A Comparison of Flipped Programming Classroom Models – Results by Gender and Major

Benjamin Tyler and Aigerim Yessenbayeva
Department of Computer Science
Nazarbayev University
Astana, Kazakhstan
{btyler, aigerim.yessenbayeva}@nu.edu.kz

***Abstract*— This Innovative Practice Work in Progress Paper presents our findings when analyzing the results from flipping introductory programming courses over the course of several years, and comparing the performance of students of different genders and majors. As part of this study, we investigate the impact of making modifications to these courses over time, including changing the nature of lab assessments and in-class contact time with the students. Our main motivations of this study were to determine (a) which modes of instruction resulted in better student performance overall, (b) which changes in the courses may have impacted males and females differently, and (c) if changes in the courses impacted students of different majors differently.**

In our study, we did not find any significant differences in student performance between pre-flipped and flipped modes. Furthermore, we found that performance trends were mostly consistent between females and males for any given major. However, we did find that males generally did better overall in the programming fundamentals course, though there is a moderate positive correlation between the percentage of females in that course with their performance. Neither gender did consistently better than the other in the follow-on data structures course, however.

Keywords—Flipped classroom; blended learning; Central Asia; Kazakhstan; Computer Science; Programming

I. Introduction

In an effort to facilitate student learning, alternative modes of instruction that leverage technology have been investigated and employed in the classroom. Three years ago, we began our transition from a standard lecture/lab approach for teaching introductory programming courses, to one that uses the flipped classroom model [1, 2, 3]. In our flipped classroom approach, students are provided with online course materials in the form of video lectures, exercises, and practice quizzes that they are expected to watch and do outside of class. In-class time is mostly spent on activities such as lab assignments and regular quizzes. Students can also get direct help from the instructor and TAs during regularly scheduled labs, recitations, and office hours. These courses are not self-paced, however, and students are required to keep to the schedule of course topics and exercises.

While we have initially found the use of the flipped classroom to be beneficial in terms of student engagement and performance on average [4], we wanted to know if this was consistent across different genders and majors. Furthermore, we wanted to investigate if the changes that we have made to course delivery over time has had an impact on student performance. Our work may also be of interest to those looking into differences due to culture, given that we are working in the context of a relatively new, Western-style university in Central Asia.

In this paper, we present how we have used the flipped classroom in our courses, and how our approach has evolved over time. We then provide the findings from our study on the comparative performance between the different genders and majors taking these courses. In the following section, we discuss the courses and motivation behind our using the flipped classroom approach, and in Section III, we briefly cover related work. In Section IV, we describe the different approaches to flipping we have used. Results of our study are presented in Section V, and we conclude with Section VI.

II. Background

A. About the University

Nazarbayev University was launched in 2010 as the premier research university for Kazakhstan. The admissions are highly competitive, and the language of instruction is in English, which is usually the third language of our students (Kazakh and Russian being the first two). The faculty are from more than 50 different countries. The university has been granted autonomous status by the government to develop its own academic procedures and curricula in line with best international practices. The university has partnered with six of the top thirty universities in the world, and is currently undergoing institutional evaluation by the European University Association (EUA).

B. The Courses and the Decision to Flip

We began offering our two introductory programming courses in Fall semester of 2012, primarily for CS and Robotics students, using a traditional lecture/lab approach. Over time, however, other departments in the sciences have begun requiring their majors to take one or both courses. Enrollment numbers can be seen in Table I. The courses are:

- *CSCI 151: Programming for Scientists and Engineers*. An introductory programming course intended for majors in the sciences using the C language. Topics include types, variables, control structures, functions, structures and

978-1-5386-1174-6/18/$31.00 ©2018 IEEE

arrays, pointers, memory allocation, and basic sorting algorithms.

- *CSCI 152: Performance and Data Struct*ures. The follow-on course to CSCI 151 focuses on abstract data types and their implementations, as well as object-oriented concepts. Binary search trees, hash tables, and algorithmic analysis are also topics of discussion. The course was initially taught in C++, but was changed to Java before we flipped the course.

We found that for these courses, students benefited the most from doing hands-on work, and practicing their programming skills in the lab. While in-class lectures were necessary to present the primary course material, students mentioned (informally, and through course evaluations) that lectures had less of an impact on their understanding of the material. Since we were spending most of the allotted class time on lectures, and much less on hands-on work, we investigated the use of alternative modes of instruction to maximize the way we use class time.

During the 2014-15 academic year, we decided on using the flipped classroom approach for both courses, where all lecture materials would be online, and class time would be devoted to hands-on work and student evaluation. We went ahead and flipped both courses during the Spring 2015 semester, creating screen-captured video lessons and narrated demonstrations outside of class. (We did not record lectures as they would be given in the classroom.) A single "lesson" generally consisted of about 6 separate video clips of about 3 to 5 minutes each, where each clip covered a subtopic for the lesson.

Benefits that we have seen from this approach include:

- More opportunities to work with students individually in class, as they work through lab exercises.
- Allows us to cover course material in more depth, since we are not constrained by in-class time limitations (although we still try to be concise.)
- Allows students to rewind and replay videos if they did not fully understand the concepts the first time. This is very helpful, given that our students are not native English-speakers.
- Allows for a more uniform presentation and delivery of the course material. This is quite useful, given that we would usually have multiple sections of the course with different instructors. This factor has only become more important as enrollment sizes for these courses have significantly grown over time.

TABLE I STUDENT ENROLLMENT IN CSCI 151 AND 152 BY MAJOR

	2012-13		**2013-14**		**2014-15**		**2015-16**		**2016-17**		**2017-18**	
	151	**152**	**151**	**152**	**151**	**152**	**151**	**152**	**151**	**152**	**151**	**152**
CS	39	61	41	45	52	54	56	61	82	95	92	108
Robotics	29	3	33	8	27	24	35	43	34	39	30	39
Mathematics	26	5	59	12	35	3	72	16	104	65	60	75
Physics	2		9		14	1	10	5	19	16	14	15
Biology					4		3	2	89	3	114	2
Chemistry							27	1	22	2	30	1
Hum/Soc Sc	15	3	6	3	3	1	10	3	18	3	28	7
Undec/Other			1					1	24	3	18	6
Total	**111**	**72**	**149**	**68**	**135**	**83**	**213**	**132**	**392**	**226**	**386**	**253**

III. RELATED WORK

Regarding gender in the CS classroom, Alvarado and Cao [5] present their own survey to evaluate whether there is some difference in behavior between female and male students. While they note that student performance in terms of grades between genders is essentially the same, the perceived level of ability for females is lower than for males in CS courses. Alvarado and Cao's further experiments determined that gender balance in the class could make female students feel more confident, however. They also noticed that males have more prior experience in CS before university than females.

Similarly, Orr, Swafford, Hahler and Hall [6] reported that in Engineering, males have more confidence than females in hands-on coursework. Krieger, Allen and Rawn [7] found that females do less tinkering with hardware, and assumed the same for software. They also mention that females often perform better in theoretical questions, while males often perform better on more application-oriented problems.

Fokum and Coore [8] noted that females in developing countries such as those in the Caribbean tend to have the same level of interest in CS as males, which differs from what is statistically seen in the US and Western Europe. They also noted that females would often perform better than males in programming courses. Sax and Jehman [9] noted that introductory CS courses are more likely to be taken by females in non-CS majors, while the amount of the males significantly exceed the number of females among CS majors.

A comprehensive overview of the flipped classroom model can be found in the survey by Bishop and Verleger [10], which also examines its underlying pedagogical theories. Another survey by Giannakos, Krogstie and Chrisochoides [11] provides an evaluation of the flipped classroom, and concludes that student engagement and performance are improved, although students do need to adapt to the new approach. Maher, et al. [12] specifically look at how the flipped classroom model can be applied to programming classes, and they found that students overall had a positive perception of the experience.

In an ongoing study, Lee and Lee [13] are investigating the impacts of using the flipped classroom in programming courses in Asia. Currently, they have noticed an increase in student participation. Hayashi, et al. [14] used the flipped classroom in Japan in their two introductory programming courses, and found that students' performance improved and the students expressed more confidence.

IV. EVOLUTION OF OUR FLIPPED APPROACH

Over the past three years, we have had to adjust our approach to how we conduct the CSCI 151 and 152 courses, in part due to limitations of faculty and classroom/lab availability. In our study, we are looking at how these changes may have impacted relative student performance, and break things down by gender and major to look for possible trends and differences. Here, we present a brief description of the five different approaches we have used in delivering these courses since their inception.

A. Mode 0: Pre-flipped (Fall 2012 to Fall 2014)

Initially, we used a fairly traditional lecture/lab approach in teaching CSCI 151 and 152. Given the smaller class sizes then, all class time was spent in our two lab classrooms which could accommodate up to 32 students each. A typical 50-minute class session would start with a 30-minute lecture with coding demonstrations by the instructor. The remaining 20 minutes was spent on students doing in-class exercises on the lab computers, alone or in pairs, which would need to be submitted later in the day. We would occasionally have scheduled quizzes in the labs. Students' grades were based on exams and (out-of-class) programming assignments, along with the quizzes and lab exercises.

B. Mode 1 – Moodle-Based Hosting (Spring – Summer 2015)

In our first flipped iteration, the video clips and other lesson materials were created and uploaded to Moodle, the course management system used by the university. Students were expected to go through the required lesson materials outside of class before coming to scheduled labs. Classes met two or three times a week in the lab, for a total of 150 minutes a week. As before, students would work on lab exercises during class, but now, they would have more opportunities to get assistance from TAs and instructors. During that Spring semester, student feedback and performance was very positive, so we decided to continue and further refine our approach.

C. Mode 2 – Using WordPress (Fall 2015 – Summer 2016)

Despite the initial positive feedback from our flipped courses, we found the Moodle interface to be inconvenient for both students and faculty. We soon decided to migrate our course materials to externally hosted WordPress (https://wordpress.com/) webpages, and upload the videos to YouTube (https://www.youtube.com/). The actual structure of the course did not change much from the previous iteration, where students spent all of their class time in the computer labs, mostly working on assigned exercises.

D. Mode 3 – Limited Labs + Summary Lectures + Recitations (Fall 2016 – Summer 2017)

Due to the sudden growth in class sizes, while not having additional labs available for use, we had to restructure the format of the CSCI 151 and 152 courses in Fall 2016. Specifically, we had to limit lab time for students to a single hour-and-a-half session each week. To offset the loss in contact hours, we added two lecture periods a week, one which was used to give a summary of the online material covered in the past week, and the other to act as a recitation section where students could ask questions. One serious issue that we encountered is that students would approach lecture sessions as a substitute for the online lesson materials, and would then not do the online work, which resulted in poor performance.

E. Mode 4 – Limited Labs + Recitations (Fall 2017 – Spring 2018)

To prevent students from relying on the summary lectures, we eliminated the summary lecture sessions starting Fall 2017. Furthermore, during the recitations, we would consciously not spend time summarizing course content, and made their attendance optional. In this way, students would have no other option but to go through the online materials to receive the course content.

V. Results

For our study, we examined the final grades of all students who have completed CSCI 151 and 152 from the beginning in Fall 2012 to Spring 2018, and classified each student based on major and gender. The enrollment breakdown per instructional mode can be seen in the following table.

TABLE II Mode Course Enrollments by Gender and Major

	Instructional Mode / Course									
	0		1		2		3		4	
	151	152	151	152	151	152	151	152	151	152
CS										
female	30	24	4	18	13	15	19	23	26	26
male	95	82	3	36	43	46	63	72	66	70
Robotics										
female	7	3	3	8	8	7	13	11	6	5
male	66	8	13	16	27	36	21	28	24	29
Mathematics										
female	52	5	10	1	43	4	69	40	37	35
male	51	12	7	2	29	12	35	25	23	16
Physics										
female	4				1		5	3	6	3
male	15		6	1	9	5	14	13	8	9
Biology										
female					1	1	62	1	88	
male	3		1		2	1	27	2	26	1
Chemistry										
female					9		11		22	
male					18	1	11	2	8	
Hum/Soc Sc										
female	8	3	1		9	1	8	2	14	3
male	14	3	1	1	1	2	10	1	14	1
Undec/Other										
female							15		12	2
male	1					1	9	3	6	1

In the following analysis, we calculated the difference between students' final grades (based on a standard 4.0 scale) and the average grade for the given class in which they were enrolled. We did this to minimize variance due to using different evaluation tools and criteria for the different classes.

The following figure (Fig. 1) shows the relative performance between females and males, irrespective of major, for the different course modes.

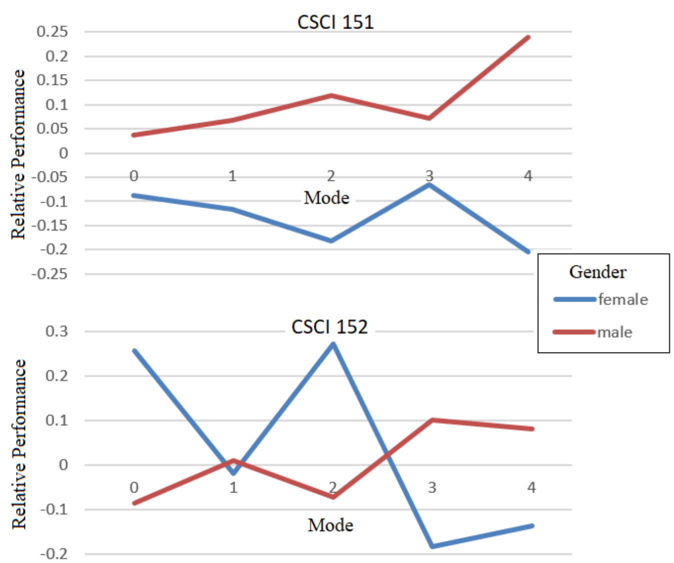

Fig. 1. Relative Performance – All Majors

Here, we see that in CSCI 151, the performance of males is consistently better on average, before (Mode 0) and after (Modes 1 - 4) flipping. The situation is different in CSCI 152, where relative performance of the two gender groups fluctuates from mode to mode. It is interesting to note that Modes 0 and 2 both had a lecture component to the course – which are the cases where females outperformed males in CSCI 152.

Other possible explanations for the differences between CSCI 151 and 152 can be seen from Table II. Note that there is a significant number of Biology students (a majority of whom are female) taking CSCI 151 in later semesters, but not CSCI 152. Also, Mathematics students (whose numbers are also significant) did not start taking CSCI 152 as a requirement until later, as seen in Modes 3 and 4.

To get a better idea of trending for individual majors, we chose the three majors who have had significant enrollments in both CSCI 151 and 152 from the beginning, CS, Robotics, and Mathematics, and compared their relative performance in Figure 2 below.

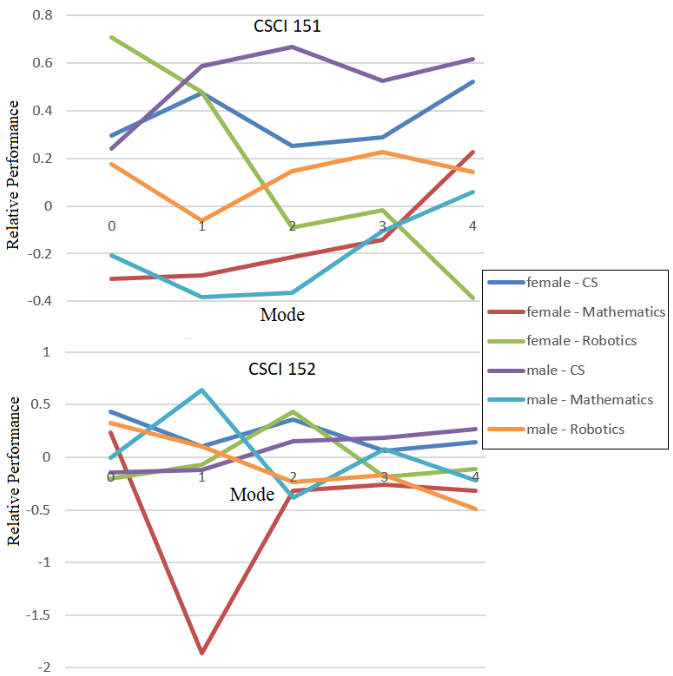

Fig. 2. Relative Performance between CS, Robotics, and Mathematics

What is interesting to see here for CSCI 151 is that a student's major tends to have a greater impact on relative performance rather than gender, and that females and males for each major often follow similar trending. The main exception is female Roboticists, whose relative performance has steadily declined. Note in Table II their relatively low numbers in comparison to the other groups. In CSCI 152, it is interesting to see a sort of leveling-off of all six groups of students after Mode 2, though this may be due to fewer students in other majors impacting the average course grades, in comparison to CSCI 151.

Finally, we wanted to see if the overall percentage of females enrolled in each of the courses impacted their relative performance, irrespective of major. In Figure 3, each point represents the CSCI 151 or 152 course offering for a single semester, and the labels to the left of the points give their instructional mode for that semester.

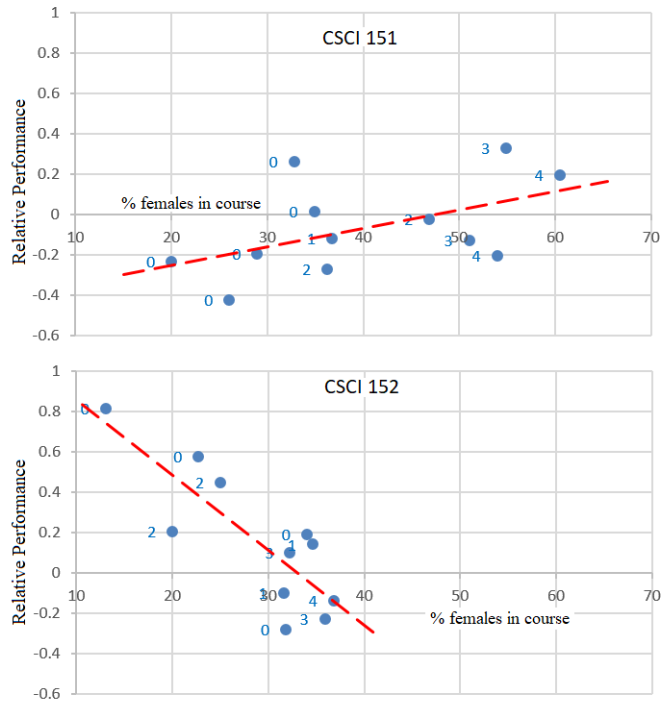

Fig. 3. Average Relative Performance of Females for each Course Offering

The results for CSCI 151 shows a moderate positive correlation between the percentage of females in a course, and their relative performance, with a coefficient of +0.517; this is consistent with expectations. Note that CSCI 151 tends to have much better gender balance, and the students are more heterogeneous in terms of majors in comparison to CSCI 152.

However, the more striking result in Figure 3 is for CSCI 152, which shows a strong *negative* correlation between percentage of females and their relative performance, with a coefficient of -0.823. Note, however, that the percentages of females in CSCI 152 tend to be much lower than those in CSCI 151. Furthermore, the Mode 3 and 4 instances of CSCI 152 which are near the lower right of the trend line have significantly more non-CS females compared to CS females.

VI. Conclusion

While our results are preliminary, it appears that transitioning to the flipped classroom model did not significantly change the relative performance between males and females, regardless of major. We did see that although males did relatively better in the introductory CSCI 151 course, neither group did consistently better in the follow-on data structures course, CSCI 152. A better performance predictor for both courses is a student's major. We also saw that in the more heterogeneous and gender-balanced CSCI 151, the percentage of females in a course had a moderately positive impact on their relative performance.

As a department, we are moving forward with making separate major-based tracks for these introductory courses, so that we can tailor the experience to better suit student needs. We will continue to collect and compare grade data and feedback for these and other courses in CS. Hopefully, this will help us make more informed decisions about future course changes that will not negatively impact any particular group.

References

[1] M. Lage, G. Platt and M. Treglia, “Inverting the Classroom: A gateway to Creating an Inclusive Learning Environment,” Journal of Economic Education, vol. 31, no. 1, pp. 30-43, Winter 2000.

[2] L. Abeysekera and P. Dawson. “Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research,” Higher Education Research & Development, vol. 34, no. 1, pp. 1-14, 2015.

[3] A. de Oliveira Fassbinder, D. Moreira, G. Cruz, and E. Frantine Barbosa, “Tools for the flipped classroom model: An experiment in teacher education,” Proceedings of the 2014 IEEE Frontiers in Education Conference (FIE 2014), pp. 1–8, 2014.

[4] B. Tyler and M. Abdrakmanova, “Flipping the CS1 and CS2 classrooms in Central Asia,” Proceedings of the 2016 IEEE Frontiers in Education Conference (FIE 2016), pp. 1-5, 2016.

[5] C. Alvarado, Y. Cao and M. Minnes, “Gender Differences in Students’ Behaviours in CS Classes throughout the CS Major,” Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education (SIGCSE ‘17), pp. 27-32, 2017.

[6] M. K. Orr, C. Swafford, S. Hahler and D. Hall, “Factors that influence confidence: Untangling the influences of gender, achievement, and hands-on activities,” Proceedings of the 2014 IEEE Frontiers in Education Conference (FIE 2014), pp. 1-5, 2014

[7] S. Krieger, M. Allen and C. Rawn, “Are Females Disinclined to Tinker in Computer Science?” Proceedings of the 46th ACM Technical Symposium on Computer Science Education (SIGCSE ‘15), pp. 102-107, 2015.

[8] D. T. Fokum, D. N. Coore and Y. E. Lewis-Fokum, “The Performance of Female Computer Science Students across Three Caribbean Islands,” Proceedings of the 47th ACM Technical Symposium on Computing Science Education (SIGCSE ‘16), pp. 419-424, 2016.

[9] L. J. Sax, K. J. Lehman and C. Zavala, “Examining the Enrollment Growth: Non-CS Majors in CS1 Courses,” Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education (SIGCSE ‘17), pp. 513-518, 2017.

[10] J. L. Bishop and M. A. Verleger, “The flipped classroom: A survey of the research,” Proceedings of the 120th ASEE Annual Conference & Exposition, American Society for Engineering Education, pp. 1-18, 2013.

[11] M. N. Giannakos, J. Krogstie, and N. Chrisochoides, “Reviewing the flipped classroom research: Reflections for computer science education,” in Proceedings of the ACM Computer Science Education Research Conference (CSERC ’14), pp. 23–29, 2014.

[12] M. L. Maher, C. Latulipe, H. Lipford, and A. Rorrer. “Flipped Classroom Strategies for CS Education,” Proceedings of the 46th ACM Technical Symposium on Computer Science Education (SIGCSE '15), pp. 218-223, 2015.

[13] G. C. Lee and P. Lee. “Data Structures in Flipped Classroom: Students' Effort and Preference,” Proceedings of the 2015 IEEE Conference on Learning and Teaching in Computing and Engineering (LaTiCE), pp. 152-155, 2015.

[14] Y. Hayashi, Yasuhiro, K. Fukamachi, and H. Komatsugawa. “Collaborative Learning in Computer Programming Courses That Adopted the Flipped Classroom,” Proceedings of the 2015 IEEE Conference on Learning and Teaching in Computing and Engineering (LaTiCE), pp. 209-212, 2015.