Flipping Calculus: The Potential Influence, and the Lessons Learned

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Abstract

Within the United States, there exists concern about the small numbers of STEM majors and the rate of attrition of students within STEM majors, especially for under-represented minorities. Improving the classroom experience with unique learning opportunities through student-centered instructional practices has been studied and reported as an effective means to influence retention and graduation rates of students in STEM fields. The project presented serves as an initial study examining how the implementation of the flipped classroom approach in Calculus influenced students' math achievement and attitudes about math and learning. Additionally presented is a personal review of the process, including the pros and cons of the experiences of the instructor and ideas on how to improve the flipped process for future classes.

1. Introduction

The fastest growing careers are those found in STEM fields. In 2013 the Obama administration has set aside approximately $3.1 billion to help improve recruitment and retention of STEM majors including $450 million directed towards increasing the number of trained educators [16]. Additionally from this funding, new national programs and initiatives (e.g., *Improving Undergraduate STEM Education* (IUSE)) have been developed [13].

While attrition in STEM-related fields is significant, it is highest among underrepresented minorities (URM) [9]. To combat this rate of attrition, specific attention needs to be made in college preparatory years. In a study conducted by Seymour & Hewitt (1997), it was found that instruction was deemed poor by 90% of surveyed students who switched majors and 75% of students who persisted through a STEM major. The negative views from students can be attributed to a variety of factors, including: emphasis on lectures, perceived hostility from the instructor towards student questions, curving procedures for tests and course grades, and classroom competitiveness [2, 18, 20].

Student-centered learning has been a focal point in improving the experiences of the student in the classroom at all levels of learning. These instructional improvements that utilize more reform-oriented methods in STEM courses have been found to improve retention within STEM majors [6, 19, 22]. Other changes in methods of instruction of STEM courses include small-group collaboration, hands-on discovery-based activities, and project-based learning. Evidence points out these methods are also beneficial to improving retention of URM [6, 12]. Courses that focus on student-centered learning additionally provide new opportunities for students to be actively engaged in the material and generate an atmosphere which promotes learning [17].

One common phrase is that lecturers and professors at universities "*teach the way they were taught*" because many have received little or no formal training in teaching before entering the classroom [7]. Oleson and Hora (2014) found faculty often model their teaching practices after their instructors. In many traditional STEM courses, instructor-led lectures has been the primary source of teaching. This often results in a continued cycle of new instructors emphasizing the use of instructor-led lectures [10]. Unfortunately, Halpern and Hakel (2003) state, "This is a satisfactory arrangement for learning if the desired outcome is to produce learners who can repeat or recognize the information presented. But it is one of the worst arrangement for promoting in-depth understanding" (p. 40). Faculty are capable learners and benefit from innovations to teaching methods in higher education [8]. Under this premise, one can then argue that it is our role as instructors and teachers to direct learning in a manner that would maximize the students' ability to have a stronger grasp of the core material presented in a course and would not only benefit the students, but also ourselves as educators.

One such method proposed is the use of student-centered learning by flipping the method of instruction. In contrast to a traditional lecture class, the flipped classroom has the student view lectures outside of the classroom as part of the work done at home [5]. Often, the lectures are viewed as short videos. Time in class is then spent collaborating with their classmates on practice problems or other hands-on activities. With time now available to the students to practice problems within the classroom setting, the instructor is free to assist groups of students who may need additional help in understanding key concepts and methods demonstrated in the videos.

Various studies have demonstrated positive effects on student engagement and achievement in the flipped classroom setting. For example, Dove (2013) found that students who participated in a flipped statistics course significantly preferred the flipped classroom approach to lecture-based classes and wanted more flipped class options. In examining math anxiety of pre-service elementary teachers, Dove & Dove (2015a) found that the research-based correlation between high math anxiety and low achievement was maintained in the traditional course while not being present in the flipped class. Similarly, Wilson (2013) found that students in a flipped statistics course significantly improved in their attitudes towards statistics, and their grades were significantly higher than when traditional methods were used. Within Calculus, the gateway course for many STEM majors, McGivney-Burelle and Xue (2013) found that students in the flipped class outperformed the traditional class on the final exam. More importantly, the students felt their learning opportunities were increased due to the activities presented in class. Although limited, these positive results in both student achievement and attitudes suggest that the flipped classroom may have an opportunity to help remove the chilly atmosphere that exists in many STEM-related classes, which in turn may assist in improve recruitment, retention, and graduation of students in STEM majors.

The purpose of this study was to examine the potential academic and perceptual effects of the flipped-classroom approach on the first semester of a Calculus and Analytical Geometry course.
Specifically, this study explored the following questions:

1. What influence did the flipped-classroom approach have on classroom achievement in comparison to a traditional instructionally-based Calculus class?
2. What influence did the flipped-classroom approach have on students' perceptions of mathematics and learning in comparison to a traditional instructionally-based Calculus class?
3. What lessons could be learned in flipping a Calculus course from an instructor's perspective?

2. Methods

Radford University is primarily an undergraduate institution composed of just under 10,000 students. Approximately 24% of the total undergraduate population is self-identified as members of the URM population and 35% are first-generation college students. In comparison, 35% of the incoming new freshmen identified as members of the URM population and 37% of the incoming new freshmen class were first-generation students. Within the smaller population of students enrolled in STEM programs offered at Radford University, 26% of the total population and 39% of new freshmen are identified as within the URM population.

2.1 Description of Course Design

To prepare for utilizing the flipped-classroom approach for Calculus, the instructor examined various flipped models and training. After examining various trainings, the instructor completed the online program *Flipped Classroom Training Program [Professor]* by Dr. Lodge McCammon and Dr. Steven Toaddy (http://professor.fizzedu.org/) during the summer of 2014. Training activities included: learning how to create lecture videos in multiple formats, effective note taking, utilizing student roles, creating student-centered activities, and asking high level questions.

Three sections of Math 151, Calculus I, were taught in the Fall 2014 semester. All three sections met three days a week for 50 minutes each day. The three sections were taught back-to-back in the morning as well. Two sections were designated to be instructed in the traditional method of instructor-led lecture and one section was selected to be instructed in the flipped classroom process. The semester began with a total of 41 students in the traditional classes and 20 students in the flipped class. By the end of the semester, only 30 students in traditional classes and 12 students in the flipped class completed the course.

The traditional classes were provided with in-class lectures by the instructor. This lecture typically lasted the entire 50 minutes of class. One section from the related text typically took one to two days to complete. Once a section was completed, students had until 12PM the following class meeting date to complete a five-question "lesson quiz" (LQ) on material directly related to theory and examples covered during the lecture. For example, if a section was completed on Wednesday, students would have until Friday at 12PM to complete the LQ.

The flipped class was scheduled three days per week for fifty minutes per class meeting. Students of the flipped class were required to view one to five short lecture videos, each lasting between five to fifteen minutes, prior to the class meeting. The theory and examples found in the videos were identical to those presented in the lecture classes. However, the nature of video lectures allowed these lectures to occur in an abbreviated amount of time [5]. The videos and playlists for this course can be found here: https://www.youtube.com/channel/UC4UOtOEBQFP5XgFKH3ikBSw.

During class meeting times, additional problems were worked in small groups, with typically two to three students per group. On occasion, group sizes were increased to between four and six students as the instructor believed this may promote additional collaboration. During group work time, the instructor observed student progress, corrected students if errors were seen, and answered questions as they arose. Solutions were presented primarily by students, but sometimes by the instructor if a problem was found to be difficult for groups. Students in the flipped class were sometimes tasked with creating and filming their own videos of working examples. These videos were submitted for review by the instructor for understanding of the material related to the example completed. As with the traditional classes, once a section was completed, students had until 12PM the following class meeting date to complete a five-question "lesson quiz" (LQ) on material directly related to theory and examples covered in the lecture videos.

To encourage the watching of the videos, no review about an item, theorem, examples, etc. to be found in the video was discussed. Questions specific to an item in the video were answered at the start of the class; however, no instructor-led lecture was given.

All classes were provided access to note sheets, which students could use as "fill-in the blank" style for note-taking purposes. All classes were also given the same tests, WebWork (online homework), Maple lab assignments, and written homework. The only pedagogical difference between the sections was the method of instruction.

2.2 Achievement Data Collection and Analysis

During the first two weeks of class, an achievement exam was administered. With permission from the College Board, an exam was composed of 25 AP-level exam questions from the released AP Calculus 208 Exam [1]. All questions selected were based upon material to be covered in the course. The achievement exam was given again as part of the final exam. In addition to the 25 questions, 6 common questions to all Calculus courses and 7 free response questions specific to the instructor's courses were included.

Three sets of data were analyzed for achievement data: individual class changes in achievement from the pretest to the posttest; differences between the two group's change in achievement; and differences between the two group's final exam grades. To compare individual class changes in achievement, each student's pretest and posttest scores were paired, and a Wilcoxon Signed ranks test was conducted. To compare differences between the groups, each student's difference score was calculated (posttest score minus pretest score), and a Mann-Whitney test was conducted. Similarly, a Mann-Whitney test was conducted on the group's cumulative grade on the 6 common questions and 7 free response questions of the final exam.

2.3 Perceptions of Learning Analysis

During the first week of class and last week of class, a survey on the attitudes of learning mathematics was administered to all three sections (pre-course survey: https://goo.gl/xxEFwG; post-course survey: https://goo.gl/2vG96g). This survey included 29 questions from a validated longitudinal study, *The Michigan Study of Adolescent and Adult Life Transitions* (MSALT) (http://www.rcgd.isr.umich.edu/ msalt/home.htm). These questions were chosen because reliability tests by MSALT's research team had shown strong loading patterns into seven specific categories related to students' attitudes and perceptions of learning. Five categories used a 7-point Likert scale, which were: Math Efficacy; Standard of Excellence in Mathematics; Mastery Potential of Mathematics; Utility and Importance of Mathematics; and Perception of Difficulty of Mathematics. Two categories used a 4-point Likert scale, which were: Intrinsic Value of Mathematics; and Self-Consciousness about Mathematics. Student scores were loaded into each category for both the pre-course survey and post-course survey. Change scores were calculated for each question (post-course score minus pre-course score).

Additionally, students were asked two 5-point Likert scale questions on the final survey, whether they would take another flipped math class and whether they would recommend a flipped math class to a friend. For both scales, "1" represented Very Unlikely and "5" represented Very Likely. These two questions were analyzed separately from the seven survey categories as they provided a potential personal perception of the value of flipped learning.

3. Results

3.1 Achievement Results

Analysis was conducted on both the pre/post course assessment, as well as the final exam to determine whether there was an influence of the flipped classroom approach on student achievement. As the number of paired samples for the test was under 30 pairs for each class, the Kolmogorov-Smirnov Test was run on each data set. As significant values were found for both group's post course test, non-parametric statistical analysis was conducted. First, each group was examined for any change in achievement scores from the pretest to the posttest using a Wilcoxon signed-rank test (Table 1). Both groups significantly increased, suggesting that participation in either form of the Calculus course led to an increase in achievement.

Table 1: Pre-Course and Post-Course Median Scores on the Achievement Test

	Median Scores		
	Pre-Course	Post-Course	*Z*
Traditional Classes	4.5	6.5	3.6*
Flipped Class	3.5	5.0	2.3*

*Note: * p<0.05*

A Mann-Whitney test was conducted to examine if there were any differences in the median score increase. The Mann-Whitney test indicated that there was no significant difference in the scores of those in the traditional courses (Mdn = 3.5) and the flipped course (Mdn = 2.0), Z(U) = 0.28, p = .78, r = 0.05. Additionally, a Mann-Whitney test was conducted to examine if there were any differences in the final exam scores. The Mann-Whitney test indicated that there was no significant difference in the scores of those in the traditional courses (Mdn = 64.5) and the flipped course (Mdn = 58.0), Z(U) = 0.16, p = .88, r = 0.03. This suggests that neither instructional method was significantly better at improving student achievement.

3.2 Perceptions of Learning Results

Analysis was conducted on difference scores for each of the seven categories and two recommendation questions to determine whether there was an influence of the flipped classroom approach on student perceptions of learning. As the number of paired samples for the survey was under 30 pairs for each class, the Kolmogorov-Smirnov Test was run on each data set. As significant values were found within several groups, non-parametric statistical analysis was conducted. Additionally, reliability analysis was conducted on the pre-course survey responses and the post-course survey responses. Cronbach's alpha was at least 0.8 for six of the seven categories on both the pre-course survey and the entire post-course survey. Only the category of *Standard of Excellence in Mathematics* was substantially lower at 0.67. Additionally, when each item was analyzed using "Cronbach's Alpha if Item Deleted," every individual item maintained a value within 0.1 of the each category's overall value on both surveys, thus suggesting acceptable reliability within each survey.

A Mann-Whitney test was conducted to examine if there were any differences in the median score changes from the pre-course survey to the post-course survey between the two groups (Table 2). No significant differences occurred between the two groups for the seven survey categories. This primarily occurred because there was little to no change in students' perceptions in either group, thus suggesting that participation in either course did not necessarily improve nor decrease their overall perceptions of learning mathematics.

Student responses to the open ended questions about what was liked, disliked, and additional comments support this belief as well. While several students mentioned the additional work outside of class due to the lecture videos, they also saw its added value. As one student stated, "I like that [the instructor] lets us try problems on our own and walks around in case we get stuck. If we didn't watch the lecture videos ahead of time, we wouldn't have time in class for that kind of assistance on problems."

Table 2: Median Change Scores on the Perceptions of Learning Survey

	Median Change Scores			
	Flipped	Traditional	*Z(U)*	*p*
Math Efficacy	0	0	-0.57	0.57
Standard of Excellence in Mathematics	-1	0	-0.23	0.82
Mastery Potential of Mathematics	0	0	-0.19	0.85
Utility and Importance of Mathematics	-2	-1	-0.63	0.53
Intrinsic Value of Mathematics	0	0	-0.71	0.48
Self-Consciousness about Mathematics	0	0	-0.23	0.82
Perception of Difficulty of Mathematics	-1	-0.50	-0.25	0.80

Table 3: Median Scores on the Perceptions of Flipped Courses

	Median Change Scores			
	Flipped	Traditional	*Z(U)*	*p*
Likely to Take Another Flipped Math Course	5	2	-2.4	0.02
Likely to Recommend a Flipped Math Course	5	3	-2.3	0.02

4. Discussion

The purpose of this study was to examine whether different instructional practices, specifically flipped versus traditional lecture, influenced students achievement and perceptions of learning. For this small sample size, the flipped classroom approach was not found to have any different significant impact on students than the traditional lecture method. However, students in the flipped classroom did show appreciation for the method and their survey results suggested they wished to take more math classes that used this method.

One factor that may have influenced the limited significance found in this study was full student responsibility in watching the videos before class, as well as consistent attendance. Research has suggested that a key component to successful flipped classes is the continuous engagement of the students in class [5]. There was a specific subset of the class that regularly came prepared watching the video and rarely missed class. This group did well overall, however the small class size does not allow for data extrapolation from this subgroup. Future research may wish to consider requiring attendance and lecture video completion through a method such as notebook checks, or requiring notes to be turned in for a homework grade.

4.1 Instructor Observations of the Process and Implementation of a Flipped Class

Interest in the flipped classroom process began for the instructor when he was given in 2013 a 10-week summer Calculus II class which met four days per week approximately 3 hours per day. It was believed that both the students and instructor would have difficulties if the class was taught as a traditional lecture course. To mitigate this concern, the instructor created short lecture videos, no more than 5 minutes each on the topics for the course which highlighted essential concepts. Additional short videos of worked example problems were also made available to the students.

Based upon the self-perceived success of the class, the instructor was curious if this process would be successful in a regular semester. Preparing for a transition between a traditional to a flipped class can be seen as overwhelming. However, the instructor had materials needed for the traditional class already available as he had previously taught the course in the traditional setting. Such materials included PowerPoint presentations for lectures, skeleton note sheets, WebWork problems, and exam reviews. With these materials available, most of the time could be focused on generating the flipped classroom materials.

The time to convert an entire previously designed traditional lecture course to one for flipped instruction totaled approximately 70 working hours. Included in this total was approximately 6 hours needed to initially learn how to use and become comfortable with the technology required for creating the flipped class (e.g., webcam and *Screencast-O-Matic*, developing lesson-quizzes in the learning management system, etc.). Once the technology was mastered, the predominant amount of time was spent creating the videos and subsequent lesson quizzes. Videos filmed were created matching the PowerPoints which were labeled with each section from the text. However, a significant lesson was learned by including these labeled sections in the videos. Since the teaching of the flipped Calculus class, the course has changed to a different textbook. Although much of the in-class material can be reused or minimally modified, the lecture videos needed to be recreated as the sections and topics between the textbooks were not equivalent. For example, "Basic Differentiation Rules" in one text book may be in Chapter 2, Section 2 in one book and Chapter 3, Section 1 in another book. Therefore, it is recommended that the video should only mention the primary topic in order to be able to use the videos for future modifications to the textbook. For example, "2.2 Basic Differentiation Rules" would be recorded just as "Basic Differentiation Rules."

As stated earlier, one major difficulty for the flipped process is the reliance on students watching the lecture videos. Early in the semester, students were not consistently watching the lecture videos before class. In order to combat this issue, a notes check was implemented. However, no score was assigned to the note check.
Shortly after the midpoint of the semester, students were asked if they watched the videos for completion or for understanding. Unfortunately, most replied it was for completion so that they would receive credit for the note check. This was of concern because students were provided skeleton notes that could have been completed without the student truly listening to the presentation in the video. However, several students did eventually learn to watch for understanding by the end of the semester. As one student stated on the survey, "With the pre-recorded lectures, I liked that I was able to learn at my own pace and did not have to rush to write everything down in time. I would usually pause the video to copy down notes and equations, that way I would be able to pay full attention to the explanations given instead of furiously trying to scribble notes."

In contrast, while students in the traditional sections took notes using the skeleton notes, they were required to listen to the entire lecture. Traditional students suggested this to be a positive aspect of their class as well. As one student stated, "The fill-in notes were great so that I could pay attention more to what was being said than having to write down everything and miss something [the instructor] said." While students may also lose their attention during a 50 minute course, it was perceived that the flipped class would have a significant advantage in note taking as they would have the ability to pause and/or rewind the video in order to process the concepts at a higher cognitive level. Unfortunately, that did not transpire as fully within this study as was anticipated.

For the flipped class, in-class activities often included problems directly from the textbook. It is believed that these activities could be improved by creating activities that not only question the students' ability to solve problems similar to those demonstrated in the videos, but also force the students' to explain both the methods used and core mathematical concepts found in the problems. For basic practice, problems from the text can be helpful. However, it was observed that students appeared more engaged during the flipped class meeting times with the lessons that were more application-based. As most textbook sections include applications of the basic skills these observations suggest that more of these problems should be a part of the in-class activities.

One interesting activity that only occurred with the flipped class was the opportunity for students to create their own videos. To further check student understanding of items found in the activities, students were tasked several times throughout the semester with creating their own videos of how they worked problems. Students worked in small groups creating their own videos in a variety of manners: some used smart phones or iPads recording themselves working the problems at a board, while others filmed their work over their shoulder either walking the viewer step-by-step or in a manner of revealing their results line-by-line. Upon completion, the students submitted their videos through the learning management system's drop box for the instructor to review. The instructor commented on their videos indicating any item that was not clear or incorrect, or that their work was well done and thoroughly explained. The best videos were then posted on the learning management system, along with the lecture videos, for students to use when reviewing for the day's activities, for tests, or for the final exams.

Another distinct aspect of the flipped class was how time in class was used. Whereas, with the traditional sections the instructor is typically speaking ***at*** the students, in the flipped class an instructor speaks ***with*** the students. During most meetings, students were asked to form their own groups of any size. While the instructor believed this would help promote collaboration, students typically banded with individuals in their immediate vicinity. In an attempt to increase collaboration amongst the students in the classroom, the instructor increased the size of the groups hoping for the smaller groups to mix beyond proximity seating. While there were some cases of this improving group discussion, students would often recreate their subgroups within the larger group. For that reason, maintaining groups no larger than 3 to 4 may often be more relevant in promoting collaboration.

Whether discussion occurred within larger groups or the subgroups, it did provide a positive opportunity for small group dialogue with the instructor. As students worked the problems from the day's activities, the instructor listened and observed each group's discussions. In the event the group erred in their thoughts or practices, the instructor would intervene asking questions to gauge whether or not the error was minor or major. On occasion, the instructor would refer members of one group to assist another group in the event they finished early and did well on the activities. This allowed the instructor to work with all groups without one group or individual monopolizing his time in class. Additionally, there were instances in the class where a common error existed. In those cases, the instructor would stop the class and address it as a collective group. These opportunities are not possible in the traditional class. Though critical thinking skills can be challenged with question and answer conversations between instructor and students, these often occur with the best students in the class, and there is typically not enough time during a lecture session to allow for student collaborations.

5. Future Research

Although the process of using a flipped class for Calculus did not result in significant improvements on student scores, there was evidence that there may be some positive aspects of the method that should be further investigated. As more instructors and teachers in post-secondary education are gravitating toward a more student-centered learning style, continued research is necessary to garner the effects of this approach. It is proposed that longitudinal studies should be developed tracking the progress of students, especially those in STEM fields, as they encounter more classes instructed in the flipped process. Questions to be addressed should include, "What are the long-term effects of the flipped classroom process on achievement and retention," "Does the flipped class alleviate math anxiety across STEM programs," and "How will students view the effects of lecture if they have a predominant number of classes taught in the flipped process?"

6. References

[1] The College Board Advanced Placement Program. (2009). *2008 AP Calculus AB and AP Calculus BC: Released Exams*.

[2] Daempfle, P.A. (2003). An analysis of the high attrition rates among first year college science, math, and engineering majors. *Journal of College Student Retention*, *5*(1), 37-52.

[3] Dove, A. (2013). Students' perceptions of learning in a flipped statistics class. *Proceedings of SITE International Conference 2013 (pp. 393 – 398)*. Chesapeake, VA: AACE

[4] Dove, A. & Dove, E. (2015a). Examining the influence of a flipped mathematics course on preservice elementary teachers' mathematics anxiety and achievement. *Electronic Journal of Mathematics & Technology (eJMT),* *9*(2), 166 - 179. Retrieved from: https://php.radford.edu/~ejmt/deliveryBoy.php?paper=eJMT_v9n2n2

[5] Dove, A. & Dove E. (2015b). Flipped mathematics classroom: What? Why? & How? *Virginia Mathematics Teacher*, *42*(1), 36 – 40.

[6] Gainen, J. (1995). Borders to success in quantitative gatekeeping courses. *New Directions for Teaching and Learning*, *61*, 5-14.

[7] Halpern, D. & Hakel, M. (2003). Applying the science of learning to the University and beyond: Teaching for long-term retention and transfer. *Change: The Magazine of Higher Learning*, *35*(4), 36-41.

[8] Hellman, J., Paus, E., & Jucks, R. (2014). How can innovative teaching be taught? Insights from higher education. *Psychology Learning and Teaching 13*(1), 43-51.

[9] Higher Education Research Institute. (2010, January) Degrees of success: Bachelor's degree completion rates among initial STEM majors. Retrieved from http://www.heri.ucla.edu/nih/downloads/2010%20-%20Hurtado,%20Eagan,%20Chang%20-%20Degrees%20of%20Success.pdf

[10] Mazur, E. (2009). Farewell, lecture? *Science*, 50-51.

[11] McGivney-Burelle, J. & Xue, F. (2013). Flipping calculus. *PRIMUS*, *23*(5), 477 – 486.

[12] McShannon & Derlin. (2000). Retaining minority women engineering students: How faculty development and research can foster student success. *Proceedings of New Mexico Higher Educational Assessment Conference*, Las Cruces, NM.

[13] National Science Foundation. (2013). *Improving Undergraduate STEM Education.* Retrieved from https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504976.

[14] Obama, M. (2011, September 26). *When you make life easier for working parents, it's a win for everyone involved.* Speech presented at the National Science Foundation Family-Friendly Policy Rollout. Retrieved from http://www.whitehouse.gov/photos-and-video/video/2011/09/26/first-lady-michelle-obama-national-science-foundation-family-frien#transcript.

[15] Oleson, A. & Hora, M. (2014). Teaching the way they were taught? Revisiting the sources of teaching knowledge and the role of prior experience in shaping faculty teaching practices. *Higher Education, 68*(1), 29-45.
[16] Petty, K. (2013, April 22). *Obama Administration commits $3.1 billion to STEM education.* Retrieved from http://ivn.us/2013/04/22/obama-administration-commits-3-1-billion-to-stem-education/?utm_source=ivn&utm_medium=featured&utm_content=prevnext&utm_campaign=opt-beta-v-1-0
[17] Rhoads, T.R., Murphy, T.J., & Trytten, D.A. (2005). *A study of gender parity*: *Department culture from the students' perspective*. Proceedings of 35th ASEE/IEEE Frontiers in Education Conference, Indianapolis, IN.
[18] Seymour, E. and Hewitt, N. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press.
[19] Springer, L., Stanne, M., & Donovan, S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research, 69*(1), 21-51.
[20] Strenta, C., Elliott, R., Russell, A., Matier, M., and Scott, J. (1994). Choosing and leaving science in highly selective institutions. Research in HigherEducation. 35. 513-537.
[21] Wilson, S. G. (2013). The flipped class: A method to address the challenges of an undergraduate statistics course. *Teaching of Psychology, 40*, 193 – 199.
[22] Wise, J.C., Lee, S.H., Litzinger, T., Marra, R.M., & Palmer, B. (2004) A report on a four-year longitudinal study of intellectual development of engineering undergraduates. *Journal of Adult Development*, *11*(2), 103-110.