Comparative analysis of learning gains and students attitudes in a flipped precalculus classroom

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Flipped classrooms are becoming increasingly prevalent at the undergraduate level as institutions seek cost-saving measures while also desiring to implement technological innovations to attract 21st century learners. This study examined undergraduate pre-calculus students' (N=427) experiences, attitudes and mathematical knowledge in a flipped classroom format compared to students in a traditional lecture format. Our initial results indicate students in the flipped format were more positive about their overall classroom experiences, were more confident in their mathematical abilities, were more willing to collaborate to solve mathematical problems, and achieved slightly higher gains in mathematical knowledge.

Key Words: *Flipped Classrooms, Technology Enhanced Learning, Precalculus, Student Attitudes*

INTRODUCTION

The development of online math education has made huge strides in recent years with the creation and wider availability of open source math tutorials such as Khan Academy, Udacity, and Coursera. This has lead traditional institutions to seek time and money saving measures by developing pre-recorded lectures and utilizing problem-based education inside the classroom (Bacow & Bowen, 2012; Mehaffy, 2012); however, little consideration is given to the effects that these changes will have on students' attitudes and academic performance toward the subject of mathematics. One of the key-concepts behind the "flipped classroom" or the "inverted classroom" approach is using technology to offload traditional style lectures to allot more classroom time for problem based exploration and applied learning (Lage, Platt, & Treglia, 2000; Sams & Bergmann, 2012).

REVIEW OF THE LITERATURE

There is a limited amount of international peer-reviewed research available on flipped classroom approaches; however, studies have been increasing in recent years. Preliminary reports seem to suggest that students in flipped classrooms show improved academic success and achieve greater learning outcomes as compared to students in traditional classroom models, (Baepler, Walker, & Driessen, 2014; Love, Hodge, Grandgenett, & Swift, 2014; Mason, Shuman, & Cook, 2013; Wilson, 2013) or at worst does no harm (Mason et al., 2013; McCray, 2000, Bagley, 2014). In addition, student attitudes are fairly consistent and show students view the flipped classroom as promoting their learning (Arnold-Garza, 2014; Scida & Saury, 2006), increasing confidence in their abilities (Baepler et al., 2014; Kim, Kim, Khera, & Getman, 2014) encouraging social engagement with students and teachers (Baepler et al., 2014; Jaster, 2013; Love et al., 2014), as more relevant to their future career goals (Love et al., 2014) and appreciate the flexibility allowed by online didactic videos (Jaster, 2013); however there is evidence that given a choice, students prefer a traditional model of learning (Arnold-Garza, 2014; Jaster, 2013).

Although recent studies support the use of flipped classrooms, most studies thus far have used small samples sizes, and with the exception of a few conference proceedings (Overmyer, 2013; Wasserman, Norris, & Carr, 2013; Bagley, 2014) most are not specific to the subject of undergraduate mathematics. Since the research on the effectiveness of this pedagogical approach is limited, there are clear gaps in the literature that this study hopes to address. Accordingly, this study is a first step in determining how do students in a flipped learning undergraduate math course compare to students in a traditional lecture course in their:

- Attitudes (motivation, enjoyment and confidence) and beliefs about learning mathematics?
- Experiences and opinions of the course activities and interactions?
- Perceived learning gains and mathematical knowledge?

RESEARCH DESIGN AND METHODOLOGY

Participants were students from four undergraduate pre-calculus II course sections offered at a large research university in the midwestern region of the United States. Two of the courses used the flipped learning model (FL) for instruction and two used the traditional lecture model (TL) for instruction. Each of the course sections met for three hours a week of classroom time and one hour for a Q&A section lead by a graduate assistant. The TL courses used the traditional classroom time to lecture on the classroom material with limited interaction between teacher and students. In comparison, The FL classes used online didactic video tutorials that features a voiceover PowerPoint to present the lecture material outside of classroom and classroom time was then used primarily to complete group (3-4 students) based worksheets with low level practice problems combined with mathematical proofs to derive trigonometric formulas in an active learning classroom.

The research instruments and design methodology parallel the research conducted by Laursen et al. (2014) regarding inquiry-based learning. This large scale study highlighted the beneficial impact of active learning strategies on student outcomes especially for women, low-achieving and first-year students. The first survey instrument referred to as the attitudinal assessment, consisting of 54 questions using a seven point Likert-scale, and was, “constructed on the basis of theory and previous research on mathematical beliefs, affect, learning goals and strategies of learning and problem solving” (Laursen et al., 2014). The second survey instrument is based on a subset of the mathematically focused Student Assessment of their Learning Gains, referred to as the SALG-M and measures student's experiences and learning gains using a 5-point Likert scale from (1 –No gains) to (5-Great gains) for each item. The SALG-M instrument was designed to provide faculty with summative and formative information on teaching practices, and has been shown to be a reliable measure of classroom practices and student experiences. The attitudinal assessment pre-survey was administered at the start of the second week of the course and the attitudinal post-survey and SALG-M were administered in the last week of the course. Scores from the multiple choice section of the mathematics department common final examination were used to assess student's mathematical performance. In addition, demographic information including gender, race, class year, college major, previous math courses taken, and GPA were requested.

RESULTS

We received 427 responses (87.5% of enrolled students) from the pre-survey and 300 responses (61.5% of enrolled students) from the post survey. Using the unique identifier we were able to match 214 (43.8% of enrolled students) pre- and post-surveys. Based on prior research from Laursen et al. (2014), a factor analysis was performed on each of the survey items to create composite variables to measure changes in students affect (motivation, enjoyment, confidence), beliefs about learning, and strategies for problem solving problems (See Table 1). In addition composite variables were determined to assess students' perceptions of the classroom experiences, and self-reported learning gains as a result of the course (See Table 2). A summary of the composite variables and reliability ratings are reported in Table 1 and Table 2.

Table 1: Composite variables of attitudinal and learning behaviors in mathematics

Variable	Description	Reliability *Cronbach alpha*	
		Pre	Post
Motivation	Motivation to learn mathematics	.761	.771
Interest	Interest in learning and discussing math outside of the classroom	.749	.774
Math degree	Desire to pursue a math major/minor	.838	.822
Math future	Desire to pursue and study for additional math courses.	.536	.672
Teaching	Desire to teach mathematics	-	-
Enjoyment	Pleasure in doing and discovering mathematics	.893	.908
Confidence	Confidence in math and math teaching ability	.828	.859
Math confidence	Confidence in own mathematical ability	.805	.852
Teaching confidence	Confidence in teaching mathematics	.682	.745
Beliefs about learning			
Instructor-driven	Exams, lectures, instructor activities	.687	.689

Group work	Small group presentation and critique of math	.639	.629
Exchange of ideas	Active exchange with other students	.765	.728
Strategies			
Independent	Find one's own way to think and solve problems	.450	.640
Collaborative	Work with other students to brainstorm and solve problems	.717	.683
Self-regulatory	Review and organize one's own work; check one's understanding	.562	.647

Table 2: Composite variables for student experiences and learning gains

Variable	Description	Reliability
		Post
Experiences of course practices		
Overall	Overall experience, workload, and pace of the course	.797
Active participation	Participating in discussion, group work, and explanation of work.	.800
Individual work	Studying on your own	-
Lectures	Listen to lectures	-
Assignments	Tests, homework, feedback on written work	.603
Personal interactions	Interacting with peers, TAs and instructors	.667
Cognitive Gains		
Math concepts	Understanding concepts	.906
Math thinking	Understanding mathematical thinking	.819
Application	Applying ideas outside math, making math understandable for others.	.828
Affective Gains		
Positive attitude	Appreciation of math	.812
Confidence	Confidence to do math	.889
Persistence	Persistence, ability to stretch mathematical capacity	.781
Social Gains		
Collaboration	Working with others	.773
Teaching	Comfort in teaching	-
Independent Gains	Ability to work on your own	.828

Linear regression analysis was performed on each of the composite variables in order to determine the magnitude and main effect of classroom format in addition to models controlling for demographic and interaction effects. The results of the main effects model, which are displayed in Figure 1, indicated significant differences for students' experiences in the classroom, math confidence, and collaborative strategies for problem solving. In addition there were significant differences in self-reported affective, cognitive, and social learning gains, but no difference in independent learning gains (See figure 2). We subsequently discuss the themes that emerged from this initial analysis.

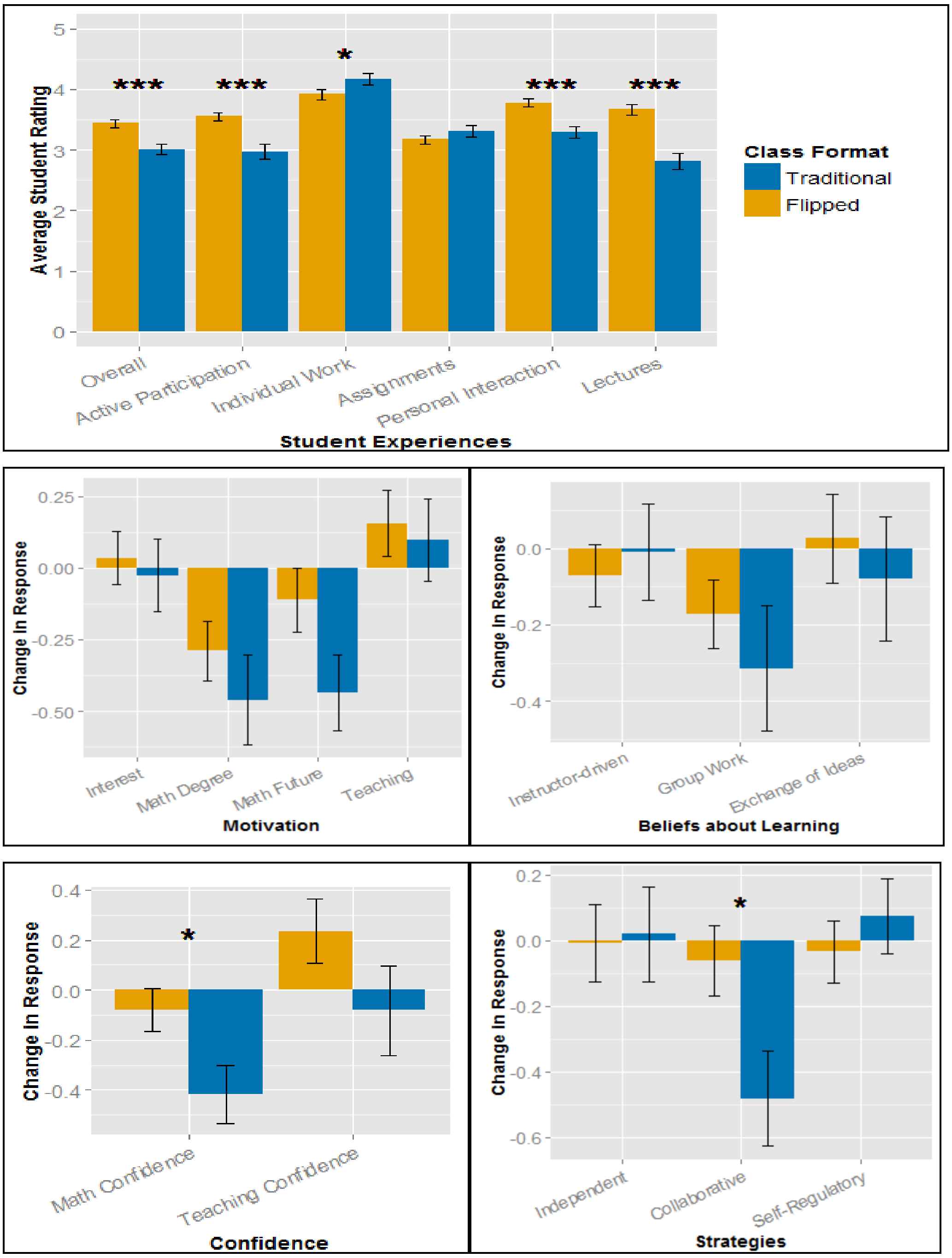

Figure 1: Average classroom experiences and changes in pre and post survey attitudinal variables based on classroom format with standard error bars.

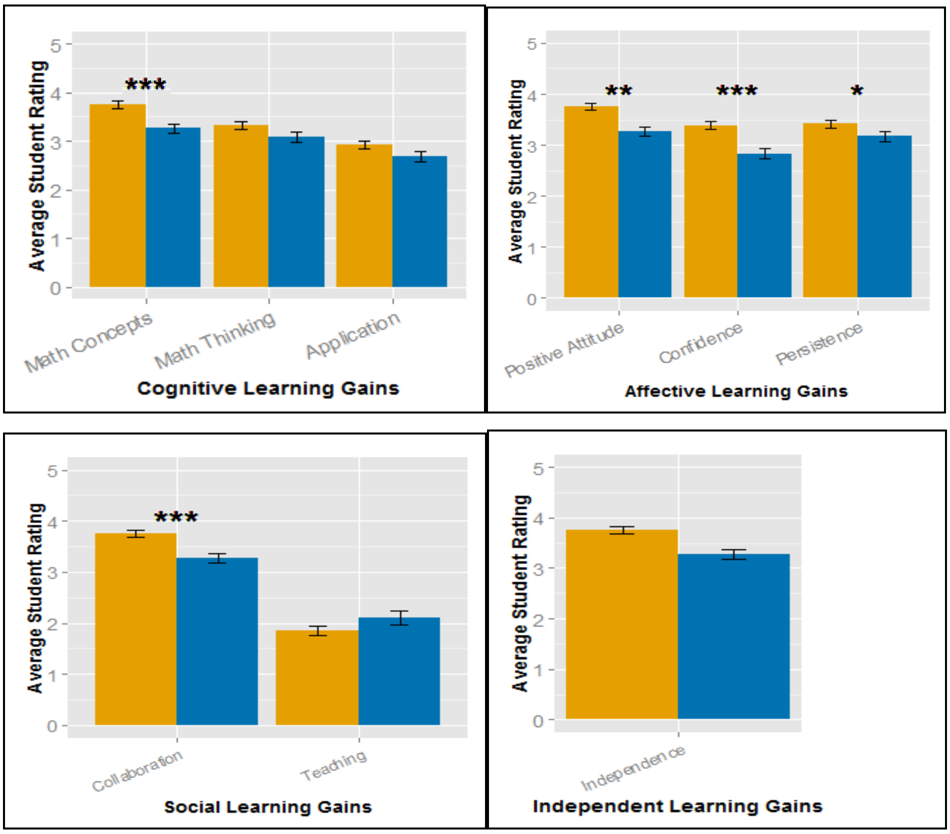

Figure 2: Average rating with error bars for learning gains based on classroom format.

Classroom Experiences

As suggested by prior research, students in a flipped format viewed the overall experiences in the course (workload, pace, and overall approach to the course) as a significantly greater help to their learning than students in a traditional format; however, the research goal was to further investigate the specific components of the course that may have contributed to the overall differential experiences of students in the FL versus the TL format. Active participation (class discussions, group work, explaining work to other students, and listening to other students explain their work), personal interactions (with the instructor, teaching assistant, and peers in the course) and lectures were seen as a greater help to students in the FL format, while individual work such as studying on your own was seen as a greater help to students in the TL format. Assignments were viewed as equally supportive for students in either the FL or the TL format.

In addition to questions about classroom experiences, students were asked, “Would you recommend taking another course offered in the SAME FORMAT as this one?” Contrary to the findings of Arnold-Garza (2014) and Jaster (2013), a large majority of the students (67%) in the FL courses would take the course again in the same format given the choice, compared to a similar but smaller percentage of TL courses students (54%) who said they would take the course again in a traditional lecture format. Further investigation into the make-up of students who would not recommend taking a flipped classroom format, showed a significant difference

$(\chi^2\ (1, \mathrm{N} = 182) = 8.12, \mathrm{p} = .004)$ in the gender composition with a larger proportion of women (N=40) saying they would not recommend the format as compared to men (N=15). The same difference was not present in the traditional class $(\chi^2(1, N = 118\ ) = .145, p = .70)$. Although gender and gender interactions with flipped learning were not significant for any of the composite variables, the fact that women were almost three times as likely to indicate a preference for not take the course again in flipped learning format warrants further investigation.

Affective and Learning Strategies Changes

Our results from the attitudinal assessment mirror the results of the MAA national study (Bressoud, Carlson, Mesa, & Rasmussen, 2013) indicating overall students are less confident in their mathematical ability after the completion of the course, but notably students in the FL course had significantly smaller declines in mathematical confidence $(F(1, 210) = 5.44, p = .02)$. In addition FL students as a result of the course reported higher affective learning gains including positive attitude $(\beta = -.39, t(282) = -2.92, p = .004)$, confidence $(\beta = -.56, t(284) = -4.65, p < .001)$, and persistence in mathematics $(\beta = -.25, t(283) = -1.98, p = .048)$. We conjecture that there are two contributing elements that resulted in the smaller declines in confidence for the FL students. One notable difference between the FL and TL courses, was the implementation of ten proficiency based quizzes that students had to master in order to pass the course. This mastery based learning approach gives students the opportunity to assert that they fully understand the core topics in the course. In addition to the mastery quizzes the availability of having the online lectures, which our log data shows a majority of students watched multiple times, also provides students with increased scaffolding to support understanding and learning of the course topics.

Students in the FL course also show attitudinal changes in the benefit they see in using collaborative strategies toward learning indicating that they are more likely to seek help from others and share information with other peers $(F(1{,}211) = 5.39, p = .02)$. This change in collaborative learning strategies we attributed to the reported social gains in collaboration $(\beta = -0.53, t(259) = -2.48, p = 0.01)$ due to the course, where FL students reported higher gains in their ability to work well with others, willingness to seek help from others and appreciation of difference perspectives as a result of the course.\

Mathematical Knowledge

Results from student performance on the common math final indicate modest gains in academic performance for students in the FL course (M=67.2) compared to students in the TL course (M=64.7) format $(F(407{,}1) = 3.38, p = .067, d = .18)$. Although it was not possible to obtain prior mathematical ability, the two course formats had no significant differences between the GPA's, number of college math courses taken, and highest high school math taken for the students, indicating that the prior mathematical ability among the two course formats were roughly equal. This information coupled with the reported higher cognitive learning gains for math concepts ($\beta = -.48, t(285) = -4.25, p < .001$) for the FL students, indicates the FL format was beneficial for student learning. Future studies should examine if the increases in collaboration and confidence for FL students will translate to better knowledge of higher level mathematical concepts, since we were only able to assess lower-order mathematical thinking on final exam multiple choice items.

CONCLUSIONS AND FUTURE STUDIES

Results from this study are promising for the future implementation of flipped style learning in undergraduate mathematics education. Students generally respond positively to flipped classroom learning experiences, and as a result show increased gains in confidence and willingness to collaborate with others in solving mathematical problems. In addition students show modest gains in mathematical knowledge. These positive trends indicate that flipped learning not only does no harm, but actually benefits students academically and attitudinally.

The next phase in this study will assess the qualitative data obtained through the survey instruments as well as course artifacts in order to understand with greater richness the experiences students had throughout the course, and answer some of the questions raised through our initial quantitative analysis. We seek to understand what factors contributed to the gender disparity in preference for taking a flipped course and whether there exist gains in higher-order mathematical knowledge as a result of using the flipped format. Additionally, we will be collecting longitudinal data to assess the impact this course had on persistence in STEM fields and student performance in subsequent math courses.

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