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A Fully Online Accredited Undergraduate Electrical Engineering Program

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Abstract:

We have implemented full online delivery of the undergraduate electrical engineering program at a large public university (Arizona State University). This paper describes the objectives for the program, its implementation and an assessment of student performance.

The curriculum, admissions standards, accreditation and faculty delivering the program are identical for face-to-face and online delivery. The program was initially conceived primarily to extend the access to our existing program to more underserved student populations. Our enrolment statistics show that this goal has been achieved to an extent much greater than anticipated. The characteristics of the online students enrolled in online delivery (age, professional experience, veteran/military status etc.) differ from those of the students enrolled face-to-face.

Another goal of the program is to develop and instructional approach that leverage the technology of online delivery to fundamentally change how student access the material and organize it according to their individual learning styles. We have developed course materials that are very dense, highly efficient and flexibly delivered. Our approach is completely different from “lecture-capture” approaches to online delivery. Our assessment process shows that there is very little difference in student performance between the face-to-face delivery and online delivery.

Significant challenges for our online delivery have been the development of laboratory experiences and the proctoring of exams. Our assessment of student outcomes shows that students enrolled online have achieved the outcomes related to the laboratory exercises. We have engaged an external proctoring company to independently verify and monitor the academic integrity of the online exam process.

Another challenge is acceptance of online delivery among our constituencies. This has been achieved to a large extent as verified by the unexpectedly large demand among our students, the willingness of employers to fund tuition and fees, the enthusiastic participation among a growing group of faculty members and discussions of our external advisory board which is dominated by industry members. A recent accreditation visit provides additional evidence of acceptance among the engineering community.

Introduction and Brief History:

Our online development history has its roots in the MIT open courseware project which published its first course in 2002 and very quickly gained widespread interest among engineering faculty in the US[1] . At our institution faculty began experimenting with both developing their own freely available online materials as well as referring students to MIT open courseware for supplemental materials for their courses. Until 2010 these efforts in our electrical engineering program were individual and not generally coordinated even at the program level. At the institutional level discussions were progressing toward a formal enterprise to provide degree programs online. In 2010 the university launched six degree programs available fully online.

The following year Sebastian Thrun and Peter Norvig at offered an artificial intelligence course at Stanford openly on the web, gathering well more than 100,000 initial enrollees. Andrew Ng subsequently offered a machine learning course with similar interest[2]. These early Massive Online Open Courses (MOOCs) led Thrun and Ng to found Udacity and Coursera respectively. In 2012, dubbed "The Year of MOOC" by the New York Times, these companies, along with edX, formed by MIT and Harvard, generated unprecedented interest in online delivery of education[3]. This spawned the effort to develop a web-based delivery system for our electrical engineering program at Arizona State University.

The initial discussions involved a core of two faculty members, the authors of this paper, and centered on how to leverage technology to provide a student experience better than our existing face-to-face delivery. A second object was to use technology to increase student access to our program. We surveyed the web-delivered education landscape at the time including MOOCs, the open courseware project, our institution's newly launched online environment (ASU Online) as well as models used by for-profit universities and nontraditional entities such as Kahn Academy. We rejected the MOOC and open courseware approaches because, although they provide tremendous access, they suffer from very poor completion rates and have weak student support structures to help struggling students to succeed[4]. Also important is that they do not normally lead to a degree, nor are they accredited.

We believed that delivering providing web-delivery of our entire accredited degree program offered the best match to our goals and our institution. Our next steps were to explore the administrative and accreditation challenges (Stephen Phillips) and to study the strengths and weaknesses of various delivery technologies and their pedagogical implications (Marco Saraniti).

Accreditation:

It quickly became clear that achieving ABET accreditation was an important goal and presented some potential challenges. At the time there were no 100% online undergraduate programs accredited under the engineering accreditation commission of ABET. Initial discussions with ABET staff in 2012 identified two likely paths to accreditation. One approach was to seek accreditation as a separate program. This allows for differences between the online delivered program and the face-to-face delivered program. But is has some significant disadvantages. First, a separately accredited program must be clearly distinguished from the face-to-face program on student transcripts and in institutional literature to avoid any confusion between the programs[5]. This might give the perception that the online delivered program is inferior to the face-to-face delivered program. Since this would be a new program we could not seek accreditation until the first student would graduate.

The second approach was to seek accreditation as part of our existing accredited program. This had the advantages of not waiting for the first graduate and not being seen as inferior but required us to meet the high standard of proving that both paths through the program meet accreditation criteria and are substantially equivalent. We chose the second approach and submitted a formal "notification of change/request for continuation of accreditation" in May of 2013. The notification/request led to the generation of a detailed report (similar to a self-study or interim report) detailing how we were implementing our program, assessing student outcomes, advising students, delivering course materials and laboratory experiences etc. The report was reviewed by the executive committee of the engineering accreditation committee. In July of 2013 ABET approved our request to include the online delivery as part of our accredited program and identified several items of "concern" to be addressed at the next genera review. In fall 2015 our program was reviewed as part of its regular general review cycle.

Sustained planning and effort was required to achieve this accreditation and our program was the first 100% online program in any discipline to be accredited under the engineering accreditation commission of ABET. Particularly important elements included ensuring equivalency of the curriculum, the admissions process and criteria for transfer credit evaluation. Also important are that the school's faculty members control the online delivered content, that the laboratory experiences are appropriate and that all constituencies are informed. As of this writing, there has been one additional 100% online undergraduate program to achieve accreditation under the engineering accreditation commission (electrical engineering at Stony Brook).

Admission, Enrollment and Student Characteristics:

The first students were admitted in 2013 and enrolled online in the fall semester 2013. The 2013 cohort was 90 students online and 816 students enrolled face-to-face. Online enrollment has grown much more quickly that we had planned: 0 in fall 2012, 90 in fall 2013, 213 in spring 2016, 479 in fall 2014, 800 in fall 2015. Meanwhile face-to-face enrollment has grown from 719 in fall 2012 to 978 in fall 2015 (Figure 0). There is clearly demand for online delivery of our program.

The admissions process is the same for both face-to-face and online students. We have the same admissions criteria and process transfer evaluations though the same mechanism. However some of the student characteristics are different between the two populations. The online students have an average age about ten years older than the face-to-face students. The online students are nearly all part-time and are transferring in a much larger number of credit hours. It appears that working students who have started, but not completed EE bachelor's degrees form the majority of the online enrollment. A clearly underserved constituency is active military and veterans who constitute about a third of the online enrollment (and less than one tenth of the face-to-face enrollment). Another difference is that only about 15% of the online enrollment consists of students from Arizona, whereas about 75% of our face-to-face students are eligible for "in-state" tuition. This relative lack of online "in-state" students is by design. We believe that the traditional on-campus face-to-face experience is especially valuable for recent high-school graduates from our state and the tuition is structured to reflect this; online students are not eligible for "in-state" tuition.

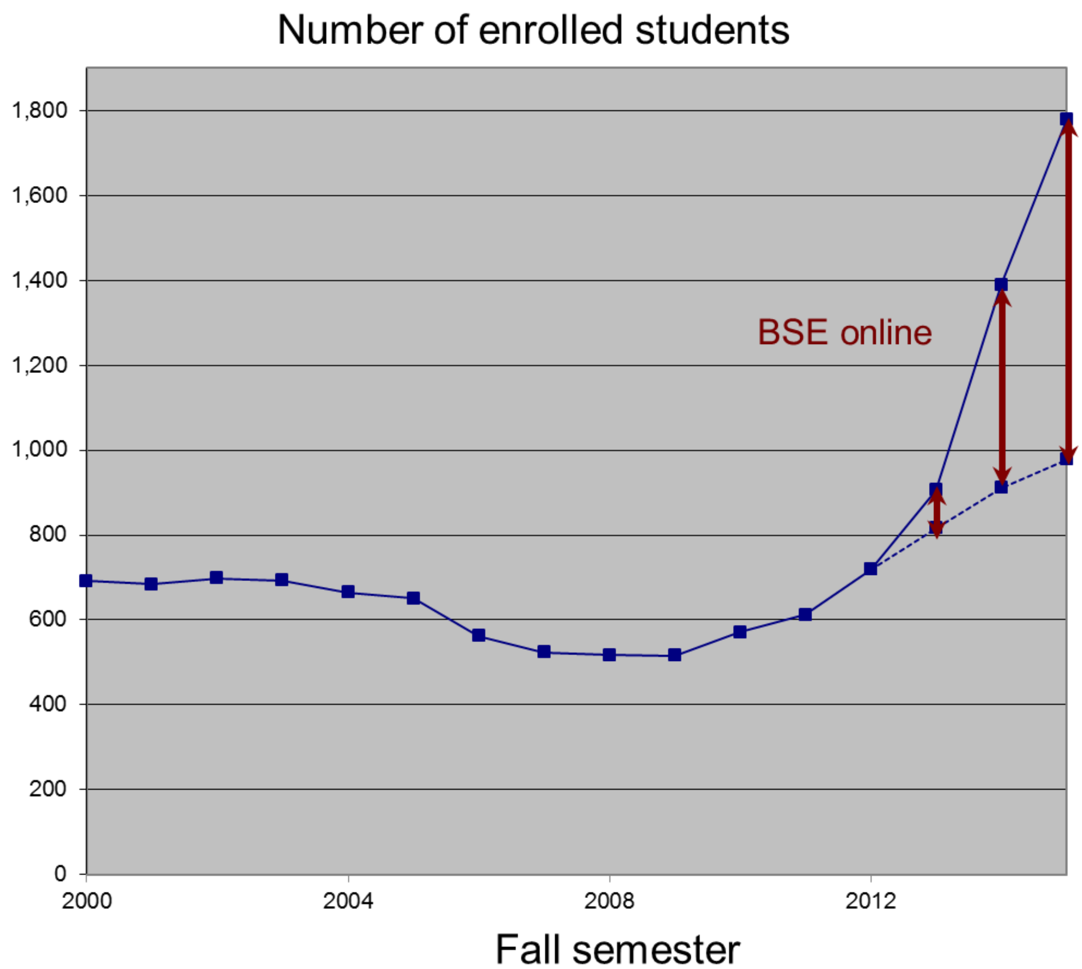

Figure 0: Enrollment in the BSE Electrical Engineering Program

Delivery:

Our approach to web delivery leverages technology already developed in conjunction with our institution's online enterprise along with several new technologies introduced by our program. An important component is interaction between faculty developing online materials and instructional design professionals employed by the university. Reviewing even a small fraction of the material with the instructional designers generally leads to significant improvement in the quality of the overall course. Lecture material is typically divided into relatively short (10 minute – 30 minute) video clips produced in a recording studio with technical support professionals. This infrastructure is provided by our institution's online enterprise.

The electrical engineering program has augmented this infrastructure to provide our faculty members with additional options for recording and editing their own content. Several faculty members have made extensive use of this infrastructure produce their own material for lecture topics, laboratory activities and supplemental activities such as worked examples, exam reviews and student projects. We have built a small studio with video and audio recording technology integrated with full editing capability. This allows the integration of animations, simulations, CAD software, web-based content and laboratory experiences into the course videos. We produce videos with real-time hand-annotation of dynamic power-point slides as can be seen in the screen captures below (Figures 1, 2).

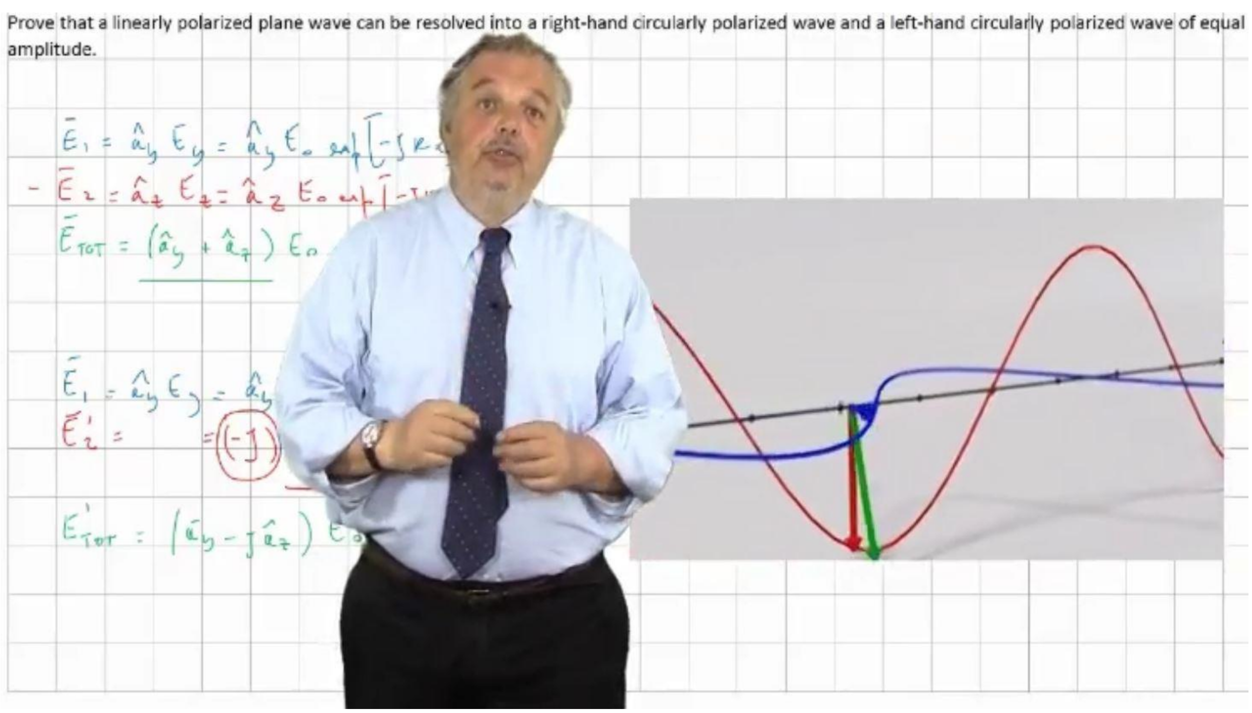

Figure 1: Screen capture of video with hand annotation

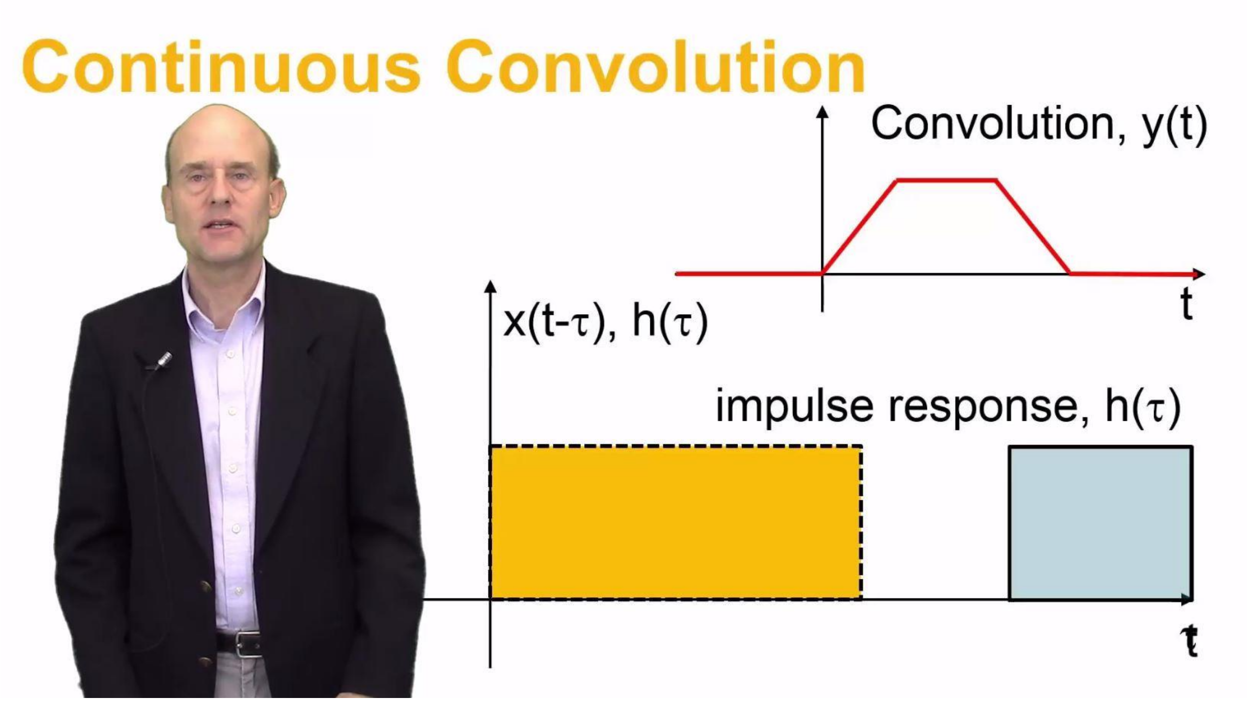

Figure 2: Screen capture of instructor with animation

Our produced videos have generated many positive responses from students. Based on these responses we have created several hybrid classes using the web-delivered content for campus-based students. These hybrid courses have resulted in student performance similar to the face-to-face courses (see the Student Performance section of this paper).

We use a paid independent proctoring service for course exams. For some courses these are multiple choice and short-answer questions which can be graded in an automated way. For most of the courses delivered by electrical engineering program faculty (mainly the courses with an EE prefix) we provide a mechanism for handwritten student answers. Our current approach is to allow students to work the exam on paper and immediately scan (or take a photograph) and upload their work. This presents some challenges to the proctoring organization since it is outside of their usual proctoring parameters and we were initially the only institution for which they have allowed this approach. We are currently working with the proctoring service to develop an application so that students can use a tablet to take exams directly.

Laboratories:

We offer laboratories using several different technologies. Instructors choose a technology to match the laboratory experience of the face-to-face delivery. One example is laboratory kits that students purchase to do the laboratories at their locations. These kits are well suited to our lower division analog and digital circuits courses and consist of breadboards, circuit components and low-cost test probes that are USB-connected to a virtual benchtop of test equipment on the student's computer. We do not sell the kits through the university bookstore but rather provide a list of kit components for the students to purchase commercially. This has provided a very high level of satisfaction for the students and the faculty. Another approach is web-controlled hardware that is housed at the university. Figure 3 shows a digital signal processing lab setup with web controlled test equipment and the ability for students to download their code via the web to our hardware and monitor the result via remotely controlled test equipment in our lab.

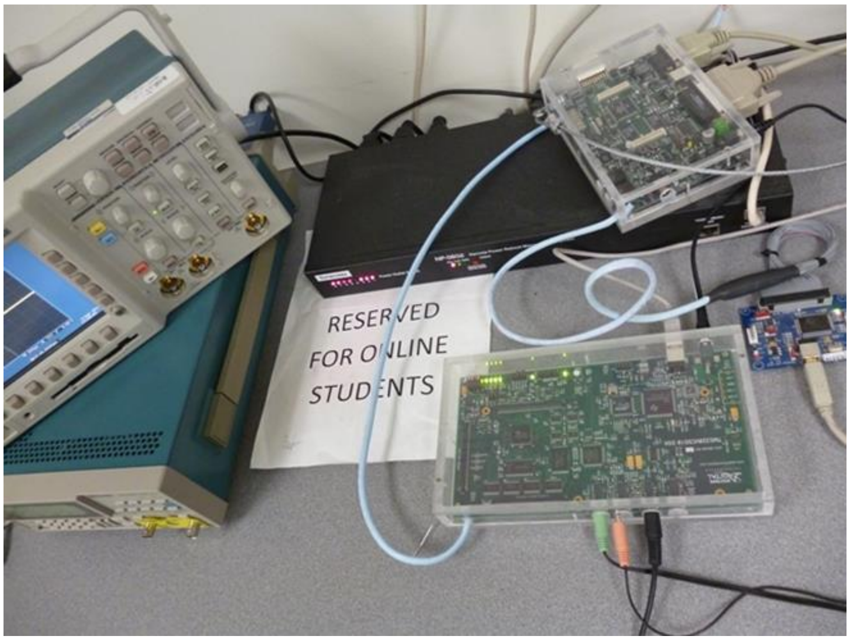

Figure 3: Web controlled laboratory equipment.

Our upper division circuits courses use industry-standard CAD packages for our face-to-face program. We have negotiated remote-access licenses so that students can access these packages on our servers from any location. Similarly some of our systems labs are simulation based and the mapping to online delivery is straightforward. While we have a robust offering of courses, we do not offer every lab course online at this time. For example the cleanroom lab experience is not available online. We have found that the materials and videos produced for the laboratories are very effective and have started to make someof them available to the students enrolled face-to-face.

Student Experience:

We place a high value on the student experience and the ability of students to directly access our faculty and teaching assistants. Faculty offer real-time office hours via Skype, phone, web conferencing or other tools of their choice. We also use online discussion forums such as Piazza, Google Hangout and other learning management system (LMS) –specific tools. The forums are monitored by course staff since the crowd-sourced nature of the questions and answers benefit from some guidance. We provide student support services such as advising, tutoring, career coaching and access to corporate recruiting to all of our students, online and face-to-face. Advising has been challenging due to the large number of transfer credits most of our online students are seeking. This requires significant customized one-on-one advising (usually including both phone and email) and some patience due to the detailed nature of the transfer credit process.

Our program encourages students to participate in student activities outside of their coursework including professional organizations, community service and entrepreneurial activities. We have the same encouragement for our online students. While many of them have full-time traditional employment and limited time for these activities, several students have taken advantage of these opportunities. One of our online students recently received a prestigious fellowship for his startup work and has applied for VentureWell support through our university. As our online enrollment has grown the students have built several social media communities to maintain connectivity and build comradery outside of their courses. Overall the online students have expressed satisfaction with the service provide by our program and university.

Student Performance:

As part of our ABET accreditation continuous improvement process we regularly assess and evaluate student performance. In fall 2015 we were visited by an ABET evaluation team and the electrical engineering program was specifically tasked with comparing the online and face-to-face student performance. We have collected data in several ways: admissions characteristics, retention and time-to-degree, student outcomes, course performance and exam performance.

The admissions process and criteria are the same for online and face-to-face students and the traditional academic qualifications (average SAT scores, average ACT scores and high school GPA) reflect this. However more online students enter as transfer students so these qualifications are likely less relevant in predicting their success. Retention of freshmen in the program (70-75%) and at the university (88-92%) has not changed appreciably with the enrollment of online students. The six year graduation rate will not be available for the first online students until 2019 however our advising staff has not seen an unusual loss of online students in the program. A higher fraction of online students is part-time and so they will have a longer time-to-degree.

As an example of course performance we can examine the sophomore-level introductory electromagnetic fields class. This has been offered by one instructor (the same faculty member who developed the web content) in three ways in 2014 and 2015: traditional face-to-face (F2F), web-delivered to online students (oClass) and web delivered to campus-based students (hybrid or iClass). This is instructive since it separates the delivery mechanism (web or face-to-face) from the student cohorts (online or campus-based).

The instructional material of both oClass and iClass formats was entirely web-delivered through the institution's learning management system (Blackboard). The material consists of 129 video-clips with a total duration of 42 hours, 50% of which is devoted to theoretical lectures and the remaining 50% to the detailed solution of about 100 problems or exercises. The average duration of the 55 theoretical videos is 22 minutes, while the average duration of the 74 exercise videos is 16 minutes.

In both the F2F and iClass formats students were evaluated with exams taken on campus, and had the option of attending office-hours remotely (via Skype), or in person. The proctoring service remotely administered the exams in the oClass, and office hours were administered exclusively via Skype. A Graduate Student graded the homework assignments, while the faculty instructor graded all the exams. The instructor exclusively administered office hours.

Detailed histograms of the student performance on the two midterms, the final exam and the overall course score for all three cohorts are shown below in Figures 4-7.

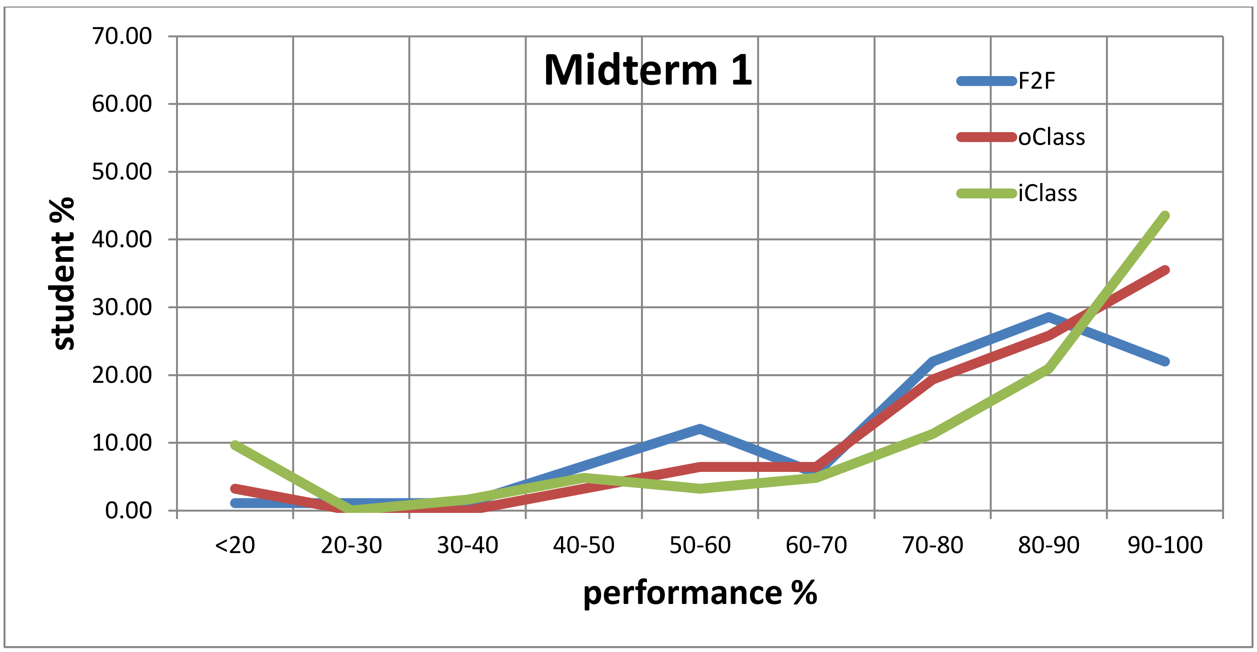

Figure 4: Midterm 1 Histogram

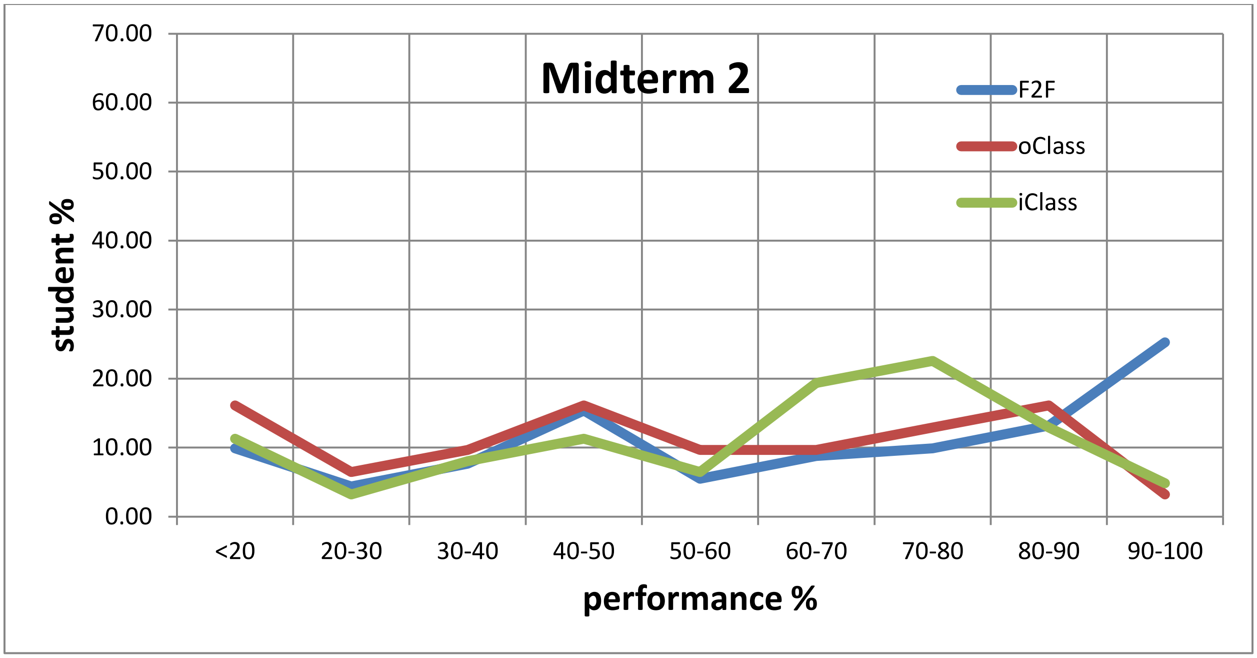

Figure 5: Midterm 2 Histogram

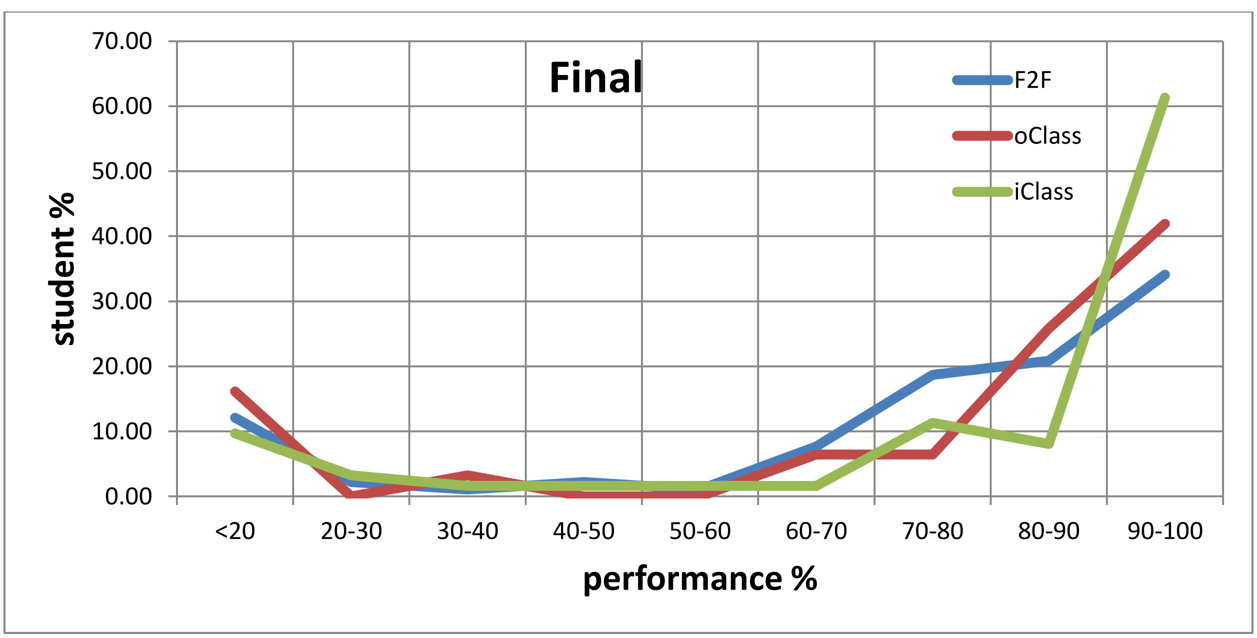

Figure 6: Final Exam Histogram

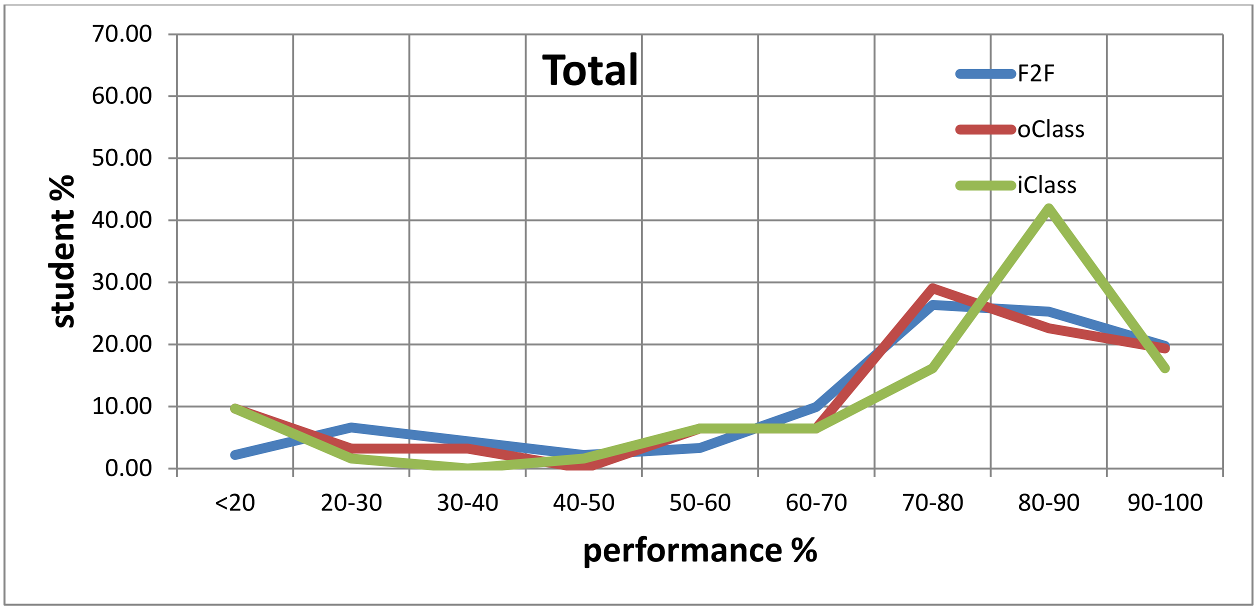

Figure 7: Course Score Histogram

The histograms show that the score distributions are nearly identical for the face-to-face and online classes and still quite similar for the hybrid offering.   Student satisfaction surveys for the three offerings are very positive with the hybrid offering only slightly less favorable than the other two. Anecdotal evidence suggests that this is likely due to the fact that campus-based students are less experienced with web-delivered courses. A detailed analysis of specific course performance for a different class is presented in another paper at this conference authored by Chao Wang and Michael Goryll "Design and Implementation of an Online Digital Design Course."

Conclusions:

Our overall evaluation is that in every course we have witnessed online student performance that is often indistinguishable, and always comparable, to face-to-face student performance. Our ABET evaluators have confirmed the achievement of student outcomes by students who pursue the online path to the degree as well as those who pursue the face-to-face path. Our students have a high level of satisfaction with their program and our industry and faculty constituents are supportive of our efforts to broaden access to our program while improving the quality of the instruction though the use of technology.

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