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Impact of Flipped Classroom Model on High-workload and Low-income Students in Upper-division Computer Science

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Impact of Flipped Classroom Model on High Workload and Low Income Students in Upper Division Computer Science

I. Introduction

The perception of a student solely as a scholar, dedicated to their course of study, has been in decline since the 1960's [1], [2]. A Bachelor's degree was a means of academic integration and status [3], facilitated by conventional lecture where an expert addresses the students using *authoritative lecture style* [4]. In this paradigm, students benefit from the student-mentor relationship having prepared for the interaction with intensive study. This has been shown to be less beneficial to non-traditional students [5]. *Non-traditional students* come from populations such as community college transfer students or people who work temporary jobs that are unrelated to their course of study [6]–[8]. Heavy workloads—greater than part-time work obligations—hamper their ability to do well. Minority and low-income students have substantial financial obligations [8], [9]. At the California State University, Bakersfield (CSUB), many students identify as minority individuals and have a high-workload, thus are at risk for worse academic performance [2], [10]–[12] and time-to-degree completion [13]. Taking these things into consideration, this becomes an equity problem as well. They juggle the demands of full-time enrollment and full-time work, where employers may have no interest in professional development of temporary employees [5] which makes it challenging to accommodate work hours with classes. The traditional classroom model may work well for unencumbered students, but non-traditional students at CSUB struggle due to unaccommodating and unavoidable workload which leads to an insufficient amount of time to prepare for traditional pedagogy.

In our work, we have implemented several techniques/concepts to provide a productive environment for non-traditional students. To better accommodate the student's workload, instructors provide recordings of lecture that can be paused and revisited around one's work schedule. Videos/recorded lectures are a major pillar of the Flipped Classroom (FC) model [14]–[16], also known as the inverted classroom [17] or flipped learning [18]. FC is a type of blended learning that combines online/remote and face-to-face instruction. Students view videos outside of class at their own pace [16], [17], [19]. Students are watching videos for their first exposure to a new concept. Instead of lectures, FC students come to class for peer instruction activities [14], [20]–[24]. Students apply concepts from the videos with activities comparable to homework. The instructor and teaching assistants survey the class and guide groups having difficulties. Just-in-Time-Teaching (JiTT) [23], [25]–[28] is another major pillar of FC, where the instructor identifies misconceptions/knowledge of the class when the students are first introduced to the subjects. It is similar to concept inventory, where the instructor assesses misconceptions at the start of the class [29], [30], though JiTT testing occurs continuously through the class. JiTT evaluation lets the instructor adjust the daily topic to provide informed scaffolding. *Scaffolding* is the educational strategy where the instructor observes the student working, and provides individualized feedback to facilitate learning [31]. The benefits of FC, JiTT and peer-instruction are well studied in literature [15], [18], [19], [21], [27], [32], [33]. However, much has changed in the twenty years since FCs inception [17]. Teaching strategies should now be tailored to a new generation of students who are technology driven. As our findings demonstrate, students would rather watch videos on YouTube than read the assigned textbook. Classrooms are increasingly online, reliant on the learning management system (LMS), using online systems for quiz/test

proctoring, and recording lectures for students. If videos are the most prominent feature of FC, *do students still prefer FC over a modern traditional classroom?*

Additionally, CSUB is a regional, comprehensive public university serving a population with a high number of first-generation and Pell-eligible students. CSUB is also designated as both a Minority Serving Institution (MSI) and Hispanic Serving Institution (HSI). ~60% of students identify as Hispanic/Latinx. Literature suggests that students like the CSUB's demographic prefer authoritative instruction styles [34]. We would like to verify that FC works for students at CSUB, who are majority Hispanic/Latinx, low-income and high-workload. We measure student attitudes, performance, resource use, and social integration, after participation in a class in a FC, relative to a control population. We are also interested in the tradeoff between instructor investment and improvements to academic performance.

II. Related Work

The first application of the FC model was an economics course in 2000 [17]. The reader is referred to a survey by Bishop et al. for in-depth historical basis and current findings of many FC studies [35]. FC continues to be an active field of study for postsecondary educational strategies. In 2015, a multi-year study at the University of North Carolina, Charlotte found that FC implementations should be conscious of student perceptions of the instructors' preparedness and commitment to the class [21]. Critical sentiments exist despite the study cataloging instructor prep times that were tens to hundreds of hours. In the most extreme case, one instructor spent three hundred hours creating video content for a single class. The study included courses in Human Computing Interaction, web development, user experience and GUIs, and media programming. FC implementations varied greatly with some videos outsourced to a Stanford MOOC or YouTube. A study in 2018 at the Computer Science department at Rivier University found that the FC model improved the classroom engagement of students with language barriers [27]. This study focused on an Algorithms and Data Structures, and a web-design class. The authors found JiTT quizzes to be the only effective way to determine if students watch the videos. In 2020, a study found that FC improves student attitudes for a class (Electromagnetic Fields and Waves) that was forced to transition online due to COVID-19 [18]. Their findings show that students are dissatisfied with remote instruction due to COVID-19 and prefer face-to-face classes. However, adding an FC element to an online class improves student attitudes. Another recent study in 2020 at the Chalmers University of Technology combined online and FC to improve student performance in a statistically significant way [33]. It included many sections of a graduate-level class on modeling nuclear reactors. Though JiTT is not specifically named, students participated in online discussion of video content, but response rates were low. It is notable for its lack of structured peer-instruction and required JiTT.

The major theme of this brief survey is that video content may be the most effective feature of FC, and the most demanding from an instructor's perspective. Our study also differs from previous work in many ways. Outcomes of a FC are compared to a control population. Few works have the opportunity to collect data from a control population with a fixed instructor and fixed curriculum [33]. Most other works use JiTT during class, and our work requires students to complete JiTT before coming to class. Additionally, there are few FC studies for undergraduate Artificial Intelligence (AI). Our complete set of research questions follow:

- *Do students still prefer FC over a traditional classroom?* I.e., *what happens if you add FC's video element to a traditional class?* (Noting that modern classrooms are highly online with video content)
- *What resources do current students prefer to use?* (Noting that much has changed since FC was originally proposed)
- *How do students view the social interaction with peers, and with the instructor?* (Noting some literature suggesting Hispanic/Latinx and South-East Asian students do not prefer dialogic instruction)

III. Methods and Data

We study two classroom models: a traditional class used as control population (CON) and a FC model population (FC). See Table 1 for population demographics. To measure attitudes, resource use, and social integration, students complete a pre-survey and a post-survey. A pre-survey occurs at the start of the class. It gives a baseline and normalizes pre-study biases. The post-survey measures how behaviors/attitudes change through the term. CON group was treated to online videos, and authoritative traditional lectures. FC group was treated to online videos, JiTT and peer-instruction. Surveys include quantitative (Likert) questions. Responses are a 7-point scale [36]. Results are given in terms of mode and frequency. Results of Likert-style questions on student attitudes about lecture are given in Table 3-A on page 17. Students reported on resource use in Table 3-B, and social integration in Table 3-C. Because the responses are ordinal [37], [38], we are measuring differences in populations and subjects/independent-measures (enforced with exclusion criteria), a two-tailed Mann-Whitney U Test is the most appropriate significance test [39]. Significance of all tests is based on $p < .1$. Due to Likert responses being ordinal we do not prune outliers from quantitative analysis. We also collect qualitative data. Pertaining to student attitudes, students were asked:

1. What are some improvements that could be made to lecture time?
2. Concerning lecture, what are the good things?
3. Concerning lecture, what are the bad things?

FC surveys also asked students to comment on JiTT quizzes. Pertaining to student resource use/preference, questions asked were:

4. Describe how you study for class.
5. What resources do you turn to when studying for a class?
6. Comment on the materials that are given to you by the instructor(s). Can they be improved? Are they effective?
7. Do you view online videos for class?

To measure student social integration and satisfaction, students were asked to comment on feelings about social interaction with other students and/or CSUB's instructors. For post-survey it was rephrased to refer to Instructor A/B. Finally, at the end of the survey students could leave any comment at all. Qualitative analysis follows Lincoln and Guba [40]. For each question set, comments were iterated over noting major themes. Results are presented as a normalized percentage, the total number of comments for the population, pre- or post-survey, and question

set. Ninety one themes were noted, though we present only the themes with significant trends when comparing the gains in FC and CON populations.

We also track classroom (midterm) performance. Classes in our study have similar midterms so a fair comparison can be drawn. Collecting midterm exam data rather than final exam data is better because student involvement lags toward the end of a semester, and students may notice the similarity of the midterm to past sections to game the final. Exam performance is reported as mean and standard deviation. For exams, outliers greater/less than 2σ from the mean are pruned. The Mann-Whitney U Test is appropriate for ordinal and numerical data, and we continue to use it for significance of exam scores.

III.A. Classroom Models

CON and FC have the same textbook; instructor-made lecture-notes which model 2-3 example problems; similar homework/quiz questions and lab assignments/manuals; a LMS; and video access. Videos include recorded lectures of Instructor A from the past one to two semesters, and recommended YouTube videos. Each lab activity was identical: the instructor gives a brief introduction, then the students self-organize into small groups to collaborate on the lab activity.

CON instruction is authoritative [4]. Class begins with an outline, and the instructor quickly reviews the previous lecture to engage prior knowledge. During lecture, the instructor provides an algorithm, method or topic and works backward to demonstrate correctness. Lectures are intended as the students' first exposure to the material. CON completes weekly homework assignments consisting of twenty to thirty multiple choice (MC) and three to five free response questions, administered through the LMS. Daily topic is fixed. The lecture follows the notes, and the examples are modeled on the white board. Recording videos is a one-time commitment by the instructor, and this classroom model does not have a recurring, additional workload for the instructor compared to a traditional class.

Our FC model includes JiTT [23], [25]–[28] and peer-instruction [20], [22], [24], [30]. To reproduce our work, we recommend the following classroom model. FC students learn a new topic from online videos. Students complete a JiTT quiz before lecture for assessment, and to ensure they watch the videos. Questions are reused from CON homework sets, but the assignments are less complex: ten to twenty MC and up to three free response questions. Unlike CON, the instructor varies the daily topic based on JiTT results. JiTT quizzes are worth 5% of a student's overall grade. During lecture, students apply knowledge with peer-instruction. We use pair programming, a software engineering paradigm where one person is the driver and the other is the navigator. The driver focuses on the problem and writes/codes. The navigator reads ahead, manages time, and validates. The driver and navigator get the same grade. The instructor scaffolds with dialogue as needed. As a tertiary benefit, students become familiar with the pair-programming paradigm used in industry. The worksheet problems are a single arc where students construct a solution/algorithm (computational thinking [20]), rather than work backward from an existing solution. The pairs are randomly assigned each day. Pairs are chosen carefully by the instructor to avoid towers of knowledge [41] and ensure zone of proximal development [42]–[44]. The worksheets are graded and worth 25% of an overall grade. Adjusting the plan for the day based on JiTT was a time intensive process that significantly increased prep time for the

instructor by one to two hours before each lecture, in addition to the large one-time cost of refactoring a class to a worksheet-based model. This increased prep time for Instructor A by hundreds of hours, concurring with other work [21].

III.B. Data Collection and Analysis

Table 1: Data collection summary, including sections, collection date, and population size. CON: Control population. FC: Flipped classroom population. Consenting: Percent of individuals consenting to participation and meeting inclusion criteria (not repeating the class, prior participation, etc.).

Semester	Population(s)	Class	Instructor	Class Size	Cons./Incl. (%)	n
Fall 2019	CON	AI	A	34	58.82%	20
Fall 2019	CON	Architecture	A	37	32.43%	12
Spring 2020	FC	AI	A	22	72.73%	16
Spring 2020	FC	Architecture	A	23	65.22%	15
Fall 2020	FC	AI	B	21	9.52%	2
Fall 2020	FC	Architecture	A	32	15.63%	5
					Total	**70**

The study spans three semesters, Fall 2019 to Fall 2020. An explanation of the class titles, class sections, and dates, are given in Table 1. Most populations have the same instructor (Instructor A). Only two of seventy participants had a different instructor (Instructor B). Instructor B's AI class used Instructor A's curriculum and videos. Instructor A completed a grant-funded teaching transformation program [grant title/award no. blinded] in 2018 and is competent in the areas of computational thinking, active learning, and FC. Prior to the study, Instructor A taught four sections of AI and three sections of Architecture. 95% of students would recommend or strongly recommend Instructor A as an instructor of AI, based on student feedback. In Fall 2020, exclusion criteria and low interest resulted in very low participation. Students identify with yes/no questions if they are repeating the class, have participated in another section, or have taken a class with a FC model. Responding yes to any criteria is an exclusion criteria. In Architecture, students learn to code assembly language, binary representation of instructions, issue path, cache organization, multi-issue, and parallelism (SIMD and loop unrolling). Students gradually improve a processor given new knowledge. In AI, students discuss inference in formal logic (propositional logic, fuzzy logic, probability theory), machine learning (neural networks), and constraint satisfaction (genetic algorithms, evolutionary strategies, and genetic programming). Students have less time to understand a concept before moving on to a new one due to the variety of topics. Unlike Architecture, AI is more: abstract, math-based, and compares algorithms via computational cost. Informed consent for the surveys is obtained from participants at time of data collection. Our work is IRB-exempt ([IRB # redacted]). Participants may believe their feedback will be read by Instructor A/B. To avoid this, and the coercion problem, a third-party solicited involvement and collected data.

IV. Results and Discussion

In computing, females are underrepresented. In AY 2018-2019, at CSUB, 41 of 257 (13.76%) first-Bachelor's/undergraduate students in the Computer Science program were female.

More must be done to close the computing gender gap. One of the most compelling comments collected by our study follows:

> *[My interactions with other students are] Negative. For me personally it is difficult making friends since there are little to no females in my classes.*

However, among consenting participants, less than ten are female. We cannot analyze the impact of the FC model on female students, though it will be studied in future work. Consequently, we focus outcomes with our general population, which is majority Hispanic/Latinx, low-income and/or high-workload. 43% of Computer Science students at CSUB identify as Hispanic/Latinx and 52% work 20-40 hrs. per week while enrolled full-time. A table summarizing the parameters of our work and guidance for instructors to reproduce our classroom models are given in Table 2.

FC showed improved exam performance for abstract/theory intensive classes. Traditional classes with video remain a valid method of teaching, and when well taught improve attitudes (not performance) of students more than FC. Worries of resistance to forced peer activity are unfounded when instructors carefully select partners. Most criticism of FC from our study is due to JiTT quizzes *in the way we have implemented them*. It can be addressed by allowing students to retry the quizzes. When considering an FC class, instructors should consider the additional hundreds of hours of prep time required to prepare videos. Videos are a preferable resource for individuals in our study, who are high workload/low-income and cannot study rigorously/continuously in the conventional sense. The following comment is an exemplar of this sentiment:

> *[I prefer] The lectures provided [videos] as well as the YouTube videos I found while trying to understand the concepts. I hardly read the book, I dislike reading textbooks a lot and enjoy seeing problems and examples done and explained in front of me through video or in person instead. Because of this I relied mostly on video material for studying.*

We highly recommend that all classes record lectures or at least curate a list of MOOCs or online videos for students to preclude them seeking out dubious/irrelevant resources.

Table 2: Study overview. Baseline: A baseline behavior obtained from pre-surveys for each population.

Population/Model	**Traditional Class (CON)**	**Flipped Class (FC)**
Section staff	One instructor and one teaching assistant	
Home activity	Weekly homework sets	Pre-lecture video & online quiz
Laboratory	Weekly self-organized, instructor-scaffolded group work	
Lecture topic	Fixed topic	Varies based on JiTT
Lecture style	Authoritative, chalk talk, modeling examples	Peer-instruction, pair programming
Videos	Lectures recorded	Abbreviated lectures videos, supplemental full versions
Student academic performance	No measured improvement	Improves exam scores for AI

Student feedback for lecture style	Modeling examples is helpful	Improves lines of communication
Student opinion of class	Overwhelmingly positive	Mixed response to graded JiTT quizzes *(can be addressed)*
Student opinion of instructor	Both positive, improvement from baseline	
Student opinion of instructor materials	Both populations favor instructor-created video and if provided reduces tendencies to seek outside resources	
Student opinion of peers	Positive, no improvement from baseline	Very positive, improvement from baseline
Student resources	No change in baseline, students already prefer internet resources and videos and will seek them out if they are not provided by the instructor	
Instructor Prep Time	One-time cost of recording videos	1-2 hrs. for each lec. to analyze JiTT, hand-pick partners, edit videos

IV.A. Student Attitudes vs. Student Performance

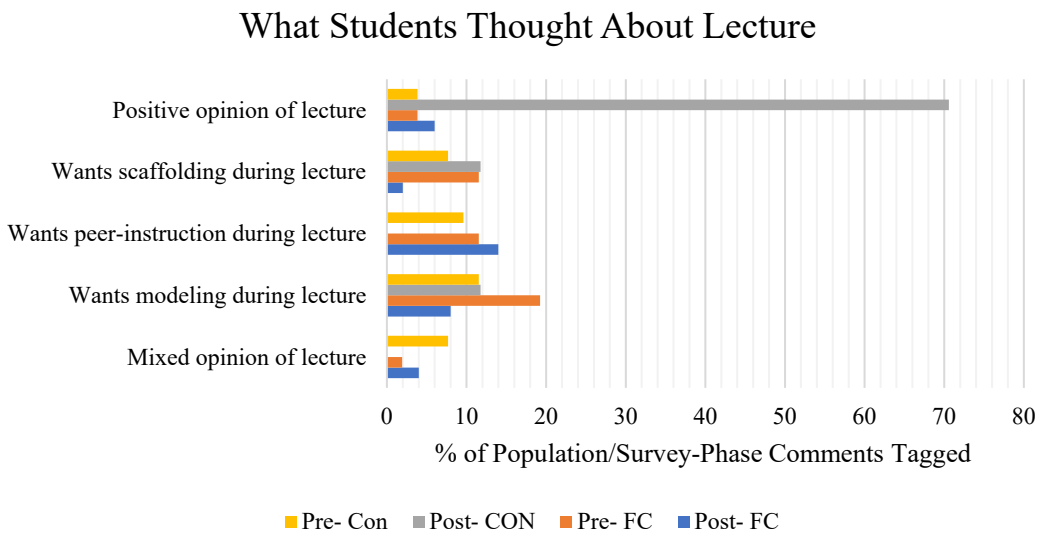

Figure 1: Major themes of what students think about lecture. Results are normalized by total number of comments left for questions pertaining to the quality of lecture, population group, and whether pre-survey or post-survey.

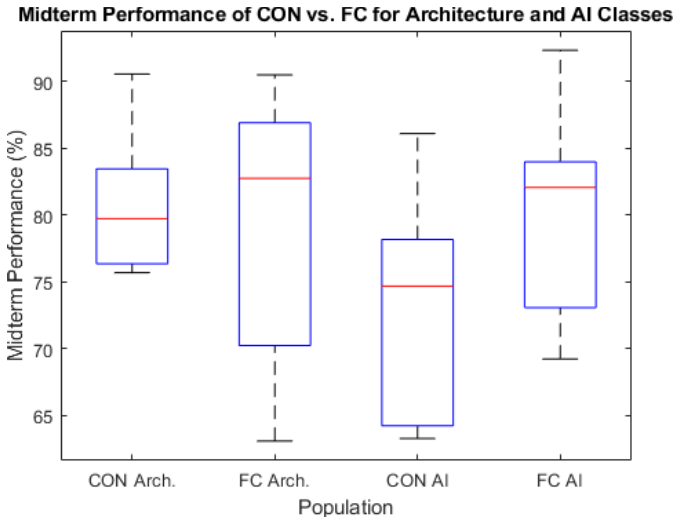

Figure 2: Midterm performance comparing CON vs. FC classrooms, for the classes of Architecture and AI. The central mark indicates the median. The bottom and top edges of the box indicate the 25th and 75th percentiles, respectively. The whiskers extend to the min and max data points not considered outliers.

A figure summarizing the major themes of the qualitative responses pertaining to student attitudes about lecture are given in Figure 1. Test results are given in Figure 2. Concerning Likert responses (Table 3-A), results are mixed. Few questions have a statistically significant increase/decrease comparing pre- and post-survey questions for either population. Surprisingly, student's overwhelming favor our implementation of a CON classroom (Question 1A). 100% of CON population students report strong satisfaction in the post-survey. A first thought is to attribute this to acquiescence bias, the concept that survey participants are agreeable with forced-choice scales (Likert-style) [45], [46]. Nonetheless, students were more satisfied with CON than FC. Though FC post-survey satisfaction increased (from 3 to 6) it was not statistically significant ($p > .1$). Overwhelming satisfaction with CON classes is also reported in free-response data (Figure 1). Positive opinions of lecture are the rank one theme in the CON population post-survey (70.59% of all comments). This confirms the extraordinary response from qualitative analysis. This is a surprising result. A sample of comments from post-survey CON population follow:

- *This class represents my idea of an efficient and interactive learning environment.*
- *This class is the perfect example of how to use current technology. All lecture notes available at the end of class, current updated grades, all resources in one place, easy communication with teacher, no excuse for not knowing the current status of the class.*
- *Positive, the instructor provides additional resources for research or assistance as necessary.*
- *This class is one of two best classes I've taken at [redacted].*
- *Best instruction I've ever had.*

It is important to ask *why students do not like our FC implementation*, and it appears to be dissatisfaction with JiTT (as we have implemented it). FC post-survey responses about JiTT follow:

- *The quizzes helped me discover what I knew and what I needed to work on. However, I did not like that I only had 1 attempt for each quiz. This is because the flipped classroom environment had me learn the topic on my own first without the instructors help. Then I would take the quiz feeling like I was prepared and understood the topic but when taking the quiz I would do poorly because I didn't understand the topic as well as I had thought. Then after the lecture with the professor I would understand the topic but my grade would still suffer because of the quiz. I think if we were allowed a second attempt after meeting with the professor would help tremendously.*
- *I felt like the quizzes were alright, I didn't really benefit from them.*
- *Quizzes essentially don't work in this environment since we have no confirmation prehand that what we understand from the lecture video was correct. I have watched the videos and then discussed with classmates and have opposing thoughts about how things are.*

If FCs source of dissatisfaction is not JiTT, other sources are peer-instruction and instructor-made videos. The FC population has fewer students who prefer modeling or scaffolding. Modeling, peer-instruction and scaffolding are instructional strategies. In modeling, the instructor introduces a concept and the student observes. An example comment from the pre-survey: *it's nice when professor works out examples in class*, implying no peer activity or feedback. Peer-instruction is the method used with the FC model. For example, from pre-survey FC: *I appreciate the ability to work with colleagues to solve a question*. It explicitly mentions collaboration. The theme where *students want peer-instruction* was 14% of total tags for this sub-analysis and first rank (most common), so it is not a likely source of dissatisfaction. Later discussion will show that students prefer videos. Thus, we believe the dissatisfaction is due to JiTT. We do not dispute the effectiveness of JiTT, the efficacy and significance of which has been long established in literature [23], [25]–[28]. Opinions are not tangible measures of performance. Most likely the students do not prefer something which is ultimately better for them. To address this criticism, we recommend letting students repeat the JiTT quizzes for credit.

Table 3-A Question 1C and 1G are notable for the level of significance ($p < .1$). Students in CON feel that they better understand lecture and expectations. This seems contradictory because a FC model allows more opportunities for students to ask questions as the instructor wanders the class. This may be explained by previous work by P. den Brok et al.: 1) Hispanic/Latinx secondary school students prefer an authoritative learning environment over a dialogic one [34], and 2) Hispanic/Latinx secondary school students appreciate the availability of taped lessons [47]. This perfectly describes our CON learning environment, and we assert that this phenomena continues for post-secondary education. Hispanic/Latinx post-secondary students have high satisfaction with a traditional classroom that also provides taped lectures.

Despite mixed reaction to the FC model, there is a significant improvement in academic performance for the FC group in AI (see Figure 2). For Architecture, CON midterm performance

is 80.89% ± 5.26%; FC, 78.81% ±10.07%. While this seems marginally worse, a Mann-Whitney U Test yields a p-value of .4403 so it is not significant ($p > .1$). For AI, CON midterm performance is 73.22% ± 7.73%; FC, 79.97% ± 7.75%. A Mann-Whitney U Test yields a p-value of .0594 so it is significant ($p < .1$). The two classes are different in nature. Architecture is highly practical. AI requires discrete math and calculus. Thus, while students matching CSUB's demographic may not prefer the FC model they perform better on exams for abstract/math-intensive classes (AI).

IV.B. Study Resources

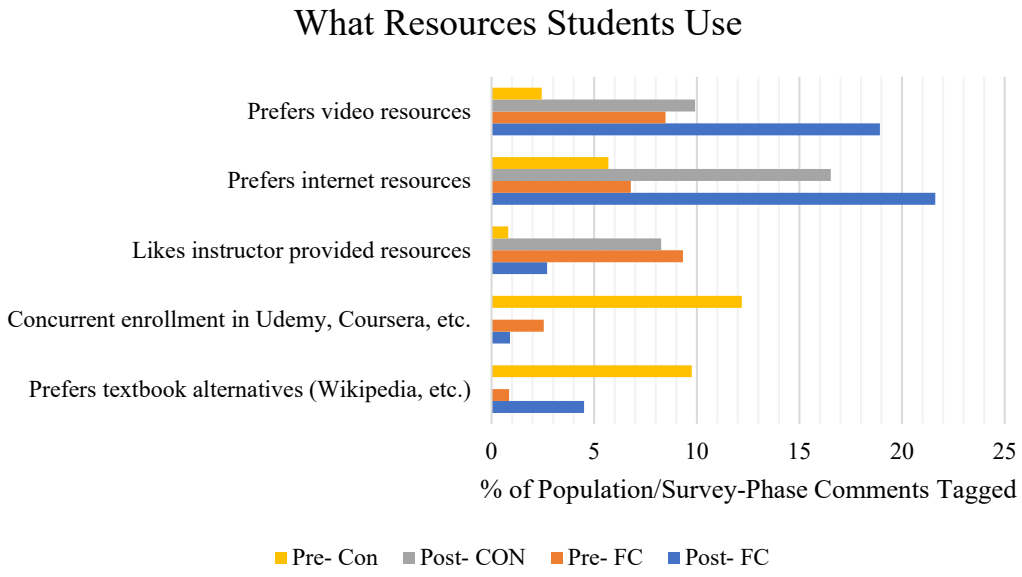

Figure 3: Major themes of resources used by students throughout the class. Results are normalized by total number of comments left for questions pertaining to the quality of lecture, population group, and whether pre-survey or post-survey.

We believe video better engage students and would like to know their preference for instructor-provided versus external resources. Though trends appear in Table 3-B, no result is statistically significant suggesting no change from baseline behavior due to participation. On a weekly or more frequent basis students: communicate on the internet, review instructor material, and read the textbook. Concerning major themes in Figure 3, CON students also prefer videos. Examples of post-survey CON responses about videos follow:

- *The videos were very effective for studying.*
- *[While instructor materials] can always be improved, videos are very effective.*
- *Instructor's videos are amazing; they care enough to put in extra effort to ensure we are never lost.*
- *[Materials are] effective, helpful notes, videos, other extra materials.*
- *The lecture notes provided by the teacher do not always contain the info provided in the respective lecture. Though this info is still in the lecture videos.*

The last comment provides insight on priorities. Students may use other resources but ultimately resolve their issues with videos. We speculate that videos provide a safety net for high-workload students in traditional classes who may miss a lecture due to a shift they cannot flex. FC students view videos—unsurprising given that JiTT quizzes are based on video content. Comparing pre- and post-survey FC, many students now prefer resources that are video format from the internet.

The pre-survey CON group enrolls in online versions of the same course while simultaneously enrolled at CSUB. This is the rank one theme of pre-survey CON responses with 12% of all comments naming Udemy or Coursera specifically. CSUB's mission is to provide a comprehensive experience to low-income persons, and it is painful to note that students feel the need to pay for supplemental classes. Speculating, the reasons for this may be: previous courses were not engaging; previous resources were ineffective and students were prompted to buy better resources; or modern students prefer a structured experience with technology and most traditional classes at CSUB are not using their LMS to its greatest potential. A minority of students seek help from textbook alternatives (Wikipedia, Google), free online question asking services (Stack Exchange, Quora), or paid homework-help services (Chegg). After participation, 0% of post-survey responses admit simultaneous online enrollment. This behavior is anti-correlated with CON populations preference for internet, online and video resources in the post-survey. Providing videos for a traditional classroom may be an effective way of reducing student concurrent/outside enrollment in online classes.

Apart from instructor-provided video viewership, participation in CON or FC did not increase use of online resources because both populations were already highly online from qualitative data. Students:

- Use unmoderated and unofficial means of internet communication (Discord and Slack) to communicate with each other in large groups spanning multiple courses and cohorts;
- Use internet-based alternatives to the textbook such as internet searches and Wikipedia;
- Potentially violate academic integrity by using paid-resources or soliciting help from online forums; and
- Simultaneously enroll in an online school or MOOC of the same curriculum while enrolled in a face-to-face class.

The high tech classroom and taped lectures are no longer unique to the FC model. If not facilitated by the instructor, students will structure their learning in an online environment. Instructors should provide these resources to all class models to ensure that students are using high quality material and not paying for it out of pocket—a significant concern for universities with low-income students. For example, instructors can provide recordings of modeled examples, so students do not feel pressured to purchase videos from Udemy, Coursera, etc.

IV.C. Quality of Classroom Interaction

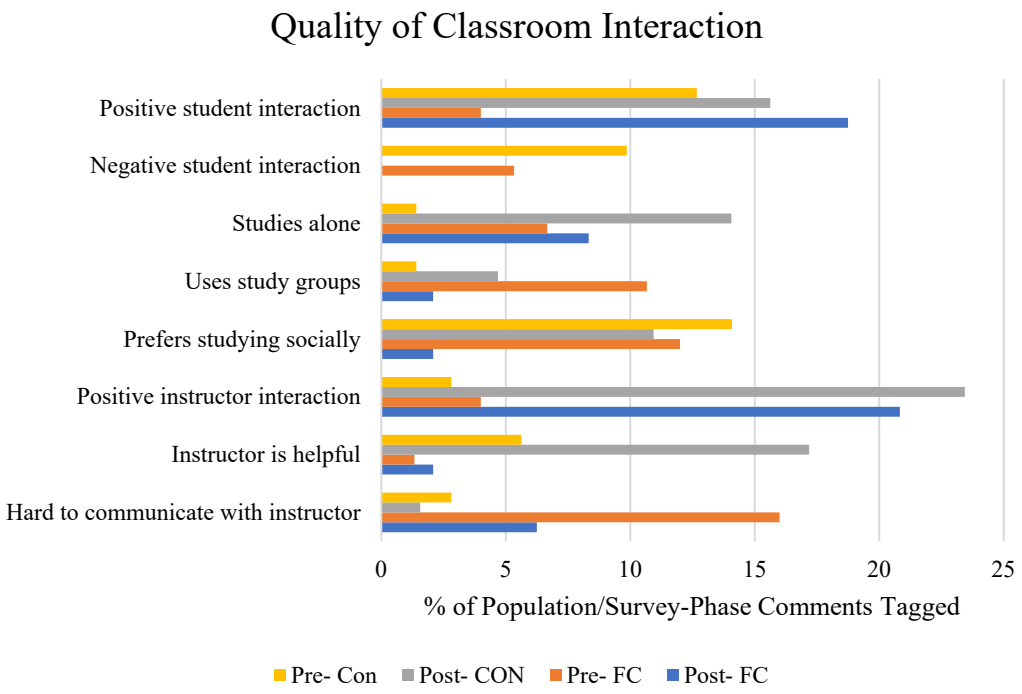

Figure 4: Student attitudes toward the instructor and each other. Results are normalized by total number of comments left for questions pertaining to attitudes about social interaction.

Learning is a social process [48]. We believe that the FC model gives students more opportunities to interact with their peers and the instructor in a positive way. Students must interact with each other during peer instruction. This rapport should lead to more frequent and helpful communication between students outside of class. The instructor and teaching assistant observe the pairs and step in when help is needed. This should give students opportunities to clarify misunderstanding from the video, leading to better attitudes and clear communication.

To approximate eagerness to communicate socially students were asked two questions. In Table 3-C Question 3A students indicated how frequently they convene a study group. But, there is no statistically significant difference from baseline behavior. Question 3B is approximately the negative keyed version of Question 3A, asking students to rate the frequency of studying for the class alone. CON has no statistically significant difference from baseline behavior ($p > .1$). Yet, FC students study for themselves more frequently than before they participated in the study, and the response is statistically significant ($p < .1$). Most likely watching videos by yourself is not a social activity. Otherwise, while there appear to be trends to Likert responses no other response is statistically significant. Themes from qualitative analysis provide better insight (Figure 4). CON population has a large increase in the number of students studying alone. FC population has a large decrease in the number of students preferring to study socially, or using study groups. Video viewership may preclude the need to convene social groups to study, and concurs with earlier conclusion in Section IV.B that current students would rather engage with things they find

on the internet. This possibly contradicts the concept that FC students would be more eager to engage socially outside of class.

Low frequency and high quality are not exclusive. Both sections had more positive opinions than negative opinions of social interaction—neither population had negative sentiment in post-survey responses. Though, FC had a significant gain in positive opinion. Students are randomly paired with each other. There is a potential concern of two students not getting along, and this does not appear in the data, when instructors carefully select pairs. Though, hand picking groups may be impossible for class sections larger than those offered by our department. There was only one negative criticism of our implementation of peer-instruction: *students should be able to pick the groups they want to be in*, a person wanted the option to work with their friends than with a random person. The CON population felt the instructor was more helpful after participation. In our CON model the instructor models examples in class. This is unlike traditional pedagogy for engineering, where lecture is a high level concept introduction, and modeling examples is delegated to a teaching assistant in another class section. Instructors wishing to reproduce our work should work through example problems (modeling examples) during lecture. A sample of comments in support of this from post-survey CON:

- *The instructor explained clearly and could elaborate and adjust to the students based on skill level.*
- *Teacher provides helpful examples.*
- *[Lecture is] Informative, I understand what the lectures aim for in a general sense of application.*
- *Great labs with very through well-thought-out explanations.*
- *Instructor is also a HUGE help for we were fortunate to have one who is so passionate about teaching.*
- *Best instruction I've ever had.*

Whereas CON was more helpful, FC made it easier to communicate with the instructor. In the pre-survey, FC students believed it was hard to communicate with the instructor (12% of all responses, rank 1). In the post-survey, this decreased to 6.3% of all responses (rank 5). This confirms part of our hypothesis that FC is a better quality activity for students. Improved quality is also achievable with a traditional classroom under specific circumstances (modeling).

V. Conclusion

Our work presents preliminary findings from a multi-year multi-section study comparing the flipped classroom (FC) model to a traditional classroom based on authoritative lecturing, modeling, and access to instructor-made videos ($n = 70$). Videos continue to be the most prominent aspect of FC, and can also be applied to a traditional class. Students will seek out videos on their own if they are not provided by the instructor—this was identified in baseline behavior of students before they participated in the study. Some external resources are costly, so this behavior should be addressed by universities that serve a predominantly low-income population. Instructors should make their own videos or provide a curated list of YouTube, Vimeo, etc. videos to preclude students paying for content. Having JiTT as a graded activity, due before the start of lecture, was a major source of dissatisfaction with FC sections in our work, however, overall, student perception of the instructor greatly improved over baseline opinion. Fears of partner

incompatibility during peer-instruction are mitigated through careful partner selection by the instructor and pair-programming methodology. The traditional classroom method has competitive performance with FC under specific conditions which concurs with findings from secondary schools that Hispanic/Latinx persons prefer less dialogic instruction styles. Modeling examples during lecture greatly improve student attitudes, even over the FC model ($p < .1$). Yet, it does not improve academic performance over baseline. The FC can improve test scores for AI, an abstract and mathematically intense class, and this result was statistically significant ($p < .1$). Instructors considering the FC model should consider the tradeoffs between culturally-effective instruction, academic improvement for specific classes, and increases in instructor prep time—which can be hundreds of hours more than a traditional classroom for first-time adopters.

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Table 3: Responses to Likert-item questions on a 7-point scale with 1 being not strong disagreement; 4, neutral; and 7, strong agreement on study behaviors. For quality/satisfaction questions, the scale is 1 strong dissatisfaction and 7 is strong satisfaction. For frequency questions, 1 is not often, 4 is weekly, and 7 is daily. AI and Architecture responses are aggregated. CON: Control group. FC: Flipped classroom. Pre-: Pre-survey. Post-: Post-survey.

(a) Student Attitudes vs. Student Performance

		CON			FC		
ID	Prompt	Pre-	Post-	p	Pre-	Post-	p
1A	Rate the quality of lecture activities.	4 (0.44)	7 (1.00)	**.0000**	3 (0.27)	6 (0.25)	.6527
1B	I can complete the required homework assignments.	3 (0.39)	4 (0.38)	.1211	5 (0.27)	4 (0.33)	.2937
1C	I understand the examples during lecture.	6 (0.37)	7 (0.46)	**.0010**	4 (0.27)	6 (0.36)	.1416
1D	I can complete lab assignments in the time given.	6 (0.39)	7 (0.46)	.2005	5 (0.47)	4 (0.33)	.3524
1E	When I explain a concept to another student, they can understand it.	5 (0.32)	6 (0.38)	.6032	5 (0.50)	4 (0.36)	.9442
1F	I feel prepared before attending lecture.	5 (0.35)	4 (0.38)	.7872	4 (0.35)	4 (0.36)	.7566
1G	Course expectations are clear.	6 (0.32)	7 (1.00)	**.0010**	7 (0.47)	5 (0.36)	.8966

(b) Student Resource Use

		CON			FC		
ID	Prompt	Pre-	Post-	p	Pre-	Post-	p
2A	How often do you discuss the class with other students on the internet?	4 (0.32)	1 (0.29)	.5485	6 (0.32)	5 (0.25)	.5892
2B	How often do you read the textbook.	3 (0.39)	4 (0.38)	.1211	5 (0.27)	4 (0.33)	.2937
2C	How often do you review material provided by the instructor?	4 (0.33)	5 (0.36)	.2801	5 (0.36)	4 (0.50)	.5552

(c) Social Atmosphere

		CON			FC		
ID	Prompt – How often do you …	Pre	Post	p	Pre	Post	p
3A	How often do you prepare for class with a study group?	2 (0.29)	1 (0.31)	.1260	1 (0.32)	1 (0.55)	.1260
3B	How often do you study for the class by yourself?	6 (0.45)	6 (0.33)	.2846	6 (0.45)	6 (0.42)	**.0512**