10% of students who completed the CS degree had a grade below B- in their CS1 course; a substantial number of the "C students" needed to repeat CS1.5 and C2 multiple times. Our analysis includes measures to control for the impact of the Calculus and B- prerequisite changes.

To provide context for the research study and results, Table 2 lists demographic information about our institution.

Institution	Comprehensive public university 19,000 undergraduates 2,000 graduates
Department	18 full-time faculty (all Ph.D.) 600 undergraduates 40 graduates
CS1 Course	Multiple sections per semester 25–30 students per section

Table 2: Institutional Demographics

2. RESEARCH DESIGN

To evaluate the possible effects of the new curriculum structure, we defined a set of research questions and hypotheses focused on student enrollment and outcomes, as summarized in Table 1. As this study focuses on the potential impact of the CS1/1a split, we restrict our focus to CS1/1a, CS1.5/1.5a, and CS2. For each course, we define the **course retention** to include enrollment in *at least one* of the subsequent courses from this group *or* eventual graduation with a CS major or minor from our institution. The CS1/1a retention rate includes students who completed accepted equivalent courses for CS1.5/1.5a and/or CS2 at other institutions en route to completing our CS major/minor requirements; CS1/1a retention also includes students who enrolled in CS1.5/1.5a but withdrew, as their withdrawal is more reflective of their CS1.5/1.5a impressions or later views than it is of their impressions of CS1/1a. Lastly, we define **course attrition** to be lack of enrollment in *all* of the subsequent core courses *and* the absence of graduation with a CS major/minor from our institution.

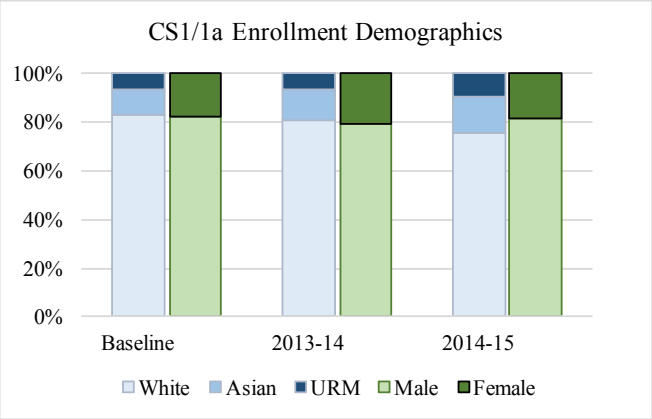


Figure 2: No difference in CS1/1a enrollment demographics occurred during the period of study.

In order to frame the analysis, we partitioned the offerings based on students' *initial* enrollment in CS1/1a.[1] We define our **baseline** population as all students who enrolled in CS1 prior to Fall 2013, which was the semester when the split CS1/1a structure was first offered. In contrast, we refer to the **split** population as students who first enrolled in CS1/1a starting Fall 2013; we omitted students who first enrolled during the 2015-16 academic year, as they have not yet had a chance to complete the introductory sequence. Where relevant to consider the impact of the B-/Calculus requirement change, we will distinguish between the two split population years as the 2013-14 and 2014-15 cohorts.

2.1 Statistical Methods

To answer our research questions, we analyzed historical data provided by our institution for all students who enrolled in CS1 or CS1a between Fall 2006 and Spring 2015. Retention rates between various sub-populations were compared using χ^2 tests of independence; except where noted, all χ^2 results were based on $df = 1$. To consider whether the CS1/1a split had an impact on grades in later courses, multiple linear regression was performed with backward elimination according to p-values to determinally statistically significant factors; after each potential model, the non-significant ($p > 0.05$) factor with the highest p-value was removed until only significant factors remained. T-tests were used to compare the CS1.5/1.5a grades for students who received either a 4 or 5 on the AP CS A exam.

This study was conducted with approval from our Institutional Review Board (IRB). To protect the privacy of student records, all data were anonymized prior to access and stored in an encrypted volume when not in use.

3. RESULTS

The anonymized data for this study consisted of 1056 students in the baseline population (first enrolled in CS1 prior to Fall 2013), 397 students who first enrolled in the split CS1, and 106 students who first enrolled in CS1a. Figure 2 shows the demographic proportions of students enrolled in CS1/1a during the time period studied. **Underrepresented minority** (URM) is defined to include all non-white, non-Asian races, based on official data from the university. No statistically significant difference in proportion was found either by race ($p = 0.07$) or by gender ($p = 0.63$).

[1]We suspect students' affective perceptions (*e.g.,* their sense of belonging) were more likely to be shaped by their initial enrollment impressions than their latter; whether or not this is the case is beyond the scope of this paper.

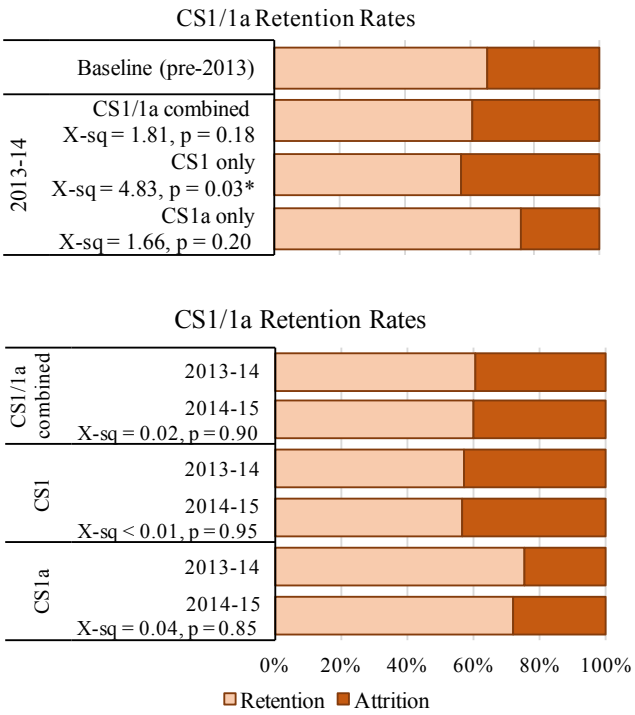


Figure 3: No effect on overall CS1/1a retention after the split or the introduction of the B- prerequisite in CS1.5. In all figures, * denotes significance at $p < 0.05$, ** for $p < 0.01$ and * for $p < 0.001$.**

3.1 Effects on Retention Rates

The baseline population had a 65.5% retention rate for CS1. Figure 3 shows a statistically significant drop (57.1%) in retention among the CS1 sub-population in the year after introducing the CS1/1a split, but the overall CS1/1a retention had no difference. The figure also shows that the retention in CS1 and CS1a remained consistent after introducing the B- prerequisite to CS1.5a and the increased Calculus requirement. Thus, the general interpretation is that *there was no difference in overall CS1/1a retention due to either the CS1/1a split or the Calculus/B- change.*

Among those who continued on to CS1.5 in the baseline, the retention rate was 77.4%. Figure 4 shows the CS1.5/1.5a retention was unchanged in the first year after the CS1/1a split. There was no difference in CS1.5/1.5a retention in the first year after introducing the CS1/1a split. However, there was a significant drop after the introduction of the Calculus change, particularly among CS1 self-selectees. Thus, while *the split curriculum itself had no effect on CS1.5/1.5a retention, there was a significant drop in CS1.5 retention after introducing the Calculus/B- change.* However, confounding factors described in Section 3.4 suggest this may be correlation and is not causal.

3.2 Effects on CS1.5, CS2 Grades

For both CS1.5 and CS2, we used multiple linear regression with an initial set of potential significant predictors under investigation. For both courses, this initial set of potential factors included of a boolean (CS1) indicating enrollment in CS1 or CS1a, the highest grade earned in the

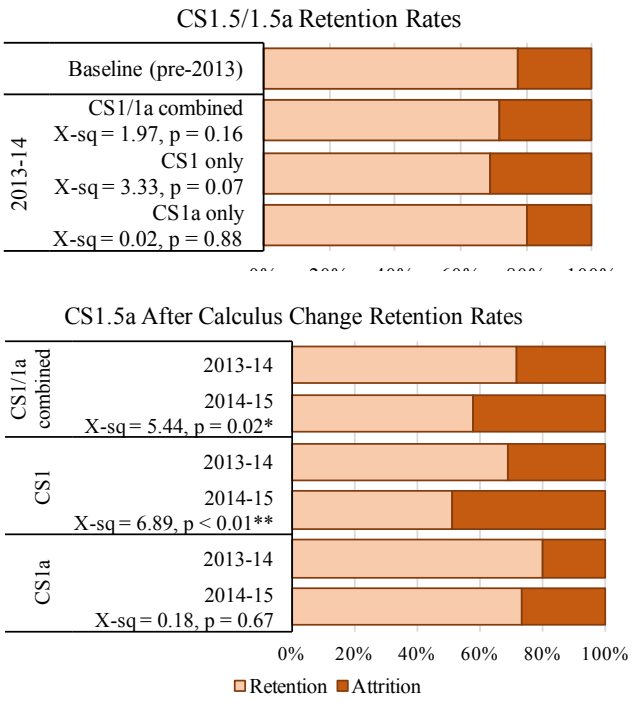


Figure 4: CS1.5 retention did not drop after the split, but did after the Calculus change.

first course (CS1X Grade), and the number of attempts for the first course (CS1X Attempts); the latter factor was used to consider whether students who repeated the course improved their mastery of the material to the same level as their peers. For CS2, the initial set also included the number of attempts and highest grade for CS1.5a.[2]

Table 3 shows the final models for CS1.5 and CS2 grades. Q-Q plots of the residuals showed a nearly normal distribution in both cases, although the residuals for the CS2 grade model included a very slight left skew. Given this skew and the modest adjusted R^2 values (0.2552 and 0.2021), Table 4 summarizes Spearman's rank coefficients that were used to confirm the findings of the regression analysis.

The key observation from these models and calculations is the change in significant factors from the CS1.5a model to the CS2 model. All else held equal, the model predicts a CS1 student would receive a CS1.5a grade that was, on average, approximately a third of a letter grade (0.319) lower than an equivalent CS1a student. The Spearman's calculation also found a small but statistically significant effect size on CS1.5a grades based on the student's enrollment in CS1 vs. CS1a. However, the CS1 boolean is no longer a significant factor in the CS2 model; the only factor that showed significance in the CS2 grade model was the student's CS1.5a grade. The Spearman's calculation also supports this conclusion, give the large p-value (0.489) for the CS1 boolean factor. Thus, *there is a difference in average*

[2]The reader may recall from Section 3.1 that there was a statistically significant difference in CS1.5 retention between the 2013-14 and 2014-15 cohorts. This difference suggests a combined model would be invalid. As this objection is valid, we also repeated the regression analysis on the two cohorts independently and produced comparable models (omitted to avoid redundancy) whose significant factors were identical to those presented here.

CS1.5 Grade				
Factor	Est.	SE	t value	Pr(>|t|)
(Intercept)	0.745	0.436	1.708	0.089 .
CS1/1a	-0.319	0.126	-2.525	0.012 *
CS1X Grade	0.834	0.096	8.685	< 4e-16 ***
CS1X Attempts	-0.600	0.224	-2.675	0.008 **
Residual standard error: 0.917 on 270 degrees of freedom				
Multiple R-squared: 0.2633, Adjusted R-squared: 0.2552				
F-statistic: 32.17 on 3 and 270 DF, p-value: < 2.2e-16				

CS2 Grade				
Factor	Est.	SE	t value	Pr(>|t|)
(Intercept)	1.187	0.234	5.079	< 1e-06 ***
CS1.5 Grade	0.512	0.075	6.788	< 2e-10 ***
Residual standard error: 0.723 on 177 degrees of freedom				
Multiple R-squared: 0.2066, Adjusted R-squared: 0.2021				
F-statistic: 46.08 on 1 and 177 DF, p-value: 1.651e-10				

Table 3: Multiple linear regression models of CS1.5 and CS2 grades.

CS1.5 grade factor	Spearman's rank coefficient
CS1	$\rho = -0.158, p = 0.009$ **
CS1/1a Grade	$\rho = 0.492, p < 3e\text{-}16$ ***
CS1/1a Attempts	$\rho = -0.182, p = 0.002$ **
CS2 grade factor	
CS1	$\rho = 0.052, p = 0.489$
CS1.5a Grade	$\rho = 0.467, p < 5e\text{-}11$ ***

Table 4: Spearman's rank coefficients provide additional evidence for the significant factors in the CS1.5 and CS2 grade regression models.

predicted CS1.5a grades for CS1 and CS1a students, but the difference disappears among students that persist to CS2.

3.3 Effect of skipping CS1 based on AP credit

To provide guidance about placement into CS1/1a, we used T-tests to compare the mean CS1.5/1.5a and CS2 grades for students who received CS1 credit for earning a score of 4 or 5. Table 5 shows the results. Given the small numbers of students with these scores, the data for all years was combined. The key observation here is that there is a statistically significant average CS1.5/1.5a grade difference between students who elect to skip CS1/1a with a score of 4 compared with those who scored a 5; however, the difference is no longer significant with the students who scored a 4 and elected to take CS1/1a despite already having credit. There were no statistically significant differences among the CS2 grades. Although the results are not strongly conclusive, *the evidence seems to suggest that retaking CS1/1a is beneficial for students with a score of 4 on the AP CS A exam.*

3.4 Impact on Underrepresented Students

To evaluate the potential impact of these curricular changes on underrepresented minority and women students, χ^2 tests were performed on data about these sub-populations as in previous analyses.[3] Figure 5 shows the results for comparing the CS1/1a retention rates among the sub-populations after introducing the CS1/1a split and the Calculus/B- change. In all cases, the p-value was very large, indicating *there was no evidence of a difference in the sub-population retention*

[3]Given small population sizes, only results with exact p-values are presented.

Course	Mean Samples	Result
CS1.5/1.5a	AP 5, $\mu = 3.4$ AP 4 (skip), $\mu = 2.8$	$t = 2.4, df = 56.2$ $p = 0.02$ *
CS1.5/1.5a	AP 5, $\mu = 3.4$ AP 4 (no skip), $\mu = 3.0$	$t = 1.9, df = 53.9$ $p = 0.06$
CS1.5/1.5a	AP 4 (skip), $\mu = 2.8$ AP 4 (no skip), $\mu = 3.0$	$t = -0.7, df = 55.2$ $p = 0.47$
CS2	AP 5, $\mu = 2.7$ AP 4 (skip), $\mu = 2.2$	$t = 1.6, df = 44.6$ $p = 0.12$
CS2	AP 5, $\mu = 2.7$ AP 4 (no skip), $\mu = 2.7$	$t = 0.2, df = 39.0$ $p = 0.82$
CS2	AP 4 (skip), $\mu = 2.2$ AP 4 (no skip), $\mu = 2.7$	$t = -1.5, df = 42.2$ $p = 0.15$

Table 5: Comparisons of CS1.5/1.5a and CS2 grades based on AP scores of 4 or 5. Both scores earn CS1/1a credit, but students with a 4 have the option to skip or repeat the class.

after introducing the split or by increasing the CS1.5 prerequisite to a grade of B- or better in CS1/1a.

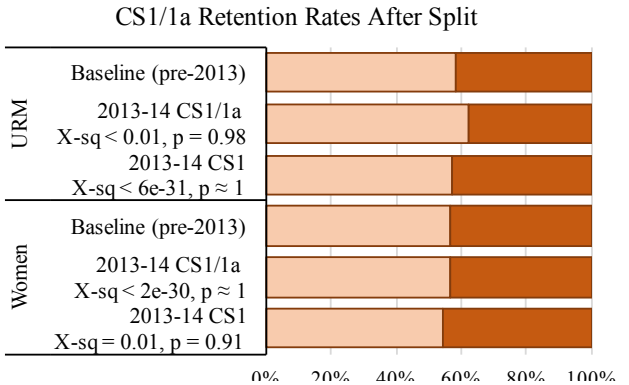
Figure 6 compares the CS1.5 retention after introducing the additional Calculus requirement, which was enforced as a prerequisite to CS2. This data shows there was no effect on CS1.5 retention for underrepresented minority students. This figure shows that, among women, there was no change in CS1.5 retention after switching to the split CS1/1a, but there was after introducing the Calculus change. (The men's data are shown for reference; the change among men was not statistically significant.) Despite these χ^2 results, further analysis suggests this drop may be simply correlational and not causal. Specifically, the number of W, D, and F grades for CS1.5 more than doubled from 2013-14 to 2014-15. However, due to privacy concerns and lack of statistical power resulting from small sample sizes, no precise results can be presented. Instead, the claim is made that, at this time, *hypothesis 7 is rejected in its entirety for both women and underrepresented minority students, though the possibility of an effect of the Calculus change on women warrants further observation.*

Table 6 summarizes the conclusions regarding the hypotheses stated in Table 1.

4. DISCUSSION AND CONCLUSIONS

Before interpreting these results in a broader sense, it is important to reiterate the context of this study. Our CS1-CS1.5 sequence is different from many other alternative introductory course approaches, such as media computation [9], themed CS0 courses [3], CS0.5 [10], or a CS0 for majors [5]. For instance, these approaches often employ a language like Python to reduce the syntactical overhead of the first course; our CS1-CS1.5 sequence uses Java in both semesters for in-depth exploration. Comparing our course sequence with these others is beyond the scope of this paper.

Given this context, our findings should not be interpreted as an evaluation of that structure on its own. Rather, the current study focused on examining the potential impact of separating the first semester CS1 course based on students' prior programming experience, typically with non-Java languages. Specifically, we were concerned the presence of students with prior experience contributed to a stressful environment for students with no background in any language. In the process of evaluating this change, we were also able to gain greater insight into subtle aspects of our program



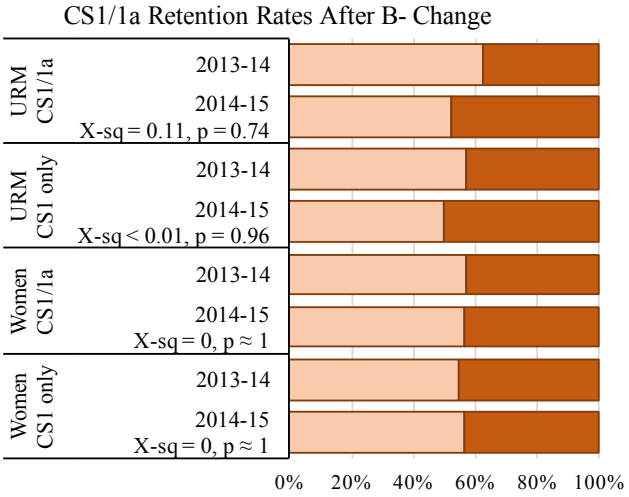


Figure 5: No evidence of change in CS1/1a retention of underrepresented minorities (URM) and women after introducing the split and B- prerequisite for CS1.5.

that we have not previously explored. Given that context, we would summarize our findings as follows:

- There is no evidence that splitting the first semester into CS1/1a had an effect on retention out of this course. This finding extends to sub-populations of underrepresented minorities and women.
- There is no evidence that increasing the CS1.5 prerequisite to a grade of B- in CS1/1a adversely affected retention. *This finding also extends to sub-populations of underrepresented minorities and women.*
- There is evidence that CS1 students earn a lower grade in CS1.5 than their peers who took CS1a, all else (including CS1/1a grades and attempts) held equal. However, this grade difference disappears by the time the students reach CS2. *This finding suggests the extended CS1-CS1.5 sequence in any form provides a structure that allows students with less or no (self-identified) programming experience catch up by the third semester.*
- There is strong evidence that students who earn a 4 on the AP CS A exam and skip CS1/1a earn a significantly lower CS1.5 grade (2/3 of a letter) than students earned a 5, on average; however, there is insufficient evidence of any other difference based on AP CS A exam score. Consequently, the evidence suggests that the primary benefit for students with a 4 and repeat

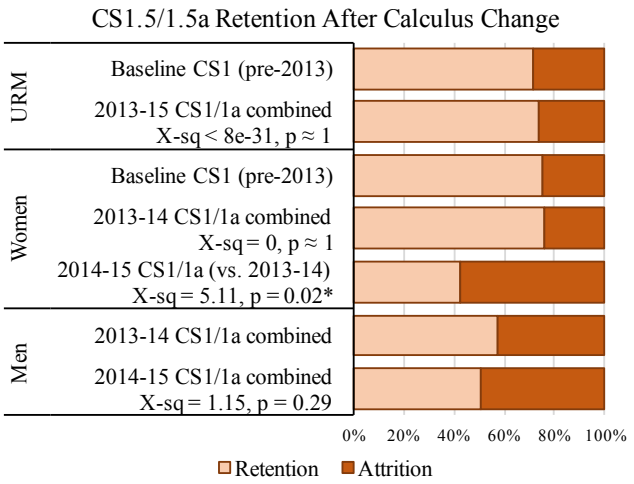


Figure 6: With the exception of the drop in women after increasing the Calculus requirements, there was no evidence of a change in CS1.5 retention among URM or women students. Confounding factors, however, make the drop in women inconclusive.

CS1a is an improved cumulative GPA; more study is needed to determine if their CS2 performance is influenced.

- There is no evidence the split CS1/1a structure had an effect on improving underrepresented minority or women retention, regardless of whether they took CS1 or CS1a, given the two-semester CS1-CS1.5 sequence.
- There was a statistically significant drop in CS1.5 retention for women after increasing the Calculus requirement (enforced as a prerequisite to CS2); there is no evidence that the men also experience a similar drop. However, the presence of a strong confounding factor (the change in the numbers of W, D, and F grades) reduces the impact of this result. Consequently, it is inconclusive whether requiring a full Calc 1 instead of the less rigorous Calc 0 had a disproportionate effect on women. There was no evidence of an effect in retention among underrepresented minority students.

In conclusion, we find that the overall two-semester CS1-CS1.5 sequence is successful in allowing students with little or no programming experience to catch up to their peers with prior experience by the time they reach CS2, which is important for broadening participation in computing, but the current findings suggest there is no additional benefit by splitting the first semester course into separate offerings based on prior experience to a programming language other than Java. Furthermore, we find that this structure makes it possible to increase the CS1.5 prerequisite as a means of enrollment management without having a disproportionate effect on women and underrepresented minority sub-populations.

Hypothesis	Finding
1 (CS1/1a improves CS1/1a retention)	Rejected
2 (Calculus/B- dropped CS1/1a retention)	Rejected
2 (Calculus/B- dropped CS1.5a retention)	Supported
3 (No difference in CS1.5a grade)	Rejected
3 (No difference in CS2 grade)	Supported
4 (AP 4 with skip CS1 lowers CS1.5 grade)	Supported
4 (AP 4 with skip CS1 not lower CS2 grade)	Supported
5 (AP 4 with no skip not lower CS1.5 grade)	Supported
5 (AP 4 with no skip not lower CS2 grade)	Supported
6 (CS1/1a improves women/URM retention)	Rejected
7 (Calculus/B- disproportionate to URM)	Rejected
7 (Calculus/B- disproportionate to women)	Inconclusive

Table 6: Summary of hypothesis evaluations

5. REFERENCES

[1] S. Davies, J. A. Polack-Wahl, and K. Anewalt. A Snapshot of Current Practices in Teaching the Introductory Programming Sequence. In *Proceedings of the 42nd ACM Technical Symposium on Computer Science Education*, SIGCSE, 2011.

[2] A. J. Gomes, A. N. Santos, and A. J. Mendes. A Study on Students' Behaviours and Attitudes Towards Learning to Program. In *Proceedings of the 17th ACM Annual Conference on Innovation and Technology in Computer Science Education*, ITiCSE, 2012.

[3] M. Haungs, C. Clark, J. Clements, and D. Janzen. Improving First-year Success and Retention Through Interest-based CS0 Courses. In *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education*, SIGCSE, 2012.

[4] M. Hertz. What Do "CS1" and "CS2" Mean?: Investigating Differences in the Early Courses. In *Proceedings of the 41st ACM Technical Symposium on Computer Science Education*, SIGCSE, 2010.

[5] C. Marling and D. Juedes. CS0 for Computer Science Majors at Ohio University. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education*, SIGCSE, 2016.

[6] L. Murphy and L. Thomas. Dangers of a Fixed Mindset: Implications of Self-theories Research for Computer Science Education. In *Proceedings of the 13th Annual Conference on Innovation and Technology in Computer Science Education*, ITiCSE, 2008.

[7] E. Patitsas, M. Craig, and S. Easterbrook. A Historical Examination of the Social Factors Affecting Female Participation in Computing. In *Proceedings of the 2014 Conference on Innovation & Technology in Computer Science Education*, ITiCSE, 2014.

[8] J. Peckham, L. L. Harlow, D. A. Stuart, B. Silver, H. Mederer, and P. D. Stephenson. Broadening Participation in Computing: Issues and Challenges. In *Proceedings of the 12th Annual SIGCSE Conference on Innovation and Technology in Computer Science Education*, ITiCSE, 2007.

[9] L. Rich, H. Perry, and M. Guzdial. A CS1 Course Designed to Address Interests of Women. In *Proceedings of the 35th SIGCSE Technical Symposium on Computer Science Education*, SIGCSE, 2004.

[10] R. H. Sloan and P. Troy. CS 0.5: A Better Approach to Introductory Computer Science for Majors. In *Proceedings of the 39th SIGCSE Technical Symposium on Computer Science Education*, SIGCSE, 2008.

[11] A. Tafliovich, J. Campbell, and A. Petersen. A Student Perspective on Prior Experience in CS1. In *Proceeding of the 44th ACM Technical Symposium on Computer Science Education*, SIGCSE, 2013.