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Applying Technology to Improve Student Learning Outcomes in Dynamics Course

Mileta Tomovic
Old Dominion University, mtomovic@odu.edu

Cynthia Tomovic
Old Dominion University, ctomovic@odu.edu

Vukica M. Jovanovic
Old Dominion University, v2jovano@odu.edu

Cheng Y. Lin
Old Dominion University, clin@odu.edu

Nan Yao

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Dr. Mileta Tomovic, Old Dominion University

Dr. Tomovic received BS in Mechanical Engineering from University of Belgrade, MS in Mechanical Engineering from MIT, and PhD in Mechanical Engineering from University of Michigan. Dr. Tomovic is Professor of Engineering Technology, and Mechanical and Aerospace Engineering, F. Batten College of Engineering and Technology, Old Dominion University, Norfolk, VA. Prior to joining ODU Dr. Tomovic had seventeen years of teaching and research experience at Purdue University, with emphasis on development and delivery of manufacturing curriculum, conducting applied research, and engagement with Indiana industry. While at Purdue University, Dr. Tomovic served as W. C. Furnas Professor of Enterprise Excellence, University Faculty Scholar, Director of Digital Enterprise Center, and Special Assistant to Dean for Advanced Manufacturing. He has co-authored three books on hydraulic systems, product lifecycle management, and manufacturing processes. In addition, he has authored or co-authored over 140 papers in journals and conference proceedings, focused on applied research related to design and manufacturability issues, as well as issues related to mechanical engineering technology education. Dr. Tomovic made over 60 invited presentations nationally and internationally on the issues of design optimization and manufacturability. He has co-authored four patents, and over 120 technical reports on practical industrial problems related to product design and manufacturing process improvements.

Dr. Cynthia Tomovic, Old Dominion University

Professor in STEM Education and Professional Studies, Darden College of Education, Old Dominion University, VA.

Dr. Vukica M. Jovanovic, Old Dominion University

Dr. Vukica Jovanovic is an Assistant Professor of Engineering Technology in Mechanical Engineering Technology Program. She holds a Ph.D. from Purdue University in Mechanical Engineering Technology, focus on Digital Manufacturing. Her research is focused on mechatronics, digital manufacturing, digital thread, cyber physical systems, broadening participation, and engineering education. She is a Co-Director of Mechatronics and Digital Manufacturing Lab at ODU and a lead of Area of Specialization Mechatronics Systems Design. She worked as a Visiting Researcher at Commonwealth Center for Advanced Manufacturing in Disputanta, VA on projects focusing on digital thread and cyber security of manufacturing systems. She has funded research in broadening participation efforts of underrepresented students in STEM funded by Office of Naval Research, focusing on mechatronic pathways. She is part of the ONR project related to the additive manufacturing training of active military. She is also part of the research team that leads the summer camp to nine graders that focus on broadening participation of underrepresented students into STEM (ODU BLAST).

Dr. Cheng Y. Lin P.E., Old Dominion University

Dr. Lin is a Professor and Program Director of Mechanical Engineering Technology at Old Dominion University. He received his PhD of Mechanical Engineering from Texas A&M University in 1989, and is a registered Professional Engineer in Virginia. Dr. Lin has expertise in automation control, machine design, CAD/CAM, CNC, geometric dimensioning and tolerancing, and robotics. He has been active in the technology application research and teaching training courses for the local industries and technology application center

Ms. Nan Yao, Beihang University

Nan Yao is currently an Assistant Professor, Beihang University, Beijing, China, and a visiting scholar at Old Dominion University, Norfolk, Virginia. Her research interests include reliability of complex networks, advanced simulation, control systems, and engineering education.

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Abstract

Motivating and stimulating students to learn material in required core engineering courses is difficult and yet essential in assuring student success. Traditional methods of teaching and learning need to be reconsidered and modified to meet student expectations and their continuously evolving ways of interaction with technology and social networks. Numerous faculty have been experimenting with various approaches which are taking advantages of both technology and student interaction with technology, with various degrees of success. In this paper authors present another comprehensive method applied in teaching/learning of core engineering mechanics course. It has been observed over a long period of time that Dynamics is one of the more difficult courses in the Mechanical Engineering and Technology programs where students are experiencing certain difficulty in mastering the material. Authors integrated technology into learning experiences in order to stimulate and motivate students to master the material, which proved to be very successful. It has been observed that new approach improved the final scores in the course as well as student satisfaction with this approach of presenting material as well as testing their understanding of the required material. The paper presents results from two years of teaching the course with the current approach, along with lessons learned from this experience.

Introduction

Teaching/learning process is an age long human activity of passing knowledge from person to person [1]. The process has experienced progressive transformation over time as people were obtaining deeper understanding of the cognitive science [2] and were provided with diverse tools to perform this transfer in a more effective manner [3]. The process of knowledge transfer is highly dynamic and dependent on its content and relationship between student and teacher [4] and needs to be tailored to both for an effective outcome [5]. A number of different teaching methods emerged over the years including active learning [6], flipping classroom [7, 8], problem based learning [9] to name just a few.

After teaching mechanics courses in a traditional format for a number of years it became apparent that any quantum jump in student learning success requires structural departure from the old teaching method and substantial overhaul modifications which would integrate different pedagogical experiences and insights along with implementation of modern tools. It was apparent that traditional teaching in a classroom was having limited results with overall passive audience which was partially engaged in the transfer of knowledge. The process of the course modification took significant planning effort along with lengthy restructuring of the material and creating extensive supporting material that would assist students with actively engaging in the learning process.

The paper describes some of the modifications made to the course along with the results achieved over the four semesters that the course has been taught in the new format. The results indicate that modifications resulted in anticipated positive outcomes as students' overall scores improved indicating better mastery of the material and ability to solve practical problems.

Method

The intent of the modifications introduced into the Dynamics course was to improve student mastery of the material and to provide them with examination mode that will be conducive to effectively and accurately conveying learned material and ability to apply their knowledge to the real world problems.

A comprehensive intervention in course delivery and assessment process was made including the following modifications:

- Assessed the knowledge of the pre-requisite material.
- Provided pre-requisite refresher review materials.
- Narrated, taped, and posted lectures on the Blackboard.
- Worked out, narrated, taped and posted numerous examples on the Blackboard.
- Provided self-assessment tools and encouraged students to review the material.
- Developed and posted numerous quizzes and homework assignments on the Blackboard.
- Encouraged students to work in teams to solve homework problems.
- Changed testing environment and timing.
- Developed grading technique to simulate various stages of learning and application.

Although these elements have been applied, individually or in groups, in different courses over the years, to the best of the authors' knowledge, all of them combined have not been implemented in a single course. Each of the items and their rationale is described in the following text.

Pre-requisite material

The requirement for successful mastery of the material in the Dynamics course for engineering technology students requires basic knowledge of Calculus I, Statics, and Physics. It has been observed that number of students have forgotten or have limited knowledge of the required pre-requisite material. In order to access their knowledge and guide them on the refresher material, basic diagnostic tests on statics and calculus are conducted during the first week in the semester. The students are incentivized to perform to the best of their abilities by including the score in the overall score for the course. Additional reading material and worked out problems are narrated and posted in the Blackboard so that students can review the material and start the class with a good understanding of what is being expected of them to successfully master material in Dynamics course.

Lectures and examples

The material covered in Dynamics course is quite challenging for most students. For most students, attending class and taking notes is not sufficient for mastery of the material. Majority of students require frequent and repetitive review of the material so that they can fully master the material. The content requires multiple, slower, and branching progression compared to linear and relatively fast paced delivery in the classroom. Hence, all of the lectures have been narrated and taped so that students can review them as many times as they need to understand the basic principles and their application to various practical problems. In addition, covering theory in Dynamics is of limited use to many students who are more practice oriented and need to solve practical problems. Consequently, a number of worked-out problems were developed, taped, and posted on the Blackboard. This allows students to go over the problems as many times as necessary.

This approach has minimized and even eliminated time spent in the classroom on taking notes as students have everything at their disposal. Students are expected to go over the material prior to attending class so that the class time is used to discuss issues that require extra attention and more in-depth explanation.

Quizzes and Homework Assignments

Mastery of Dynamics requires continuous practice by working out different problems. Hence, the course has 43 quizzes and 8 homework assignments. As the course material builds up quickly, where every additional new content depends on the previous one, students must continuously study and practice covered material. If students miss a single topic it can have a significant negative effect on the overall success. All of the assignments with appropriate feedback are uploaded on the Blackboard. The students are encouraged to work in teams on the homework assignments. The goal was to provide students with opportunities to learn from each other and to strengthen their understanding of material by explaining it to others.

Testing environment

The quizzes and exams are posted on-line and students are allowed to solve assignments at their own pace and at the location that is the most conducive to reducing stress induced by the testing experience. This approach mimics industry/job environment where students will have limited time to solve problems but still more than just one hour typically allowed in academia. In addition, additional stress induced by the presence of instructor is eliminated and reflects work environment in industry, as one would expect in most cases that supervisors would not be monitoring employees as they solve problems. Although there may be occasions where students would have to solve problems quickly, one would not expect that to be applicable to cases which would require lengthy calculations which would be common for design problems involving systems dynamics.

The students are asked to sign University Honors Code at the beginning of the semester. If the students do not sign the “contract” they will not receive the grade in the course. There were no students who refused to sign the Honors Code. The overall scores in the course indicate that there is no, or extremely limited, academic dishonesty.

Assessment method

In order to encourage continuous learning and timeliness, quizzes and homework assignments are released and closed on a predefined periodic basis. The quizzes are opened every other day for a period of 24 hours, while homework assignments are opened for a period of one week. No late submission is allowed. The quizzes and homework assignments are graded based on the highest score amongst three attempts. The homework assignments are scored based on the final answers and based on the submitted image of the work-out problem. No partial credit is given for an inaccurate solution, and zero credit is given in cases where detailed work is not submitted. Consequently the students are not penalized for missing problem during the learning phase. That is, the students are provided feedback and guided towards the correct solution while at the same time they are not given credit for partially solving problems.

Exams are open for 24 hours on a specified date, and have two parts – the first is similar to quizzes (multiple choice and short calculations) while the second is similar to homework assignments (long problems). The overall score is based on the average of three attempts for both parts. This approach is intended to encourage students to do the best they can during the first attempt, while additional attempts are recognizing the fact that they are still in the learning phase and may require some “guidance”. No partial credit is given for problems with incorrect answer. The overall strategy is to simulate learning progression from educational environment to industry/work setting. Although these modifications were initially greeted by students with apprehension, at the end of the course students recognized the benefits of this structured and rigorous approach and expressed very positive attitude towards the examination strategy.

Results

The study was performed on the results collected during eight semesters (S'13 – F'16). The course modification was made in the Fall '14 and implemented in the Spring '15. The reported results prior to Spring '15 semester (S'13-F'14) are when the course was taught in traditional manner while the results with new approach are reported for the last four semester (S'15-F'16). The number of students varied from semester to semester as shown in Table 1.

Table 1: Class size for analyzed semesters S'13-F'16.

Semester	S'13	F'13	S'14	F'14	S'15	F'15	S'16	F'16
No. students	32	29	29	39	72	22	52	22

Student success, as measured by the overall grade, across eight consecutive semesters (S '13 to F '16) is shown in Fig. 1. The figure also shows the average overall score for the class as a function of semester. As previously indicated, the major modification in the course were implemented in the Spring '15. It is apparent that student learning success improved staring with the Spring '15 and has leveled off during subsequent semesters. The average for the class was approximately 70/100 prior to the Spring '15 and it increased to approximately 80/100 in subsequent semesters. The overall improvement is close to 15%. The comparison between the two periods has to be done carefully with additional insight which will be presented in the discussion section below.

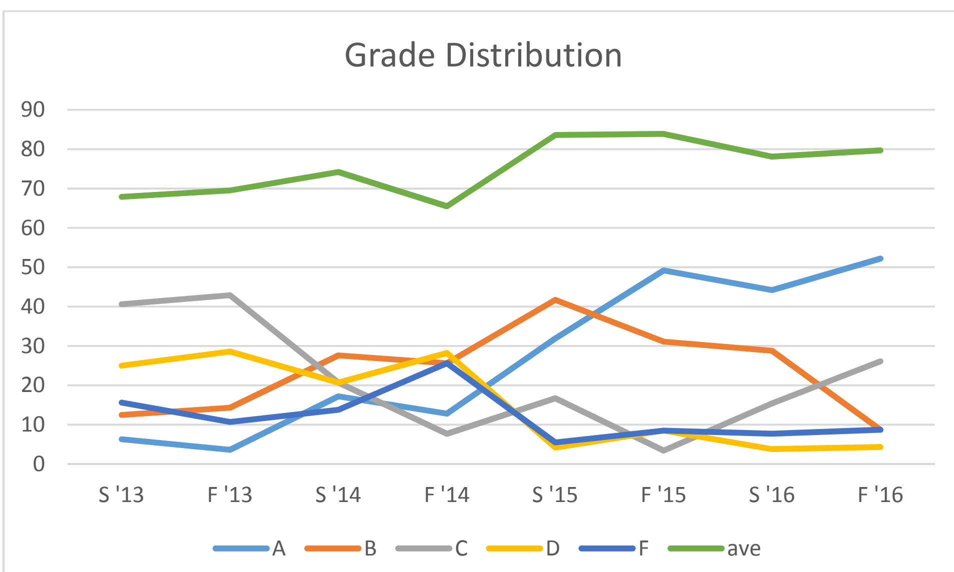

Fig. 1. Grade distribution and overall score average vs semester.

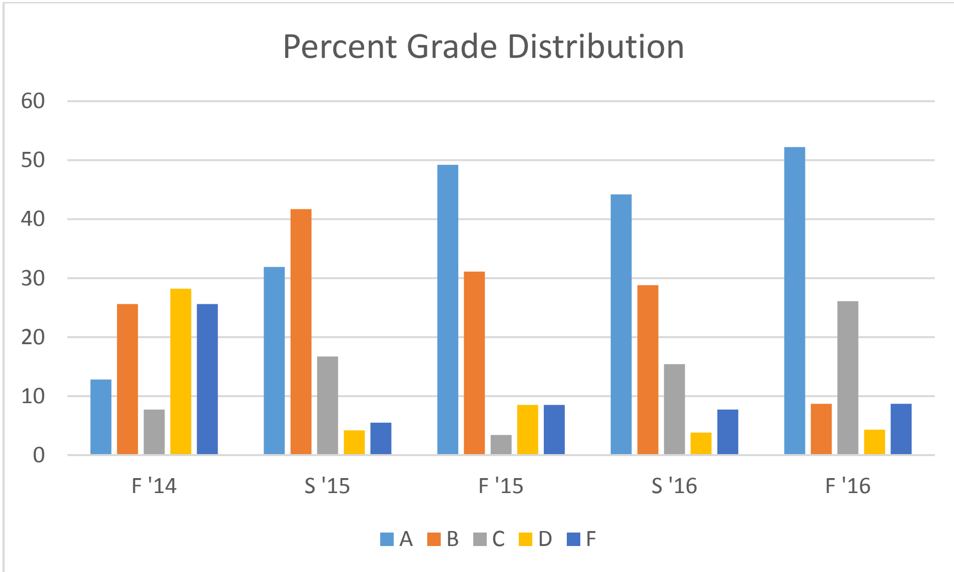

Figure 2. Grade distribution vs semester.

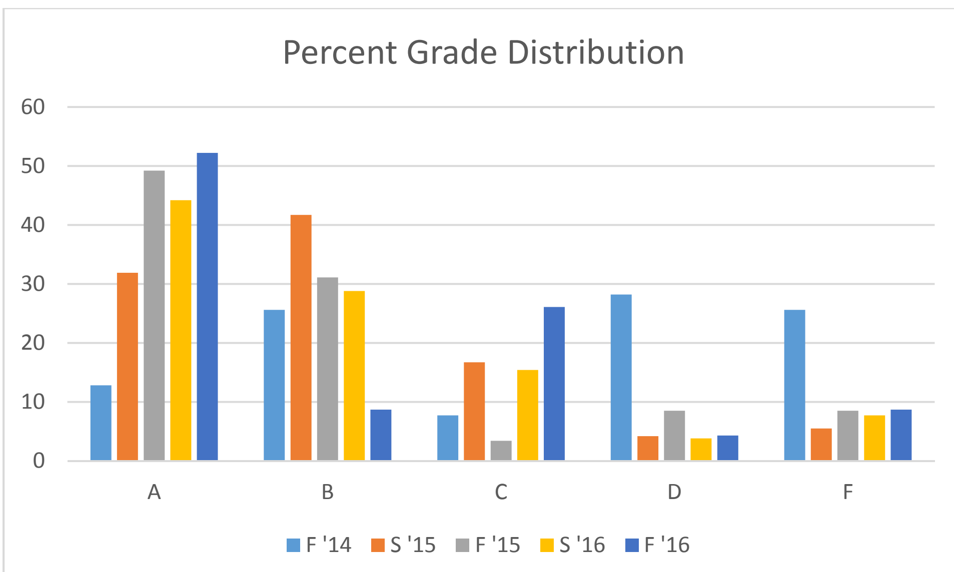

Figure 3. Grade distribution vs semester

The results in Fig. 1-3 indicate that there was substantial improvement in student learning when teaching method was switched to a new one in the Spring ’15. There could be several factors that could have contributed to that change. First, all the material was available on-line so students could access it at their own time and go over it at their own pace. Second, the number of exercises and strict adherence to those deadlines, which were every 2-3 days, forced students to focus on the course and learn the material at required pace since the material is cumulative and falling behind the pace would have negative impact on their mastery of the material. Third, students had access and utilized chat groups to discuss problems and learn from each other. Fourth, examinations were done at a more relaxed atmosphere which did not put extra pressure on students to demonstrate their knowledge. Finally, the grade was based on the average between three attempts, while there was no partial credit given.

In addition, the analysis of student performance across course objectives, Table 2, was measured and results are presented in Fig. 4.

Table 2. Course Objectives

No.	Course Objective
1	Perform kinematic analysis of particle motion for rectilinear motion. Calculate position, velocity and acceleration of a particle using different methods.
2	Perform kinematic analysis of particle motion for curvilinear motion. Calculate position, velocity and acceleration of a particle using different methods.
3	Use Newton's Second Law to solve for rectilinear and curvilinear motion of a particle and system of particles.
4	Perform kinematic analysis of rigid bodies including translation, rotation, and general plane motion.
5	Use Newton's Second Law to solve plane motion of a rigid body and system of rigid bodies.
6	Use principle of work and energy to solve problems involving particle motion.
7	Use principle of work and energy to solve problems involving rigid body motion and problems involving system of rigid bodies.
8	Use impulse and momentum principle to solve problems involving problems involving impulsive motion.

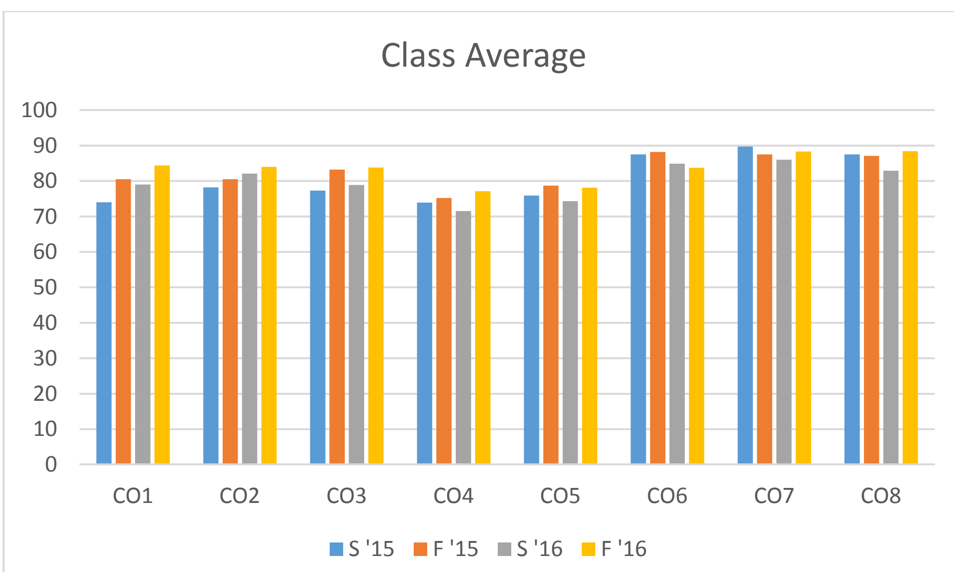

Figure 4. Student performance vs course objectives

It can be observed that students are doing very well across all eight course objectives. It can also be observed that, on average, students are doing somewhat better on course objectives 1-3 and 6-8. These objectives are dealing with motion of particles, whereas objectives 4 and 5 are dealing with rigid body motion. It has been observed, over the years, that students are having a little more difficulty with kinematics and dynamics of rigid bodies which correlates well with observed performance, Fig. 4. Also, results for objectives 6-8 are higher than for the other ones, which is in line with the experience that students do well with solving problems using work-energy and impulse and momentum principles. Nevertheless, the overall performance for objectives 4 and 5 is satisfactory, but it also indicates that future efforts need to be made to address that issue and try to improve student mastery of the material for rigid body kinematics and dynamics. Application of different software tools may assist in deeper understanding of that material and will be reviewed for future implementation.

The course is also assessed for TAC ABET student learning outcomes, Table 3. The assessment results are shown in Fig. 5-7.

Table 3. Assessed ABET student learning outcomes

No.	Course Objective
a	an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities
b	an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies
f	an ability to identify, analyze, and solve broadly-defined engineering technology problems

It can be observed that the applied instructional approach results in very good overall student performance for all assessed outcomes. The average number of students who exceed expectations across different semesters is approximately 50% for outcome (a), and 40% for outcomes (b) and (f). The semester-to-semester (spring vs. fall) variability is somewhat noticeable and no clear reason for that could be identified at the present. There is no substantial difference in teaching approach from semester to semester. The major difference between Fall and Spring semesters is the fact that course is delivered to traditional in-class students, whereas in the Spring it has two sections, where one is delivered to traditional in-class students while the other one is delivered to distance students. It has been observed that distance students perform somewhat better than traditional in-class students. Namely, they complete most of their assignments and mostly on time while it is not the case for traditional in-class students. Also, distance students are on average more mature and have different approach to their studies. This issue is interesting and will be further investigated with additional long term data to be collected in the future along with appropriate surveys which could point towards reasonable conclusion.

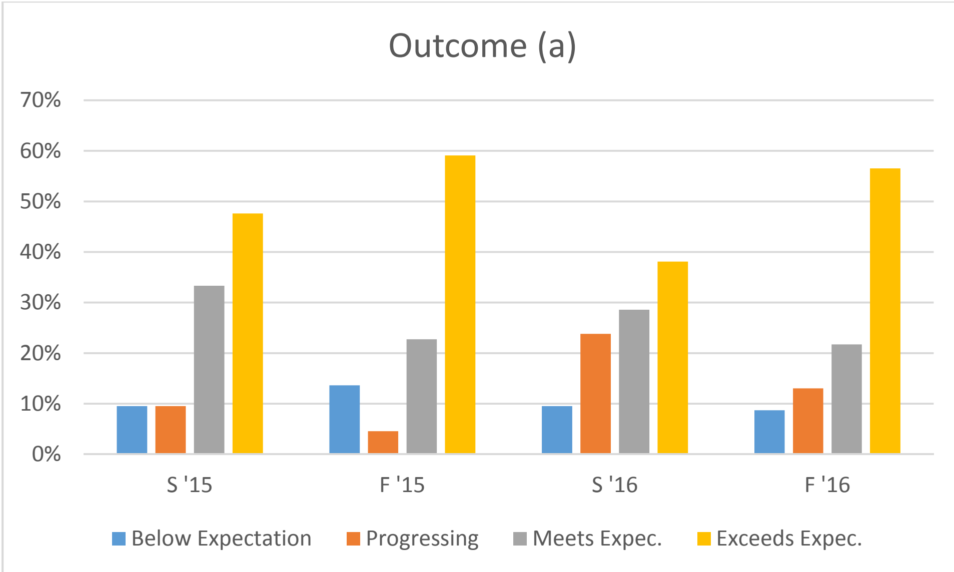

Figure 5. Performance vs. Outcome (a)

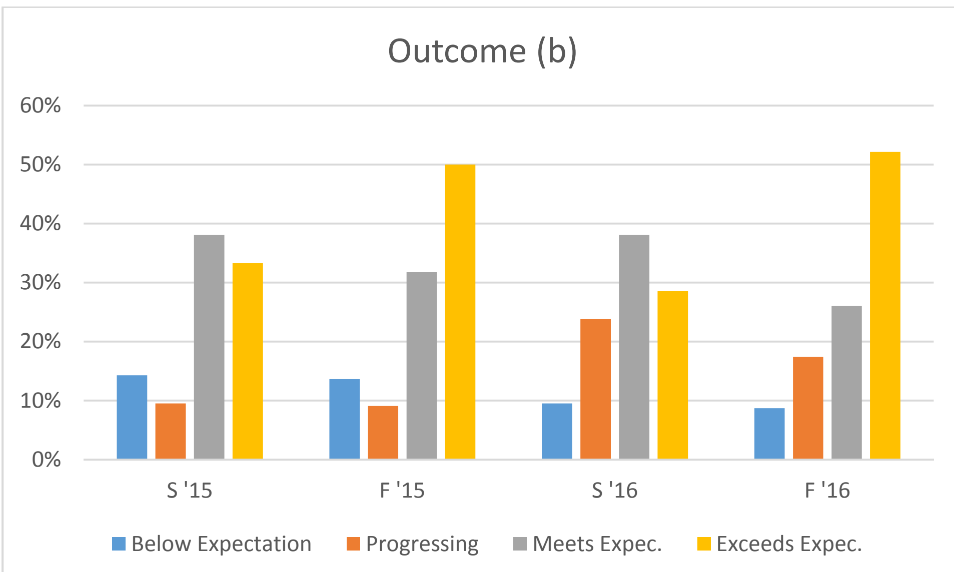

Figure 6. Performance vs. Outcome (b)

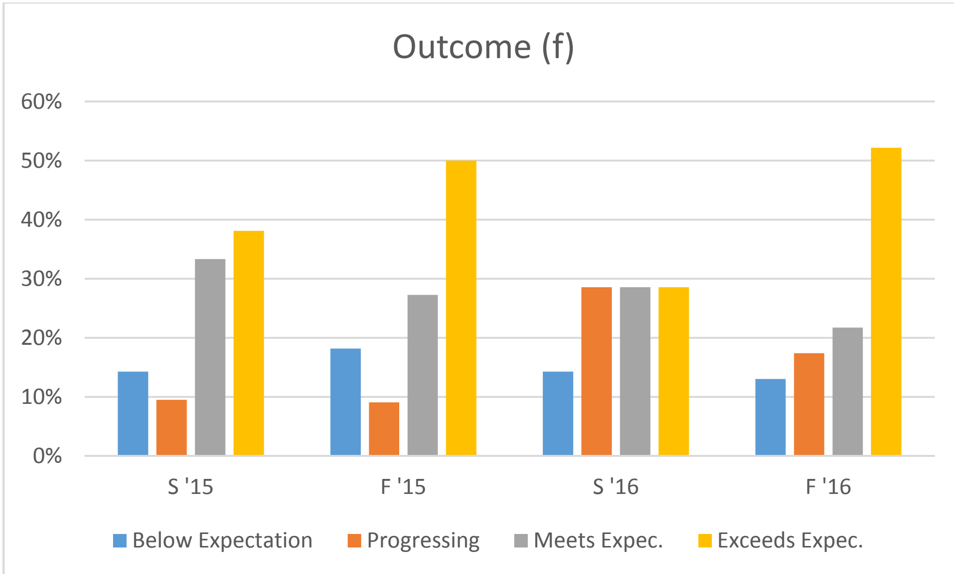

Figure 7 Performance vs. Outcome (f)

In addition, analysis of the student success across course objectives was performed between in-class and distance student population, Fig. 8-10. The results are compared only for the spring semesters when the course was offered both to in-class and distance students.

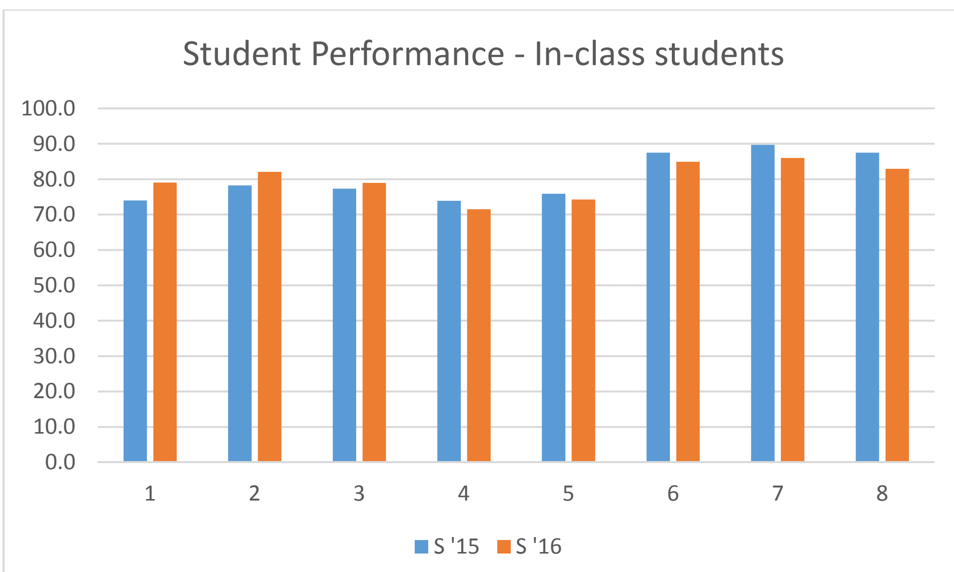

Fig. 8. Class performance – Course Objectives – In-class students

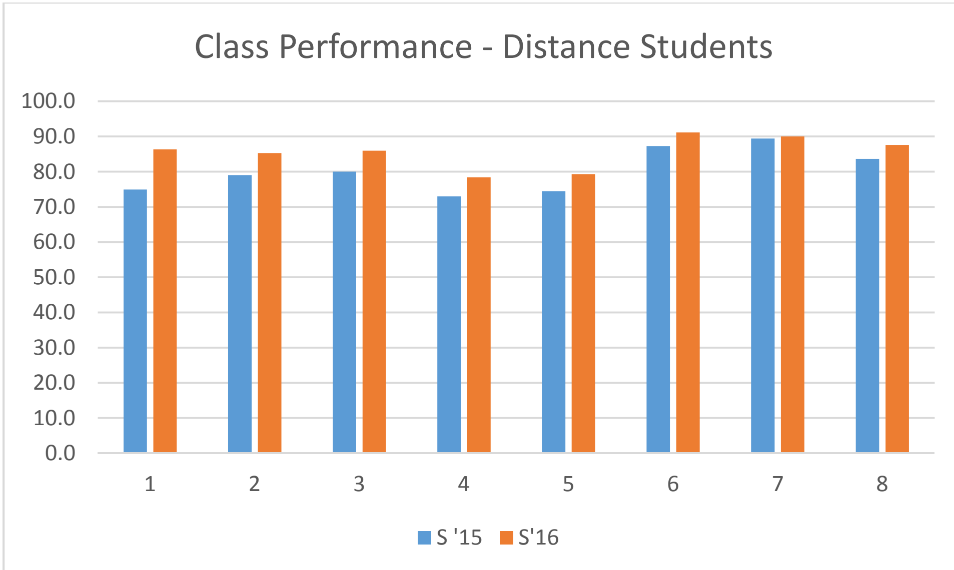

Fig. 9 Class performance – Course Objectives – Distance students

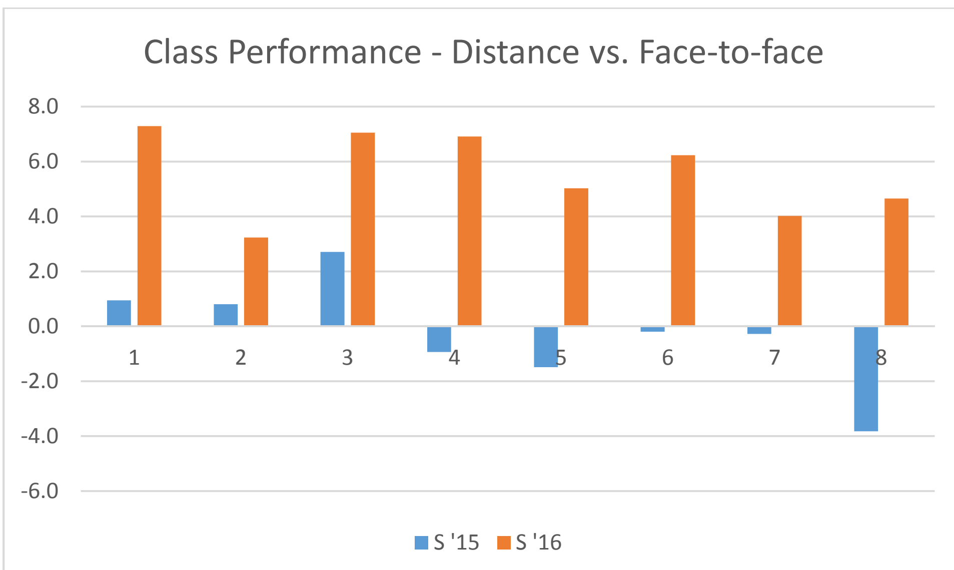

Figure 10. Difference in performance between Distance and Face-to-face students

The results indicate similar trends for both populations. The results are higher for objectives 1-3 and 6-8 compared to objectives 4 and 5 for both populations. Direct comparison, i.e. difference between the two populations is shown in Fig. 10. The results indicate that the overall difference is around 5 points in favor of distance students. This observation is in line with long term experience which indicates that distance students have somewhat better overall performance. This could be attributed to the fact that the vast majority of distance students are older non-traditional students who take academic responsibilities a little more seriously.

Discussion

The overall improvement in student performance is apparent across all the performed measures. The improvement could be attributed to a comprehensive intervention as implemented technology and pedagogical approach constituted substantial departure from the previous way the course was taught and performance assessed.

First, on-line availability of the course material, lectures and detailed worked-out problems, makes it easier for the students to review and practice material which requires additional time and effort beyond the classroom time. Also, the number, frequency, and strict deadlines of exercises most likely resulted in a more serious attitude and attention towards the course and ultimately in deeper learning. The lecture notes and assignments were released and closed in a pre-defined periodic manner, which enforced continuous learning of the material. This is a very important aspect of the modification as the material in the course builds throughout the semester and missing one portion of the material could have long term negative effects on mastering the material.

The pre and post course modification comparison on a course that underwent significant intervention may be somewhat difficult to assess due to substantial difference in the way student success was measured before and after the modifications. Prior to modifications, the partial credit was applied when grading exams and curving was used at the end of the course when determining the final grade. After the modification, no partial credit and no curving was used to determine students' final grade. The grades were determined based on whether the answers were correct or not. In the case of the homework assignments and quizzes students received grade based on the highest score between three attempts, and for the exam the grade was determined based on the average between the three attempts. No partial credit was given. This approach was designed to reflect various stages of learning and application. Homework assignments are used to provide students with initial learning experience, thus no penalty was applied if students corrected their solution. The exams assessed penalty if students did not answer the questions correctly the first or second time, but they were provided additional attempts to recognize that they are still in the learning phase. The next phase of their professional life would be work in industry where they would not get partial credit and would experience some penalty if they did not perform at the expected level on the first pass.

Also, students have extended time to complete assignments and exams and are allowed do it in environment that is not creating undue pressure. They can do it at home, dorm room, coffee shop or wherever they fell comfortable without instructor watching over them. This approach is reflective of the way students will perform at work in industry, where, in vast majority of cases, they will have more than one hour to complete the task and where their supervisor will not be watching over their shoulder as they solve problems. The supervisor will be interested only in the final answer, and it must be correct. In order to assure that students conduct their work in an ethical manner and making sure that academic honesty is observed students had to sign University Honors Pledge. The overall results do not indicate any academic misconduct.

Conclusions

Student performance data indicate that technology enabled modifications, along with team work and problem based learning introduced in the course, have positive outcome on student success in mastering the course material. The overall satisfaction with the approach is overwhelmingly in favor of changes. Students appreciated the modularity of the course, its online availability, their ability to go over material as many times as they needed, and clear grading expectations. The effort that was placed in modifying the course was significant but at the end it was worthwhile as the student performance and their satisfaction increased.

Further data collection, analysis, and review will be conducted to determine the long term effects of this approach. The authors plan to expand the study to include control groups and will also engage statistician in analyzing data to provide additional scientific strength to the research.

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